Jl S. Afr. vet. Ass. 46(1) 5-11 1975

PROCEEDINGS OF THE FIRST INTERNATIONAL EQUINE VETERINARY CONFERENCE, PRETORIUSKOP, KRUGER NATIONAL PARK, AUGUST 5 - 10, 1974

VERHANDELINGE VAN DIE EERSTE INTERNASIONALE HIPPIATRIESE KONGRES PRETORIUSKOP, KRUGER NASIONALE WILDTUIN, AUGUSTUS 5 – 10, 1974

SECTION B: THE ALIMENTARY TRACT OF THE HORSE

The Aetiology, Diagnosis and Therapy of Diseases and Metabolic Complications.

FIRST SESSION: DIGESTION

Chairman: P. BOYAZOGLU

FUNCTIONAL ANATOMY AND NERVOUS CONTROL OF THE EQUINE ALIMENTARY TRACT*

H.P.A. DE BOOM**

SUMMARY

By outlining its ontogenetic development, the topographical anatomy of the equine digestive tract is presented in concise form. Those aspects of particular significance from the functional and clinical point of view are stressed. The anatomy of that part of the autonomic system supplying the digestive tract is sketched in brief with some remarks pertaining to function.

INTRODUCTION

This paper merely serves as a general theoretical background to those that are to follow in this particular section of the Conference. Perforce, it will be restricted to generalities: it is a quick overall memory-refresher and not a presentation of research results.

ONTOGENESIS

The digestive system develops from a simple, entodermal tube, abutting rostrally on the pharyngeal membrane, which temporarily closes it off from the ectodermal bay or stomodeum, the anlage of the oral cavity, and caudally on the temporary cloacal membrane, separating it from the proctodeum which represents the future anal canal of ectodermal origin. The persistence of the cloacal membrane forms the basis of various forms of atresia ani occasionally encountered in the new-born. Atresia coli is regarded as a lethal factor in horses [18 23].

From the midgut region of the entodermal tube the yolk sac, initially a very prominent structure in the horse, is suspended by the yolk stalk with its vitelline duct. A remnant of this connection, namely Meckel's diverticulum, is best known in sheep.

From the hindgut the allantois develops as an evagination. Separation caudalwards of this evagination, between the allantoic stalk, or urachus, ventrally , and entodermal tube dorsally, produces the eventual separation between alimentary and genito-urinary tracts. Incompleteness of separation and permanence of the cloacal membrane produces the congenital recto-vaginal fistula so often associated with atresia ani. The alimentary tract undergoes relatively simple changes in principle, despite the apparent complexity of the final product.

The entoderm differentiates either into squamous stratified epithelium – oesophagus and initial part of the stomach – or simple columnar epithelium, as in the rest of entodermal component of the gut, *i.e.*, up to and including the rectum, while the surrounding mesenchyme produces the muscular and connective tissue layers.

The liver and pancreas arise initially as diverticula from the entodermal tube, the liver and major duct component of the pancreas from two closely associated ventral diverticula, the dorsal pancreatic component from a dorsal diverticulum, thus dictating the eventual relationship of their points of entry into the duodenum.

The stomach region of the tube develops a dorsal convexity, the major curvature, and a concave ventral one, the minor curvature. Rotation along a longitudinal (craniocaudal) axis to the left, approximation of cardia and pylorus, swinging the duodenum to the right, and final rotation of the stomach along a transverse axis, the fundus region tilting caudalward in keeping with diaphragmatic movement and configuration, produces the adult morphology and topography.

Elongation of the entodermal tube in great excess

* For illustrations the reader is referred to standard texts on Anatomy and Embryology.

**Department of Anatomy, Faculty of Veterinary Science, P.O. Box 12580, Onderstepoort 0110.

relative to the lengthening of the body as a whole produces loops, coils and festooning of the intestine. In the horse this relationship will eventually attain a ratio of 10:1, compared to 5:1 for the carnivorous dog, 15:1 for the omnivorous pig and 20:1 to 25:1 for ruminants.[16]

The future intestinal tract undergoes a primary or umbilical loop ventralward, with the cranial mesenteric artery as axis, which loop then rotates through almost 360° around this axis, in clockwise fashion as seen from the dorsal aspect. It is this rotation which results in the basic pattern of ascending (right), transverse and descending (left) colon, as well as in cranial flexure, descending limb, caudal flexure and ascending limb of the duodenum. The two systems fit into one another like the intercalation of an inverted and an upright U. The proximity of the duodenum to the initial part of the colon is thus effected. It is maintained by the duodenocolic ligament – a useful practical landmark in differentiating duodenum from jejunum at the duodenojejunal flexure.

