T h e s i s

on the

Gross anatomical and histological studies on the esophagus of the buffalo during its ontogenetic development

Presented

by

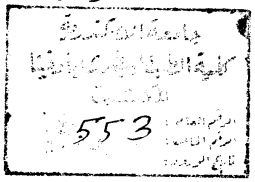
El-Sayed Issa Enany Hassan

(B.V.Sc. 1977)

for

the M.V.Sc. degree

(Anatomy)



under the supervision of

Prof. Dr. habil. Rolf Berg

Dr. Anwar Mohamed Aly Kasem (co-supervisor)

Department of Anatomy,
Histology and Embryology
Faculty of Veterinary Medicine (Edfina)
Alexandria University

(1980)

Contents

1. Introduction

Our anatomical and histological studies on the esophagus of the Egyptian Water buffalo are aimed at several goals. Firstly, due to the absence of data on the embryology, histology and anatomy of the esophagus of the Egyptian Water buffalo in the literature. This thesis intends to furnish us with facts on the histogenesis and morphogenesis of the esophagus in the late prenatal as also in the early and late postnatal stages. These facts will enable us to teach the embryological and anatomical relations of the buffaloe's esophagus to the under- and postgraduates directly and independently of the data of the ox.

In histology, special attention is paid to the changes of the stratified squamous epithelium during the ontogeny, to the appearance of the Lamina muscularis mucosae and to the Tunica muscularis.

In anatomy we focused our interests on applied aspects. For example, very few is reported in the available literature on the length and diameter of the individual parts of the esophagus in the buffalo. But these data may be some value for the clinicians, especially in the internal medicine and surgery, in introducing a stomach tube or probang.

On the other hand, there are the relations between the deep cervical fascia, especially the prevertebral and pretracheal laminae, and the esophagus, which are of great anatomical and surgical interest. We tried to clarify in the different

developmental stages of the Egyptian Water buffalo the extension of the connective tissue, surrounding the esophagus from the retropharyngeal space to the dorsal mediastinum, thus judging the conditions for spreading of septic processes from an injured esophagus or hematomas of an injured common carotid artery or internal jugular vein. A further contribution will be rendered to the applied anatomy of the carotid vagina (Vagina carotica) in the Egyptian Water buffalo.

2. Review of literature

Concerning the position of the Egyptian Water buffalo in the Natural system, COCKRILL (1974) stated that the Egyptian Water buffalo is one breed under the group of the African buffalo (Bos bubalus). It belongs to the tribe Bovini and the family Bovidae, suborder Ruminants and to the order Artiodactyla. The Egyptian Water buffalo has two vaguely differentiated local types, the Beheiri of the Nile delta and the Saidi of Upper Egypt. Both vary in colour, size and production in accordance with differences in the management and environment.

Firstly, the references on the esophagus in the buffalo fetus shall be considered. BERG, TAHER and MOUSTAFA (1969) compared the relation between body weight and esophagus weight in buffalo fetuses. They observed that the esophagus of the buffalo developed more rapidly than that of the camel. Its average relative weight was higher in the camel (0,31%) than in the buffalo (0,19%). The authors assumed that this was fulfilled by the earlier starting point of development of the esophagus in the camel. 1 gm of esophagus tissue was found at a body weight of 208,90 gm in the camel and 446,7 gm in the buffalo. In their studies on the prenatal growth of some organs in the Egyptian Water buffalo TAHER, MOUSTAFA and BERG (1969) found the development of the esophagus of the buffalo following the formula: $\log y = 0{,}83 \log x - 2{,}1$, where $\log y$ = expected esophagus weight, $\log x$ = body weight. Standard error of estimate $Syx = \pm 0{,}3$.

SENGAR and SINGH (1969) performed quantitative and qualitative

studies on the esophagus of the prenatal and postnatal Indian buffalo. They observed that the esophagus remained an insignificant organ up to the second month of intrauterine life. With the straightening of the fetal posture at about the middle of the second month, it gained in length and assumed a well defined form with the elongation of the neck by about the end of the third month of fetal life. It was further seen that while its absolute length increased in almost geometrical progression during the first half of the intrauterine life, its proportion to the total gut length showed a declining trend in the beginning and then got almost constant to account for about 4% of the total gut length. After birth it declined further to about 2,5%.

As far as the tissue weights were concerned it made about 3 - 3,5% of the total gut tissue or 0,27% - 0,12% (2^{nd} - 10^{th} month) which is in good accordance with the data given by BERG, TAHER and MOUSTAFA (1969) (=0,19%).

Histologically the growing esophagus showed interesting changes both in its musculature and mucosa. During the early fetal stages (50 days), the esophageal walls have had a well defined muscularis and mucosa. The mucosa, which was almost smooth and without folds, had a well defined epithelium resting on a basement membrane and was covered with a single layer of squamous cells. There existed no distinction between the Lamina propria and the submucosa as the Lamina muscularis mucosae was not developed to this stage. Both propria and submucosa largely had a cellular nature with well defined nuclei, the connective tissue fibres having had not yet developed. With progress of time, both, muscle and the mucosa

elaborated. More squamous cell layers were added to the mucosal lining and the muscle layers also grew in thickness so much, so that by about the middle of gestation, the fetal esophagus developed almost all these features true of an adult, except that the squamous cells did not get keratinized. The blending propria and the submucosa got differentiated with the development of the Lamina muscularis mucosae and the two started changing their cellular nature to that of the fibrous type. By about the full term fetus the keratinization set in the top squamous cells of the epithelium. At birth it got fully cornified to resemble that of adult in almost all respects.