In herbivores the ascending limb of the colon becomes greatly elongated and is consequently thrown into loops and coils. In the Perissodactyla this morphogenetic manoeuvre produces a long loop cranialward, which, within the confines of the abdominal cavity, is forced to the left and caudally, thus falling into an inverted U-pattern with the well-known components: Right ventral colon, sternal flexure, left ventral colon, pelvic flexure, left dorsal colon, diaphragmatic flexure and left dorsal colon. In the process, the mesentery of the ascending limb becomes drawn out and narrowed, finally presenting itself as a narrow ligament connecting the two limbs rather than as a mesentery, thus leaving the greater part of the colic loop potentially mobile.The caecum appears as an evagination at the ileocolic junction. Enlargement of its lumen concomitantly with that of the colon crowds the ileum to the left and gives the latter the morphological appearance of being a side-passage entering the main stream by means of a T-junction. Adopting a teleological mode of argumentation merely for ease of comprehension, one may state that the Perissodactyla, faced with the choice of site for a continuous culture system for cellulose-splitting bacteria, chose the post-intestinal region in contrast to the more logical pre-intestinal one selected by the ruminants, much to the former's detriment, and to the veterinarian's chagrin. The lumen of caecum and ascending and initial part of the transverse colon increased tremendously to supply the necessary capacity. The relatively faster passage of a barium meal through the large intestine of a suckling foal compared to the rate in a weaned foal [1] is also indicative. Besides developing a marked narrowing of lumen at the pelvic flexure and in the initial part of the transverse colon, the Equidae – as if to test the veterinarian's mettle further – developed a marked, sudden constriction in the initial part of the ascending colon (right ventral colon), whereby the caecum became enlarged at expense of the colon: the caecocolic orifice of adult anatomy is thus in reality a narrowing in the lumen of the initial part of the colon, and the cranial part of the base of the caecum is ontogenetically speaking the initial part of the ascending colon.

The Rhinoceros, representing a remaining living example of equine ancestry, retains the simpler ontogenetic pattern.

ANATOMY

For the purposes of this paper attention will be limited to certain aspects of the tubular components of the alimentary tract, *i.e.*, from oesophagus to anus.

Oesophagus: Initially it lies in the median plane, between cervical vertebral column and associated musculature dorsally, and trachea ventrally. At the caudal third of the neck (about the level of the fifth cervical vertebra) it inclines to the left, very occasionally to the right, [2 11] where it is most easily accessible. Here, in the lowest position of the oesophagus, the common carotid artery lies dorsolaterally, with the associated vago-sympathetic trunk dorsally and the recurrent nerve medioventrally to the vessel. The deep ventrovertebral fascia forms a sheath around it.[6] Disruption of the tracheal side of the sheath would give entry to the peritracheal adventitia. From this region, as well as from the perioesophageal adventitia, it is but a brief, descending pathway to the mediastinal endothoracic fascia. Further warning is unnecessary.

At the thoracic entrance the oesophagus reverts to its dorsotracheal position. I have often wondered whether its proximity here to the left cervicothoracic ganglion, hard against the upper end of the first rib, could not play a rôle in the deleterious effects of choke.

At the level of about the 14th vertebra and about 12cm below it[16] (closer to it in soft or frozen specimens)[22] and slightly to the left of the median plane, the oesophagus traverses the obliquely disposed oesophageal hiatus of the diaphragm and upon emergence therefrom enters the cardia.

The horse's powerful oesophageal musculature is of the striated type only up to the root of the lung, where it is 4-5 mm thick, [16 20] to be replaced caudalwards by smooth muscle of increasing thickness (up to 1,2-1,5 cm) [16 20] at the cardia.

Initially the outer coat forms elliptical turns in double stranded loops, which are more closely spiralled in the middle region, to go over into the outer longitudinal layer. The deeper-lying circular coat is mainly responsible for the increase in thickness of the muscular tunic towards the cardia, where many of the muscle bundles cross in irregular plexiform manner.

The oesophagus can be distended to an average internal diameter of 6 mm.[20] There are minor variations in calibre noticeable in the gas– or fluid–distended oesophagus. Succeeding a narrow entrance, there is a moderate elliptical dilatation with a slight constriction, followed by a relatively large dilatation in the cervical region and a distinct narrowing at the thoracic entrance; a widened thoracic region gradually narrows down to a minimum towards the cardia.[2]

The mucous membrane of squamous stratified epithelium is freely movable relative to the musculature owing to the loose submucosa. Only at the oesophageal entrance from the pharynx is lubrication provided in the form of mucous glands.

Stomach: The unilocular, compound stomach, with a meagre physiological capacity of 8–15 l,[16] is nestled against the diaphragm cranially. In the ventral two-thirds of this contact area the left lobe of the liver is wedged. Laterally, the diaphragm, curving to its attachment to the closely approximating rib cage, also covers the stomach. Along its greater curvature the spleen becomes interposed between stomach and left body wall. To the right, liver and large colon adjoin the stomach. Caudally the visceral face of the stomach is related dorsally to the relatively firmly fixed transverse colon (transition from large to small colon) and, more ventrally, to the coils of small colon forms a veil between the visceral face of the stomach and the above mentioned intestinal coils. The greater curvature of the stomach normally rests upon the dorsal colon; when the stomach is empty, coils of small intestine are interposed; when it is distended, it may push the left dorsal colon aside.

Dorsally, from the expanded portion of fundus peculiar to horses *(the saccus caecus)* the gastrophrenic ligament arises to form a firm link with crura of the diaphragm. When the stomach is empty, this attachment causes the *saccus caecus* to be drawn out into a cone. The stomach is thus firmly held in position, yet direct pressure on the stomach by contraction of abdominal musculature is not possible. Abnormal distension is bound to produce considerable discomfort. Clinically, the last couple of ribs on the left side will be raised, producing an asymmetrical appearance when viewed from the front.[6] Trocarization, as advocated through the dorsal end of the 17th intercostal space, does make one feel uneasy when considering the spleen's position, itself possibly enlarged because of expected compression of the gastroliental vein. Even at the 15th intercostal space danger is not entirely eliminated. In any case the pleural cavity must be traversed and lung damage at deep inspiration is not necessarily obviated.

The cardia is characterized by the oblique entry of the oesophagus, the very thick muscular coat of the latter at this site and the formation of the powerful cardiac sphincter, which appears not as a typical sphincter but as two semilunar folds, one dorsal and one ventral, which are slightly staggered in position. The more proximal, ventral one is formed by a loop of the circular fibre coat, the more distal, dorsal one by a loop of the internal oblique fibre coat. This arrangement would provide even better occlusion than a typical sphincter. Numerous folds of mucous membrane are stated to occlude the opening, so that distension of the stomach to the point of rupture may be produced by forcing air or fluid into the stomach from the pyloric side without ligating the oesophagus [22].

The edges of the layer of internal oblique fibres, lying close to the lesser curvature, form a groove, the *sulcus ventriculi*, spanned crosswise in its floor by the circular fibres. In the pyloric part the longitudinal fibres rather suddenly become thick and powerful and the circular fibres at this point form a slight retraction, which demarcates the more proximal antrum from the more distal, thick walled pyloric canal.*I doubt whether the physiological significance of these structures has been considered adequately.

Small Intestine: The *duodenum* of the horse is relatively well fixed in position, the cranial part being held to the liver by the terminal part of the small omentum (hepatoduodenal ligament). The mesoduodenum, supporting the descending transverse and ascending parts, is shortened by the fact that the base of the caecum, on account of its size and that of the caecum as a whole, has been forced against the abdominal roof; its serosal covering has fused secondarily with whatever peritoneal membranes were in the way, namely mesoduodenum containing the pancreas and ventral surface of the right kidney. One thus finds the initial part of the descending duodenum running dorsocaudally, skirting the right lobe of the liver and the right dorsal colon, the rest of it then forming a wreath around the base of the caecum. At the duodenojejunal flexure the short duodenocolic fold fixes it to the transverse colon. In view of its course, it must be subject to considerable pressure in cases of tympany of the caecum. In the first part of the duodenum the *ansa sigmoidea*, an ~-shaped curve, presents itself as two dilatations with a constriction between them. The first one is clearly demarcated between the pyloric sphincter and the above-mentioned constriction, thus producing the *ampulla duodeni*, typical of horses. This anatomical arrangement also opens one's mind to speculation as to its physiological significance.

Beyond the constriction in the second part of the *ansa sigmoidea*, about 12-15 cm from the pylorus, the *ampulla hepatopancreatica* [10] (formerly known as the *diverticulum duodeni*) is situated, in which the common hepatic duct (ductus choledochus of other species) and the major pancreatic duct open.

The musculature of the ampulla, although oblique and overwhelmed by longitudinal fibres and not independent of the duodenal musculature as in man, is now regarded as forming the *M.sphincter ampullae hepatopancreaticae.* [10] Nearly opposite the ampulla is the opening of the minor pancreatic duct.

The *jejunum* occupies mainly the left sublumber region, dorsal to the large colon and caudal to the stomach. Here it lies intermingled with coils of the small colon, which are generally more dorsally disposed.[6]

Because of the very wide mesojejunum, (about 50 cm), coils of small intestine may interpose themselves between left dorsal colon and stomach (when the latter is fairly empty), between left dorsal colon and left flank, extending to the right flank behind the caecum, (when it is relatively empty), and between the ventral colon and caecum to the abdominal floor. The width of the mesentery is sufficient also to allow coils of the jejunum to enter the pelvic cavity and even descend into the scrotum, provided of course the vaginal canal, *i.e.*, the peritoneal lining of the inguinal canal, is abnormally wide – normally it will admit just about one finger in a large stallion – or provided it has been torn. While on this aspect, the possibility of a loop of gut being caught through a tear in the *mesoductus deferens (plica ductus deferentis)* produced *inter alia* by rough handling at castration, should be borne in mind. Part of the jejunum may even enter the vestibule of omental bursa through the epiploic foramen. Apart from allowing abnormal positions to be attained, the width of the mesentery is a prerequisite for the development of volvulus and intussusception.