SENGAR and SINGH (1970) investigated the esophagus of adult female Indian buffaloes and described its position as running dorsally to the trachea in the neck and in between trachea and dorsal aorta in the thorax to the diaphragm. Its length was found variable in different animals depending upon their body length in general and that of the neck in particular. The absolute length of the esophagus was found as 98,72 ± 0,92 cm.

Histologically, the esophageal walls of the Indian water buffalo had the usual four layers, the outermost adventitia, next muscularis, middle submucosa and the innermost mucosa. The adventitia consisted of a thin layer of fibrous connective tissue. It got changed to serosa with the incorporation of the visceral peritoneum on its abdominal part after its emergence at the Hiatus esophageus. The muscularis which contributed maximum to the esophageal wall consisted of two layers, the inner circular and the outer longitudinal one.

The dispositional pattern of the two muscle layers in relation to each other were subjected to great variation. The muscle fibres of both were striated throughout its length and did not change to smooth. A well developed intermuscular nerve plexus reported to lie in between these layers in some sections. The submucosa consisted of loose connective tissue which had considerable amount of elasticity permitting the organ to stretch out at the time of swallowing and regurgitation of bolus. It contained a large number of lymphatics, blood vessels and nerves. Deep esophageal glands could not be identified.

The epithelium of the mucous membrane was thick and of stratified squamous type with a cornified border. It was deeply indented by the papilla of the subjacent Lamina propria mucosae, which consisted of a narrow band of loose connective tissue and did not contain either the esophageal cardiac glands or the superficial esophageal glands. The Lamina muscularis mucosae consisted of one or two layers of smooth muscle bundles disposed longitudinally. It was almost insignificant in the cranial region and got quite prominent in the caudal portion of the esophagus.

In a later publication SENGAR and SINGH (1971) reiterated partially the description of the above mentioned quantitative datas. They observed that the esophagus made 18,4% of the total gut length during the second month of intrauterine life, had a retarded growth (as percentage of total gut length) althrough to about 4% at birth and further down to only 2,45% of the adult age.

The esophageal tissues weighed 3,55% during the third month of fetus, showed some increased growth during the middle of gestation, returned back to 3,66% at birth and then maintained almost on this level.

RAGHAVAN (1964) reported on the esophagus of the adult Indian water buffalo. According to this the esophagus was about 0,75 - 1 m in length, which we consider as in accordance with the datas of SENGAR and SINGH (1970)(esophagus = 0,98 m). The diameter was found as to be 50 mm. No hints were found what distance of the total esophageal length was shared by the cervical, thoracic or abdominal part of the esophagus. RAGHAVAN (1964) indicated only that the cervical part began at the pharynx in the median line behind the Aditus ad esophagem above the rostral border of the cricoid cartilage, and passed backwards and downwards on the dorsal surface of the trachea, till about the level of the third or fourth cervical vertebra. At this level, it crossed the trachea obliquely, placing itself along the left side to the thoracic inlet. The thoracic part began at the level of the first rib and continued its course till it reached the level of the 2nd or 3rd thoracic vertebra, where it again crossed the left face of the trachea obliquely upwards to gain its dorsal surface. It continued this dorsal relation of the trachea to its bifurcation. As it passed through the middle mediastinum, it was pushed to the right of the aortic arch and lying to the right of the median line. It then passed upwards and backwards in the caudal mediastinum, inclined gradually once again to the left and entered the Hiatus esophageus of the diaphragm.

Passing through this opening, it gained the abdominal cavity and immediately terminated on the dome-like, ruminoreticular wall at the cardiac orifice. From this elucidates the practical absence of an abdominal part of the esophagus. This was also underlined by MULLER-BOTHA (1962) and HABEL (1975). They described the abdominal part of the bovine esophagus as absent because of the close contact of the stomach with the diaphragm. Furthermore HABEL (1975) is in accordance with RAGHAVAN (1964) and SENGAR and SINGH (1970) as describing the length of the bovine esophagus as being 90 - 105 cm. First time he gave measurements of the subdivisions of the esophagus, the cervical part as being 42 - 49 cm and the thoracic part as 48 - 56 cm. But HABEL (1975) warned also of the unreliability of the measurements of the diameter of the esophagus because of its dilatability in the living state.

The relations of the esophagus in bovine were described by WILKENS and ROSENBERGER (1957), RAGHAVAN (1964), KOCH (1970), DYCE and WENSING (1971), BERG (1973, 1974), HABEL (1975) and KRAHMER, SCHRÖDER and MICHEL (1976). According to these authors the bovine esophagus was related at its origin, to the M. rectus capitis ventralis major dorsally and cricoid cartilage ventrally; at the level of its crossing over to the left face of the trachea, to the M. longus colli dorsally and the trachea ventrally; at the level of the 3rd cervical vertebra to the left M. longus colli dorsally, the vagosympathetic trunc, common carotid artery and internal jugular vein laterally and the trachea medially; at the level of the thoracic inlet, to the left, external jugular vein laterally

and trachea medially; at the level of the cranial and middle mediastinum to the thoracic duct and aortic arch on the left; to the M. longus colli, the right large trunk of the right costocervical vein and the N. vagus dexter as also its dorsal and ventral branches on the right; at the level of its course through the caudal mediastinum to the dorsal and ventral esophageal continuation of the Nn. vagi on the respective parts, the right and left lungs on the corresponding sides and the bronchial and esophageal arteries on its left.

BERG (1973, 1974) discussed the applied and topographical anatomy of the dorsally convex head-neck-curvature and of the ventrally convex neck-thorax-curvature of the bovine's esophagus.

DYCE and WENSING (1971) mentioned that there was no anatomical evidence for the existence of a functional sphincter that was described as existing directly cranial the diaphragm. They emphasized also the important relations of the cranial and costocervical lymph nodes to the esophagus at the level of the entrance to the chest as also of the caudal mediastinal lymph nodes in the last partof its course.

TIWARI (1978) gave a detailed report on the fine structure of the esophagus of adult Indian Water buffaloes (2 - 5 years). According to him the mucosa was folded longitudinally and lined with parakeratotic stratified squamous epithelium. The basal epithelium comprised cuboidal to columnar cells with dark staining nuclei. The Lamina propria and submucosa were of coarse areolar connective tissue containing arterioles and a zone rich in capillaries. Papillary bodies originated from the

Lamina propria and extended for up to half the thickness of the epithelium and had cores containing capillaries. The Lamina propria was separated from the submucosa by a Lamina muscularis mucosae. The texture of the submucosa was coarser toward the Lamina propria than toward the Tunica muscularis. Elastic fibres were comparatively more numerous at the caudal end than the cranial end of the esophagus.

Acini of the submucosal glands were lined with cuboidal to columnar cells with distinct boundaries and flattened nuclei at the cell bases. The cytoplasm had a reticulated appearance and was PAS-positive. Acinar ducts were lined with cuboidal cells, which increased in thickness to stratified squamous epithelium at the terminal part of the duct. Reticular fibers formed a thick network around the acini and their ducts. The Tunica muscularis consisted of striated fibers of two inner layers with intercrossing and an outer special layer without intercrossing.

DELLMANN and BROWN (1976) mentioned glands in the submucosa of the bovine esophagus at its pharyngo-esophageal junction. In cattle occurred mixed acini and demilunes.

WAKURI and MUTO (1972) studied the terminal glandular portions of the esophageal glands of cattle electronmicroscopically. Mucous and serous cells could be recognized, with the mucous cells being the more numerous. Myoepithelial cells were situated between the basal surface of the secretory cells and the basement membrane. The cytoplasm of the myoepithelial cells was packed with filamentous structures, and it was concluded that these cells were contractile.

Descriptions of the blood and nerve supply are found with RAGHAVAN (1964), BERG (1973, 1974), HABEL (1975) in ox and EL AYAT (1977) in buffalo. Branches to the esophagus come from the cranial thyroid, common carotid, bronchoesophageal and reticular arteries. The veins are branches of the cranial and middle thyroid veins, the caudal part of the external jugular vein and cranial vena cava. An esophageal vein may come from the left azygos vein. The caudal esophageal vein is a branch of the reticular vein or the left ruminal.
The nerve supply is realized by the N. vagus, N. laryngeus recurrens and N. sympathicus.
VSHIVTSEVA (1970) who studied the afferent innervation of the intramural ganglia in the esophagus of adult sheep mentioned that the intermuscular plexus of the esophagus contained afferent nerves made up of myelinated fibers. Sensory nerve endings were found in the connective tissue layers.
From reasons of comparison the studies of YAP and MAALA (1973) on the esophagus of the Philippine Carabao (Bos bubalis) shall be mentioned. They found the course, topography, anatomy and histology of the Carabaon esophagus similar to that of cattle, except the total length which was found shorter.

3. Material and methods

The thesis comprises anatomical and histological studies for which different materials were collected and different methods applied.

Anatomical studies:

For the anatomical studies 14 fetuses of both sexes, with a CRL of 39 - 94 cm, 2 male buffalo calves, 20 and 30 days of age, and 2 adult buffaloes (8 years, ♀, and 3 years, ♂) were used.

According to the following formulae of ABDEL RAOUF and EL NAGGAR (1968) the CRLs can be transformed into days of age:

$$y = 28.660 + 4.496 \times CRL$$

for fetuses with less than 20 cm CRL

and

$$y = 73.544 + 2.256 \times CRL$$

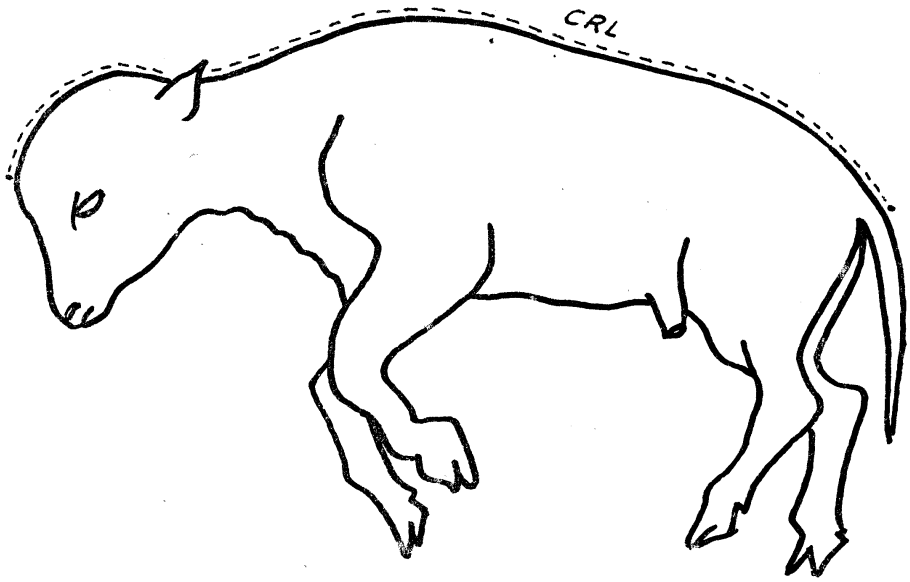
for fetuses measuring more than 20 cm CRL

y = age in days

The specimens were collected from the Cairo abbatoir, there firstly intrathoracically injected with 10% formaline and put definitely into 10% formaline in the department till to the time of dissection (about 30 days in case of lateral and ventral dissection, about 3 months for cross-sections).