The last part of the small intestine is regarded as *ileum*. In formalin-preserved cadavers it is usually tightly contracted and firm to the touch, and about 20 cm long; if relaxed and atonic, it measures 50-70 cm [21] Arbritarily, and for purposes of definite measurement (or identification), the ileum may be regarded as that part of the small intestine which moves away from the edge of the mesentery, leaving an antimesenterial fold, which subsequently attaches to the

* There is a discrepancy between the terminology in Anglo-American and Continental literature. The former is followed here, in apparent accordance with the NAV.

dorsal band of the caecum (the ileocaecal fold). The ileum in the final part of its course proceeds almost straight dorsalwards just right of the median plane at about the middle of the lumbar region or slightly cranial thereto, and ends at the lesser curvature of the base of the caecum. Here, at the ileal ostium, the ileum is telescoped into the caecum and causes a papillalike projection into the lumen of the caecum, the *papilla ilealis,* with a central system of radiating folds. Remarkably enough, the ileal musculature diminishes in thickness at the point of entry; there is no sphincter but a rich venous plexus is present in the submucosa [21]. The latter, together with the powerful ileal musculature – it can cause a threefold shortening of the ileum – represents a regulating mechanism for proper transport of jejunal contents and prevention of entry of gas from the basis caeci [21]. The relatively fixed ileum can act as a pivot for the development of a volvulus by the more mobile jejunum.

Large Intestine: The *caecum* has the classically described 'comma' shape. From the ileal ostium cranialwards, the caecal base represents the dilated and recurved initial portion of the colon, as explained under the heading 'Ontogeny'. From its highest point in the sublumbar region it curves cranial- and ventralwards to about the 15th or even 14th rib, below the middle of the latter, here touching the liver, depending on the degree of fullness of the right dorsal colon. From here it curves back, forming the blind sac ventrally. At its caudal extremity the caecocolic ostium points dorsocaudally. Consequently the two ostia, ileal and caecocolic, are in close proximity to one another (±5 cm) with an intervening fold of mucous membrane between them. The caecocolic ostium is slit-like or elliptical in outline, about 5 cm long, and is guarded by a ventrally situated valve (*valva caecocolica*) and a ring of muscle (*M.sphincter caeci*). Anatomically speaking there is no direct passage of ileal contents to the colon: The caecum forms a huge diverticulum of about 25-30 *l* capacity

The body of the caecum curves ventrocranialward to the abdominal floor, its lesser curvature roughly parallel to the costal arch and some 10–15 cm caudal to it. The apex normally lies on the abdominal floor, about a hand's breadth behind the xiphoid, fitting snugly between right and left ventral colon. It has no attachments and depends for its position on the loop of the ventral colon. A case of rotation of body and apex through 540⁰ and one of spiralling thereof, both with prolonged signs of colic, have been described.[13] Gas accumulating in the carcum will tend to rise to the highest point, *namely the most dorsal part of* the caecal base in the sublumber region. If this occurs to abnormal degree, trocarization must be performed at the highest point of the bulge halfway between *tuber coxae* and last rib on the right side.

Of its four taeniae, the dorsal one is attached for a short distance to the ileocaecal fold. It extends to the apex. The medial one also extends to the apex and bears the medial caecal vessels. The ventral one is free and joins the medial one near the apex. The lateral one, bearing the lateral caecal vessels, is attached to the right ventral colon for a considerable distance, thus the details of identity and topography in this region are obscured, although in its caudal part the band can be felt as a concave projecting edge [22]. It may peter out before reaching the apex.

The *large colon*, of more than double the capacity of the caecum, anatomically speaking begins at the narrow caecocolic ostium; it immediately widens and curves sharply dorsally, caudally and then ventrally and cranially.

This initial portion lies against the right flank immediately below the caecal base; by virtue of its shape and course it can form a gas trap. In tympany of this segment, it can push the caecal base medialward and usurp its position, thus leaving the site for trocarization unchanged. As right ventral colon, the gut continues cranialward in the position indicated by its name. For about half its initial distance its ventrolateral band is attached to the lateral band of the caecum by the caecocolic fold. At the sternal flexure it turns to the left and continues caudalward to the pelvic flexure. This flexure, being unattached, usually assumes a recurved course and a very variable position: As a rule it is directed towards the right flank and may lie against the caudal part thereof, or it might be found in the right inguinal region. From the pelvic flexure the left dorsal colon runs cranialward. At the diaphragm and left lobe of the liver it forms the diaphragmatic flexure and continues as the left dorsal colon against the liver and, below the latter's edge, against the left body wall and the diaphragm curving to its attachment to the ribs and lower rib cage. The duodenum rides atop of it. It then skirts the caecal base, partially below it but mainly to the left thereof, to turn to the left and dorsally, caudal to the stomach and cranial to the cranial mesenteric artery, to narrow considerably into the small colon under the left kidney. This transverse segment at about the level of the 17th to 18th thoracic vertebra, cranial to the root of the mesentery, represents the transverse colon. The terminal part of the large colon is attached broadly by peritoneum and areolar connective tissue to the left face of the caecal base and dorsally to the ventral face of the pancreas. This represents an area of secondary fusion owing to the large size and position of the viscus. The adherence is continued over the whole transverse colon. In the process, the origin of the omentum (dorsal mesogastrium) has become trapped between colon, pancreas and body wall and thus appears to take origin from the transverse colon. The right dorsal colon is also attached to a fold from the right lateral ligament of the liver. Apart from the attachments mentioned, the whole large colon is free to move, its size and mass (with contents) within the confines of the abdominal cavity being the only restricting factors. The mesocolon plays no part in this restriction: it has become greatly extended in width with the development of this remarkable loop of ascending colon, but so shortened fore to aft, that it merely finds the two limbs of the loop together, becoming obliterated in the process and merely recognizable as a mesenterial structure at the pelvic flexure: Elsewhere it is replaced by a broad connective tissue attachment between the two limbs of the loop. Furthermore the mesocolic axis can act as an axis of rotation, around which dorsal and ventral colons can rotate. This is most likely to occur in the left part of the colic loop, and could then be diagnosed by rectal palpation. Huskamp[9] has described amputation, closing of the stumps and anastomoses between the latter as surgical treatment where the twisted loops of colon were not viable.

As on the caecum the taeniae are useful for identifying a particular section of gut at autopsy or clinically (Fig.). The entire ventral colon has four taeniae: The ventromedial and ventrolateral bands are free and exposed, except for the first portion of the ventrolateral band which is attached to the lateral taenia of the caecum by means of the caecocolic fold as already described. The dorsal bands are concealed in the area of broadened mesocolic adherence between ventral and dorsal colons. They can be palpated. The dorsomedial one is followed by the *ramus colicus* (arterial and venous) which is the specific supply and afflux for the initial part of the ascending colon in all species. The colic lymph nodes accompany the vessels. The left dorsal colon has only one band, clearly palpable per rectum at the pelvic flexure, and swinging up from the dorsomedial one on the left ventral colon to continue ventrally along the mesocolic attachment, indicating also the course of the *A. and V. colica dextra*, the specific blood supply and afflux for the final half of colon ascendens. Sacculations are absent here. As the diaphragmatic flexure is approached, two dorsal bands are acquired, which are free and exposed.

This pattern is continued on the right dorsal colon. The lateral taenia is wide and rather indistinct, the medial one narrow and distinct. Only towards the terminal part of the dorsal colon do sacculations – such a feature of caecum and ventral colon – reappear, and then only indistinctly so.

The variations in lumen diameter are of particular importance. From a mere 5 to 7,5 cm at the origin of the ventral colon, it enlarges rapidly to 20–30 cm, reducing to 6 to 10 cm at the pelvic flexure, increasing rapidly towards the diaphragmatic flexure and beyond, to attain the enormous diameter of 30–50 cm at its transition to small colon, where it forms the *ampulla coli*, narrowing down at this point to 7,5–10 cm to continue as small colon. The implications are obvious.

The presence of more goblet cells in the right dorsal than in the right ventral colon[15] could have some physiological significance.

The *small colon* begins after the terminal funnel–like narrowing of the large colon, behind the fundus of the stomach and ventral to the left kidney. It turns caudalward; as *colon descendens* it pursues in principle a straight course to the rectum at the pelvic inlet. In horses its great lenght (about 3,5 m) and the considerable width of the mesentery cause it to be thrown into coils, which occupy the left upper quadrant of the abdominal cavity, where they lie partly intermingled with coils of the jejunum.

The small colon is thrown into definite sacculations by the presence of two taeniae, the dorsal one in the mesenteric attachment and the ventral one exposed and free. Normally the faeces here form balls which occupy the sacculations. The occasional occurrence of a singly disposed faecal ball might mislead the hasty rectal palpator or surgeon.

The *rectum* is arbitrarily considered to begin at the pelvic inlet. It takes a relatively straight or moderately oblique course to end at the anus at the level of second to third caudal vertebra. The first part is covered by peritoneum, the extent depending on the degree of full-ness of the bowel. At usually the fourth or fifth sacral segment the peritoneum is reflected cranialwards, leaving the considerable retroperitoneal portion devoid of a serosa and surrounded only by connective tissue. Here the rectum forms the flask–like *ampulla recti*. From the powerful longitudinal muscle coat the *Mm. rectococcygei* arise; they are visible as two bands ventral to the raised tail.

The anal canal is a short (5 cm) tube, lined by glandless, squamous stratified epithelium, and forming a distinct caudalward projection covered by thin hairless skin, well firmed up by the underlying well–developed *M.sphincter ani internus* (smooth muscle), *M.sphincter ani* externus (striated) and supported by the fibres of the rectal part of the smooth *M.retractor penis/clitoridis* as well as by the striated *M.levator ani*, which in the horse form strong subanal loops. The *M.levator ani* is attached to the perineal body – the perineal septum in the mare – in which its action, together with that of the anal sphincters, is responsible for the gaping of rectovaginal tears [6].

Omentum: In passing it may be pointed out that the equine omentum, although extensive enough to be able to enter the *cavum vaginale* ('scrotal cavity'), does not form an extensive covering between intestines and body wall. Consequently this 'policeman' of the peritoneal cavity cannot fulfil its function – also likened to that of a self–sealing inner tube – as effectively as in other species.