To clearify the position, relation and course of the esophagus lateral and ventral dissections and also cross sections were

Fig. 1 Diagramatic representation showing the measurement of the fetal crown - rump - length (C R L)



exerted. All measurements have an orientating character, thus giving us a first idea on the quantitative aspects of the esophagus, i.e. the results are not statistically treated, because it would have exceeded the intentions of this thesis. All measurements were taken from fixed specimens by a flexible cloth tape. The problems about these are known (inaccuracy on reason of the integration of the esophageal muscular system into the fixing environment and of the dilatability in the fresh state). The measurements include the total length of the esophagus, as also the length of its individual parts (cervical, thoracic, and abdominal parts), furthermore the diameters (taken at the level of the larynx, at the level of the thoracic inlet, at the base of the heart and immediately cranial to the Hiatus esophageus).
To obtain the diameter of the esophagus we based our considerations on the fact that the esophagus is a roughly circular structure in cross-section. The esophagus was opened and the total circumference (= $2\pi r$) measured. From this the diameter (= 2r = d) was calculated.

For the lateral dissections the following fetuses were used:

1. Buffalo-fetus of CRL 44 cm or 173 days of age
2. " " " " 51 cm or 189 " " "
3. " " " " 57 cm or 202 " " "
4. " " " " 61 cm or 211 " " "
5. " " " " 68 cm or 227 " " "
6. " " " " 94 cm or 286 " " " .

Fig. 2 Diagramatic representation showing the different levels of cross-sections through the neck and thorax

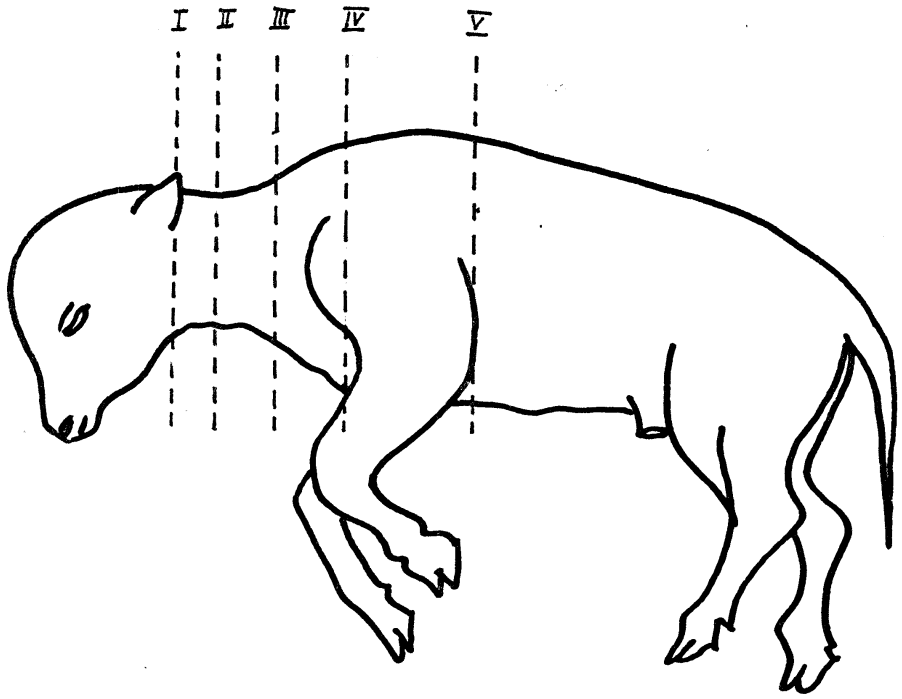
I Cross-section through the neck at the level of the larynx

II Cross-section through the neck at the level of the axis

III Cross-section through the neck at the level of the fourth cervical vertebra

IV Cross-section at the level of the thoracic inlet

V Cross-section through the thorax at the level of the fifth rib.



For the ventral dissections the following fetuses were used:

1. Buffalo-fetus of CRL 39 cm or 151 days of age
2. " " " " 51 cm or 189 " " "
3. " " " " 53 cm or 193 " " "
4. " " " " 57 cm or 202 " " "
5. " " " " 61 cm or 211 " " "
6. " " " " 68 cm or 227 " " " .

For the cross-sections (fig. 2) two fetuses were used:

1. Buffalo-fetus of CRL 53 cm or 193 days of age
2. " " " " 62 cm or 213 " " " .

Histological studies:

Samples for the histological studies were taken totally from 7 fetuses, 1 calf and 1 adult buffalo.