NERVE CONTROL

The nerve control of the equine alimentary tract may be accepted to follow the general pattern of autonomic control of the gut, *i.e.*, by parasympathetic excitory and sympathetic inhibitory effects on secretory cells and particularly on smooth muscle, which has its own inherent rhythmicity. The efferent parasympathetic innervation is by way of the vagus and the pelvic nerves (cranio–sacral outflow), with preganglionic fibres entering the gut wall, whereas the sympathetic fibres stem from the thoracolumbar outflow, mainly via the greater and lesser splanchnic nerves and coeliac and mesenteric ganglia, from whence post–ganglionic fibres extend as plexuses around the arteries, probably passing mainly to the *muscularis mucosae*,[7] and to the ganglion cells of Auerbach's plexus, so that inhibition occurs predominantly by blocking parasympathetic ganglionic transmission[12 17 19] or by vasoconstriction, and from epinephrine and norepinephrine released from the adrenal gland.[7]The myenteric (Auerbach's) plexus and the submucous (Meissner's) plexus, together with associated ganglion cells form a diffuse generalized system with the formation of local reflex arcs. Afferent fibres pass to the central nervous system through both sympathetic and vagal routes.

In the stomach the mobility and tone are increased greatly by cholinergic impulses, and are usually decreased moderately by adrenergic impulses acting on beta adrenergic receptors [14]. Sphincters are usually relaxed moderately by cholinergic action, and usually moderately contracted by mediation of alpha receptors of adrenergic impulses [14].

Secretion is strongly stimulated by cholinergic impulses; its inhibition by adrenergic impulses is questionable [14].

The same mechanisms hold good in the case of the intestine, although here mobility and tone are decreased by both alpha and beta adrenergic receptors [14].

Obviously, the mechanics of peripheral control are meaningless without control from hierarchy upon hierarchy of higher control centres: spinal cord and medulla oblongata, hypothalamus, limbic system, striatum and cerebral cortex. Considerations of this aspect fall outside the scope of this paper. Too little is known about details pertaining specifically to the horse.

The motor nerve supply routes are summarized briefly. The initial part of the oesophagus appears to be innervated from the pharyngeal plexus, mainly by the vagus nerve and probably the glossopharyngeus as well. From the plexus a large branch extends along the oesophagus.

The cervical and cranial thoracic regions are considered to be supplied by the recurrent laryngeal nerve from the vagus, whereas more caudally the dorsal and ventral vagal rami take over. A myenteric plexus is regarded as being present only where smooth muscle has supplanted the striated musculature. Sympathetic supply to the oesophagus is mainly via the cervicothoracic ganglion; whether it ultimately innervates the muscle, is unknown. The peristaltic contraction caused by a bolus placed into the oesophagus does not occur if the vagus nerves are sectioned [8].

The dorsal vagal trunk, upon reaching the stomach, divides into gastric branches to its visceral face and coeliac branches to the left and right coeliacomesenteric ganglion. The ventral vagal trunk supplies the parietal face of the stomach, the pylorus, the duodenum and the liver. From the coeliacomesenteric ganglion, where no synapses occur, vagal fibres are distributed with those of the sympathetic system to the small intestine and via the intermesenteric plexus and caudal mesenteric ganglion to the large intestine. Their target territory is usually regarded as ending at the transverse colon.

The sympathetic supply to the abdominal part of the gut[4 5 22] separates from the sympathetic trunk to form the greater splanchnic nerve, its roots originating from the sixth or seventh to fourteenth or fifteenth thoracic ganglia. Classically it passes medioventrally to the trunk to enter the abdominal cavity through the lumbocostal arch to join the coeliacomesenteric ganglion. The lesser splanchnic nerves arise from the last two or three thoracic ganglia and go to the coeliacomesenteric ganglion which also receives filaments from the most cranial lumbar paravertebral ganglia (first lumbar splanchnic nerve). The coeliac plexus is a relatively extensive dense network at the aorta and the coeliac and mesenteric arteries. The close relationship here has given rise to the well-known speculation concerning verminous aneurisms of these vessels as a possible cause of neurogenic colic. From the plexus secondary plexuses proceed, laced around the major vessels (abdominal aorta, left gastric, hepatic, splenic and cranial mesenteric arteries) to reach the various abdominal organs and viscera. The right and left coeliacomesenteric ganglia (fusion of coeliac and cranial mesenteric ganglia) are situated in the plexus, on each side of the aorta, at the origin of the homonymous arteries, and are interconnected. From them the *plexus intermesentericus* arises, seemingly part of the aortic plexus [5], and generally appearing as two trunks, with transverse connecting strands and joining the mesenteric ganglia along the face of the aorta. The caudal mesenteric ganglion is a single mass in the horse, immediately cranial to the caudal mesenteric ganglion, splitting to pass on either side of the artery, and ventrally on the vessel, giving rise to the caudal mesenteric plexus. It is supplied also by lumbar spanchnic nerves ($L_2$and interganglionic part between L_2 and L_3[5]) via the intermesenteric plexus. From it in turn the hypogastric nerves, left and right, arise and proceed in close proximity to the ureters to the pelvis, running at first in the mesocolon, then inclining laterally and finally in the lateral vesical ligaments.