The buffalo-fetuses were of the following developmental stages:

1. Buffalo-fetus CRL 9 cm or 69 days of age
2. " " " 14 cm or 92 " " "
3. " " " 17 cm or 105 " " "
4. " " " 25 cm or 130 " " "
5. " " " 36 cm or 155 " " "
6. " " " 67 cm or 225 " " "
7. " " " 94 cm or 286 " " " .

The buffalo-calf has had 20 days of age, the adult buffalo 3 years.

From all portions of the esophagus samples were taken:

- from the pharyngo-esophageal junction
- " " cervical part
- " " thoracic part

They were treated according to the classical method of paraffin sections (fixation in 10% formaline for 24 hours, dehydration in graded series of ethyl alcohole, clearing by xylene, embedding in paraffin, cutting into sections of 5 µm in thickness).

Three stains were applied:

- hematoxylene and eosin after HARRIS (1900) for general studies
- VAN GIESON (1889) stain for the differentiation of collagenous fibers, smooth musculature and glands
- elastic stain after WEIGERT (1898) for the detection of the elastic fibers.

Results

4. Anatomical studies on the esophagus of the Egyptian Water buffalo during its ontogenetic development

The esophagus of the buffalo is a musculo-membranous tube which extends from the pharynx to the stomach. During the ontogenetic development it increases considerably in length. Thus its total length measures about 15,6 cm at a buffalo-fetus of 39 cm CRL and will reach about 96 cm at the adult buffalo (table 1). The same happens with the esophageal diameter which increases roughly ten times from a buffalo-fetus of 39 cm CRL till to the adult animal (3,8 mm and 30,8 mm over the larynx or 3,5 mm and 30,2 mm just cranial to the Hiatus esophageus)(table 2).
As it is usual we have divided the esophagus for matter of description into three parts:

1. pharyngo-esophageal junction

   (studied at a cross-section at the level of the larynx /fig. 3/)

2. cervical part

   (studied at two cross-sections at the level of the axis /fig. 4/ and of the 4th cervical vertebra /fig. 5/)

3. thoracic part

(studied at two cross-sections at the level of the thoracic inlet /fig. 6/ and of the base of the heart /5th rib/ /fig. 7/)

The abdominal part is practically found only in the buffalo-fetuses and considered for some measurements.

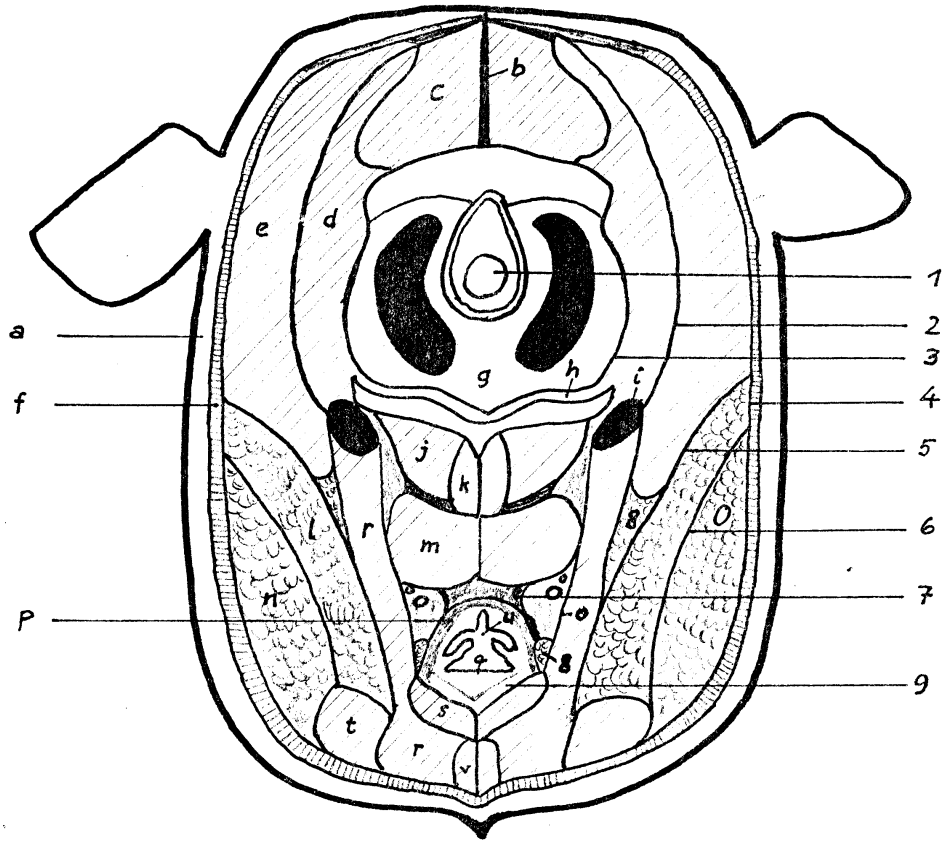
1. The pharyngo-esophageal junction (fig. 3)

It is the initial part of the esophagus and situated over the larynx. As the table 2 indicates it is in all developmental stages of the buffalo the widest part. The diameter is 3,82 mm in the buffalo fetus of 39 cm CRL and finally 30,89 mm in the adult buffalo. It is steadily increasing (table 2). May be that the former synonym esophageal vestibule for pharyngo-esophageal junction is related also to this widest diameter of the whole esophagus. The esophagus begins caudal to the pharynx and descends at the level of the atlanto-axial joint gradually from the dorsal surface to the left side of the trachea, thus forming the dorsal convex cephalo-cervical curvature which is well to consider at the introduction of the stomach tube.
As figure 3 indicates is the initial part of the esophagus directly found over the cricoid cartilage. Both, trachea and esophagus, are surrounded by the pretracheal lamina, a constituent of the deep cervical fascia. Dorsally it is by a connective tissue filled space (Spatium retropharyngeum) separated from the prevertebral lamina and the longus capitis