In the horse the 'colic tract',[4]a single nerve of considerable size, and a contributary nerve dividing usually into three trunks, together form a bypass from the cranal mesenteric plexus and left coeliac ganglion (and in small part from the coeliac plexus), directly to the caudal mesenteric plexus.

The lumbar sympathetic trunk is not regularly segmented and for a while the left and right components are fused in the sagittal plane. The sympathetic supply to the pelvic viscera is by way of the hypogastric nerves, aortic plexus and the sacral part of the sympathetic trunk. The parasympathetic supply is derived from sacral nerves 2, 3 and 4, which arise with the roots of the pudendal nerve and form the pelvic splanchnic nerves; it is also contained in the caudal rectal nerve to supply the end of the rectum and anal sphincter.

Accessory nerve fibres which bypass the pelvic plexus and establish connections between sacral nerves and pelvic organs, so that the atony of the bladder after total bilaterial resection of the pelvic plexus later clears up completely, have not yet been demonstrated in animals.

The anatomical arrangements of the abdominal and pelvic autonomic systems give a very complex and variable appearance, yet are simple in terms of general principles. Nevertheless, one would like to have more detailed and clear-cut definite data. The structural complexities and the impossibility of tracing microscopic fibre distribution to its ultimate termination, as well as the problem of differentiating between afferent, sympathetic and parasympathetic fibres anatomically, call for an experimental, anatophysiological research attack on a species, the size and cost of which tend to place it beyond the realm of being a practical research subject. It is a fantastic piece of static and dynamic machinery with a most troublous sewage system.

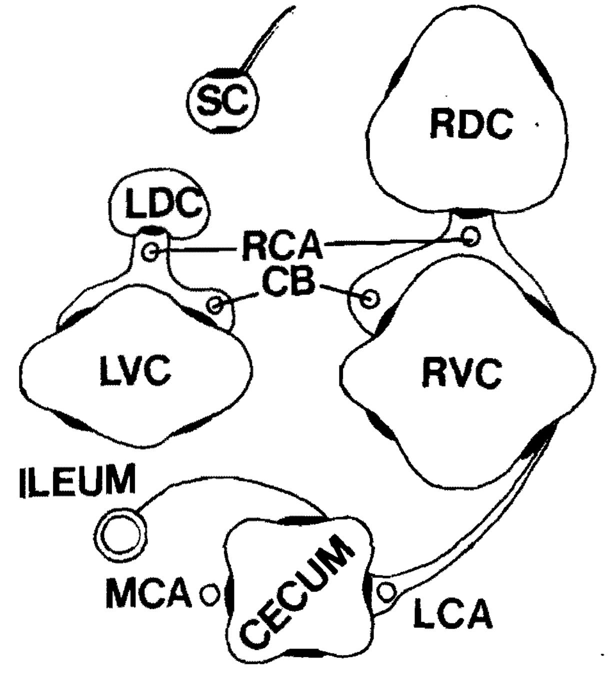

Figure: Schematic cross section of the large intestine of the horse. The longitudinal bands of smooth muscle (teniae) are shown as dense black sections. CB, colic branch of the ileocolic artery; LCA, lateral cecal artery; LDC, left dorsal colon; LVC, left ventral colon; MCA, medial cecal artery; RCA, right colic artery; RDC, right dorsal colon; RVC, right ventral colon; SC, small colon. The mesocolon connects the mesocolic bands of the large colon and contains the blood vessels; it is also attached to the small colon. The ileocecal fold connects the ileum to the dorsal band of the cecum. The cecocolic fold connects the lateral band of the cecum to the lateral free band of the right ventral colon.
(Reproduced from Habel's "Applied Veterinary Anatomy" by kind permission of the author-publisher).