Fig. 3 Cross-section through the neck of a buffalo-fetus (CRL = 53 cm) at the level of the larynx

Cranial view - schematic representation

a	Cutis
b	Septum dorsale medianum
c	M. rectus capitis dorsalis major
d	M. obliquus capitis cranialis with covering aponeurosis of the splenius and brachiocephalicus
e	M. cleidooccipitalis
f	M. cutaneus colli
g	Condylus occipitalis
h	Atlas
i	Stylohyoid
j	M. rectus capitis lateralis
k	M. rectus capitis ventralis
l	Gl. mandibularis
m	M. longus capitis
n	Gl. parotis, containing a glandular vein
o	Vagina carotica, containing A. carotis communis and Truncus vagosympathicus
p	Pharyngeal wall
q	Vestibulum laryngis
r	M. sternomastoideus
s	M. thyreopharyngeus
t	M. sternomandibularis
u	Esophagus (caudal of the pharyngo-esophaegal junction)
v	M. sternothyreohyoideus (M. sternothyreoideus and sternohyoideus)
1	Medulla spinalis
2	Fascia cervicalis profunda (superficial lamina)
3	Fascia cervicalis profunda (deep lamina)
4	Fascia cervicalis superficialis (superficial lamina)
5	Fascia cervicalis superficialis (deep lamina)
6	Fascia parotidea
7	Spatium retropharyngeum
8	Thymus
9	Cartilago thyreoidea



muscle. Both parts of the deep cervical fascia, the prevertebral and pretracheal laminae, are sharing in the formation of its third constituent, the carotic vagina, situated laterally from the esophagus and the retropharyngeal space, containing important structures like the A. carotis communis and the Truncus vagosympathicus. Ventrolaterally from the esophagus the two cervical lobes of the thymus are found (the buffalo is a typical representative of the cervical type of the thymus). Laterally from these structures the sternomastoid muscle is found and lateral from this the mandibular and parotid glands, separated by the parotid fascia. Ventrally to the esophagus the laryngeal vestibule, cricoid cartilage, the thyreopharyngeal, the sternothyreohyoid, the sternomastoid and sternomandibular muscles are following.

The outer layers are formed by the relatively strong cutaneus colli muscle, invested by the superficial cervical fascia, and by the relatively thick skin.

2. The cervical part (Pars cervicalis esophagi)(fig. 4 and 5)

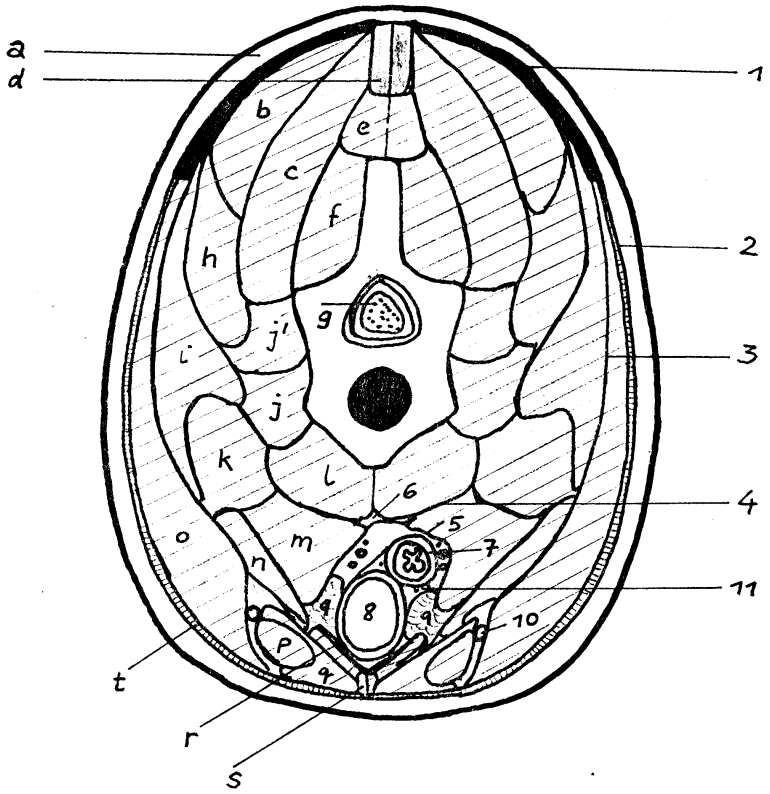
The cervical part continues the pharyngo-esophageal junction caudally and extends between a transverse plane along the caudal border of the rami of the mandible cranially and a such one through the prescapular sulcus caudally. It is situated in the region of the neck, cervix or collum.