REFERENCES

1. ALEXANDER F. & BENZIE D. 1951 A radiological study of the digestive tract of the foal. *Quart. J. exp. Physiol.* 36 : 213
2. BARONE R. 1954. Appareil digestif. Tôme 2, Fasc. 1 of: TAGAND R. & BARONE R. *Anatomie des Equidés Domestiques.* Lyon: Laboratoire d'Anatomie, Ecole nationale vétérinaire.
3. BOTAR J. 1932 Die Anatomie des lumbo-sacralen und coccygealen Abteiles des Truncus sympathicus bei Haussäugetieren. *Z. Anat. EntwGesch.* 97 : 382
4. DYCE K.M. 1958 The splanchnic nerves and major abdominal ganglia of the horse. *J. Anat.* 92 : 62
5. GOSHAL N.G. & GETTY R. 1970 Post diaphragmatic disposition of the pars sympathica and major autonomic ganglia of the horse *(Equus caballus). Am. J. vet. Res.* 31 : 1951
6. HABEL R.E. 1973 *Applied Veterinary Anatomy.* The Author: 1529 Ellis Hollow Road, RD2, Ithaca, N.Y. 14850. U.S.A.
7. HILL K.J. 1970. Gastrointestinal motility. In: Dukes' *Physiology of Domestic Animals.* 8th Ed. Swenson M.J. (Ed.) Ithaca & London: Cornell University Press.
8. HILL K.J. 1970. Prehension, mastication, deglutition, and the esophagus. In: *Dukes' Physiology of Domestic Animals.* 8th Ed. SWENSON M.J. (Ed.) Ithaca & London: Cornell University Press
9. HUSKAMP B. 1971 Zur Chirurgie der Torsio coli des Pferdes. *Dt. tierärztl. Wschr.* 78 : 533
10. INTERNATIONAL COMMITTEE ON VETERINARY ANATOMICAL NOMENCLATURE 1973 *Nomina Anatomica Veterinaria.* Distributor: Dept. of Anatomy New York State Veterinary College, Ithaca, N.Y. 14850. U.S.A.
11. IRWIN D.H.G. 1963 P.O. Box 4107, Alrode, 1451, South Africa. *Personal communication.*
12. JACOBOWITZ D. 1965 Histochemical studies of the autonomic innervation of the gut. *J. Pharmac. exp. Ther.* 149 : 358
13. KLASBEEK H.C. 1971 Enige gevallen van koliek bij het paard door een liggingsverandering van het caecum. *Tijdschr. Diergeneesk.* 96 : 472
14. KOELLE G.B. Drugs acting at synaptic and neuroeffector junctional sites In: *The Pharmacologic Basis of Therapeutics.* 4th Ed. GOODMAN L.S. & GILMAN A. (Eds) London & Toronto: Collier- MacMillan Ltd.
15. MORRIS P.G.D. 1954 The goblet cells of the large colon of the horse. *J. comp. Path. Ther.* 64 : 97
16. NICKEL R., SCHUMMER A. & SEIFERLE E. 1960 *Lehrbuch der Anatomie der Hausteire.* II *Eingeweide.* Berlin & Hamburg: Paul Parey
17. NORBERG K.A. 1964 Adrenergic innervation of the intestinal wall studied by fluorescence microscopy. *Int. J. Neuro-pharmac.* 3 : 379
18. NUSHAGG W. 1925/1927. Uber das gehäufte Auftreten einer Missbildung am Föhlendarm. *Berl. tierärztl. Wschr.* 41:646/43:158
19. PATON W.D.M. & VIZI E.S. 1969. The inhibitory action of noradrenaline and adrenaline on acetylcholine output by guinea-pig ileum longitudinal muscle strip. *Br. J. Pharmac. Chemother. 35 : 10*
20. RUBELLIO 1890 Über den Oesophagus des Menschen und der Haustiere. *Arch.wiss. prakt. Tierheilk.* 16:1
21. SCHUMMER A. 1953 Morphologische Untersuchungen über die Funktions- Zustände des Ileums. *Tierärztl. Umsch.* 8 : 244
22. SISSON S. & GROSSMAN J.D. 1958 *The Anatomy of the Domestic Animals* 4th Ed. Philadelphia & London: W.B. Saunders Co.
23. YAMANE J. 1927 Über die *Atresia coli, eine lethale erbliche* Darmmissbildung beim Pferd, und ihre Kombination mit Gehirngliomen. *Z. indukt. Abstamm. u. VererbLehre* 46 : 188

DISCUSSION

F.J. Milne: You described briefly the fact that sometimes the omentum is found as far back as the inguinal canal. In our experimental work on investigating the healing of peritoneum, we found in normal horses and also in foetal surgery, when doing an approach through the midline, that the omentum was very rarely present as in the dog, where it is the first structure one meets. Yet, *when we were following* through some of those cases that had adhesions to plastic implants, we found that the omentum had tended to migrate towards the adhesion. This reminds me of the words of one human worker, who described the omentum as 'that interfering busy-body, who always wants to interfere in someone else's affairs.' Can you explain why the omentum has this capacity to migrate to tissues, such as the midline peritoneum, and also sometimes to the inguinal region, following castration, when one would be called back a week later to deal with the omentum? Is there any reason for it?

H.P.A. De Boom: I am afraid, I cannot give a scientifically documented reason. If one looks at the anatomy of an animal, one must always remember that one is looking at the anatomy of a dead animal. In other words, one looks at one picture frame, a *still,* taken at a given instant from a moving film. I think what actually happens in practice is that the omentum is continuously wandering. With the movement of the intestines the omentum will be shifted along. I have never done any accurate detailed observations to support the idea, but when looking at successive dissecting room cadavers one observes considerable variation in the precise location of the mobile part of the omentum. I think it is continuously moving and it must be exceedingly responsive to local inflammatory reactions. So the moment one has such a reaction, the omentum, as it passes by, probably respond immediately by vascular permeability to fibrinogen, so sealing off the danger area, and forming and adhesion. Hence, despite the fact that, in the horse, it does not form a permanent and fairly complete cover to the visceral mass, it still can be reasonably effective by virtue of its wandering habit.