We found it in all our quantitative studies the longest part of the esophagus, comprising 49,36% of the total length in buffalo-fetuses of a CRL 39 cm and 51,32% in those of CRL

Fig. 4 Cross-section through the neck of a buffalo-fetus (CRL = 53 cm) at the level of the axis

Cranial view - schematic representation

a	Cutis
b	M. rhomboideus cervicis
c	M. semispinalis capitis
d	Funiculus nuchae
e	M. rectus capitis dorsalis major
f	M. obliquus capitis caudalis
g	Medulla spinalis
h	M. longissimus atlantis
i	M. splenius cervicis
j	M. intertransversarius ventralis
j'	M. intertransversarius dorsalis
k	M. longissimus capitis
l	M. longus colli
m	M. longus capitis
n	M. omohyoideus
o	M. cleidomastoideus
p	M. sternomandibularis
q	M. sternomastoideus
r	M. sternothyreoideus
s	M. sternohyoideus
t	M. cutaneus colli
1	Aponeuroses of the M. splenius cervicis and M. cleidooccipitalis
2	Fascia cervicalis superficialis (superficial lamina)
3	Fascia cervicalis superficialis (deep lamina)
4	Lamina prevertebralis
5	Vagina carotica with content (A. carotis communis, V. jugularis interna, Truncus vagosympathicus)
6	Spatium retropharyngeum
7	Esophagus
8	Trachea with Lamina tretrachealis
9	Thymus, Lobus cervicalis
10	V. jugularis externa
11	N. laryngeus recurrens



94 cm (full term fetus). It varies only very few. Practically it forms the half of the esophagus, the second half is made up of the thoracic and abdominal parts together (table 1). Absolutely the length of the cervical part is developing from 7,7 cm in buffalo-fetuses of CRL 39 cm till 19,5 cm in buffalo-fetuses of CRL 94 cm.

In its diameter is the cervical part narrower than the pharyngo-esophageal junction (table 2). This could be observed thoroughly (3,18 mm in buffalo-fetuses of CRL 39 cm and 7,32 mm in buffalo-fetuses of CRL 94 cm /full term fetus/).

At the level of the thoracic inlet it forms the dorsally concave cervico-thoracic curvature which represents the narrowest passage of the whole esophagus which is of paramount clinical significance.

At the level of the atlanto-axial joint the esophagus descends gradually from the dorsal surface to the left side of the trachea, forming the dorsally convex cephalo-cervical curvature. At the level of the 4th cervical vertebra this shift of position is finished and the cervical part is now found completely at the left side of the trachea. It continues its course in this position till to the level of the 7th cervical vertebra.

The relations of the cervical part of the esophagus are illustrated in the figures 4 and 5.

Dorsally it is related to the retropharyngeal space, which continues still caudally, and to the prevertebral lamina with the longus colli muscle. At the level of the axis the left carotic vagina is imposing between the esophagus and the

Fig. 5 Cross-section through the neck of a buffalo-fetus at the level of the 4th cervical vertebra (CRL = 53 cm)
Cranial view - schematic representation

a	Cutis
b	M. trapezius, Pars cervicalis
c	M. rhomboideus cervicis
d	M. splenius cervicis
e	M. semispinalis cervicis
f	Funiculus nuchae
g	Lamina nuchae
h	M. multifidus cervicis
i	M. intertransversarius dorsalis
j	M. serratus ventralis cervicis
j'	M. intertransversarius ventralis
k	Mm. longissimi capitis et atlantis
l	Medulla spinalis
m	M. cleidomastoideus
n	M. omotransversarius
o	M. omohyoideus
p	M. longus capitis
q	M. longus colli
r	M. sternomandibularis
s	M. sternomastoideus
t	Mm. sternohyoideus and sternothyreoideus
u	M. cutaneus colli
1	Fascia cervicalis superficialis (superficial lamina)
2	Fascia cervicalis superficialis (deep lamina)
3	Lamina prevertebralis
4	Lamina pretrachealis
5	Vagina carotica and its content (A. carotis communis, V. jugularis interna, Truncus vagosympathicus)
6	Trachea
7	Esophagus
8	Thymus, Lobus cervicalis
9	V. jugularis externa
10	N. laryngeus recurrens
11	Spatium retropharyngeum

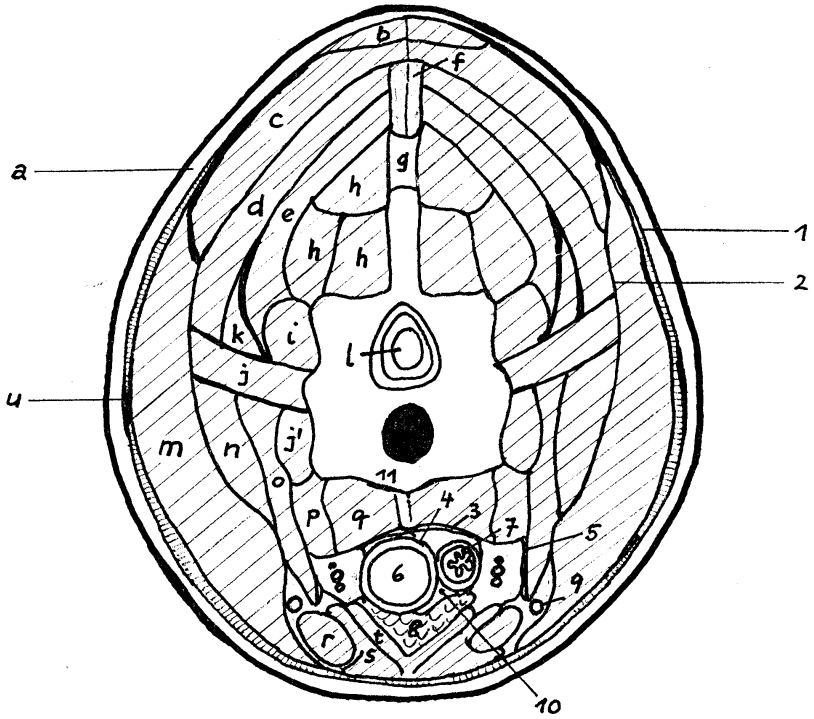
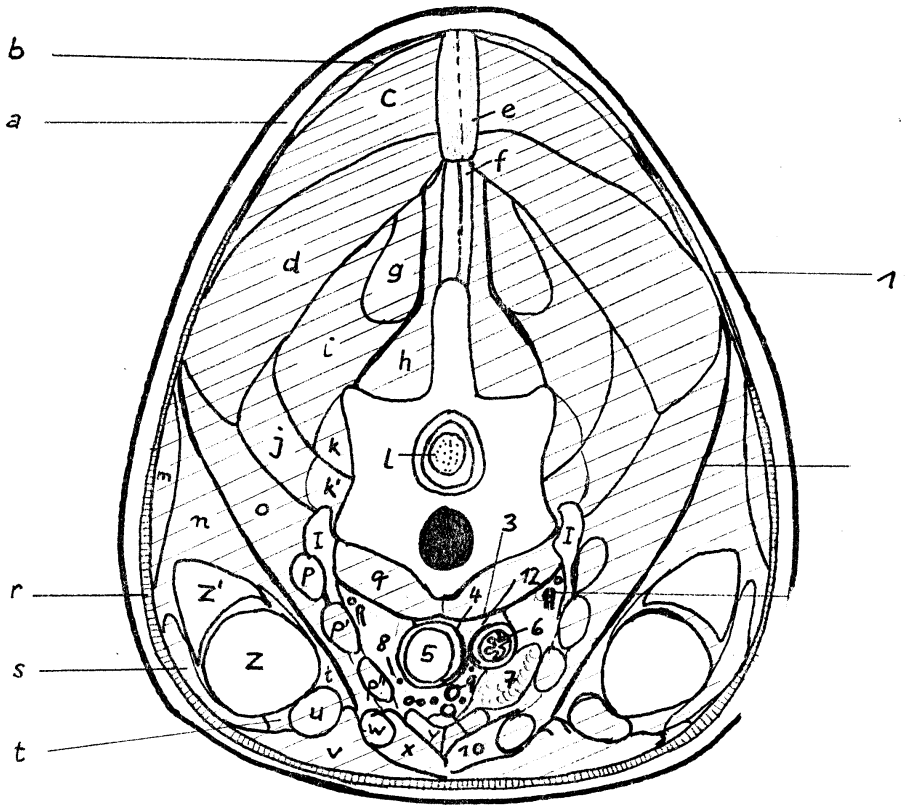


Fig. 6 Cross-section through the neck of a buffalo-fetus (CRL = 53 cm) at the level of the thoracic inlet

Cranial view - schematic representation

a	Cutis
b	M. rhomboideus cervicis
c	M. splenius cervicis
d	M. semispinalis cervicis
e	Funiculus nuchae
f	Lamina nuchae
g	M. longissimus cervicis
h	M. multifidus cervicis
i	M. iliocostalis cervicis
j	Mm. longissimi capitis et atlantis
k	M. intertransversarius dorsalis
k'	M. intertransversarius ventralis
l	Medulla spinalis
m	M. omotransversarius
n	M. supraspinatus
o	M. serratus ventralis cervicis
p	M. scalenus dorsalis
p'	M. scalenus intermedius
p''	M. scalenus ventralis
q	M. longus colli
r	M. cutaneus colli
s	M. cleidobrachialis
t	M. pectoralis profundus (M. pectoralis ascendens)
u	M. biceps brachii
v	M. pectoralis transversus
w	M. sternomandibularis
x	M. sternomastoideus
y	M. sternothyreoideus and M. sternohyoideus
z	Caput humeri
z'	Tuberculum supraglenoidale
I	1st rib
1	Fascia cervicalis superficialis (superficial lamina)
2	Fascia cervicalis superficialis (deep lamina)
3	Lamina prevertebralis
4	Lamina pretrachealis
5	Trachea
6	Esophagus
7	Thymus, Lobus intermedius
8	N. laryngeus recurrens
9	Truncus bicaroticus
10	V. cava cranialis
11	A. vertebralis
12	Spatium retropharyngeum



retropharyngeal space, which is filled by loose connective tissue.

Laterally and at the level of the axis firstly the carotic vagina is bordering the esophagus on both sides. It contains the common carotic artery, the vagosympathetic trunk and the internal jugular vein and is formed by the prevertebral lamina and the pretracheal lamina. The latter one is also investing the trachea and esophagus.

At the level of the 4th cervical vertebra the relations have changed insofar as the esophagus has shifted completely to the left side of the trachea, thus imposing the latter one between the esophagus and the right carotic vagina. Laterally to the carotic vagina are following muscles. These are the Mm. cleidomastoideus, omotransversarius and omohyoideus (fig. 4 and 5) and finally the relatively strong M. cutaneus colli, invested by the superficial lamina of the Fascia cervicalis superficialis and the skin.

Ventrally the left recurrent nerve and left cervical lobe of the thymus are related to the esophagus, which are followed outside by the sternomandibular, sternomastoid, sternothyreohyoid, cutaneous colli muscles and the skin.

3. <u>The thoracic part (Pars thoracica esophagi)</u>(fig. 6 and 7)

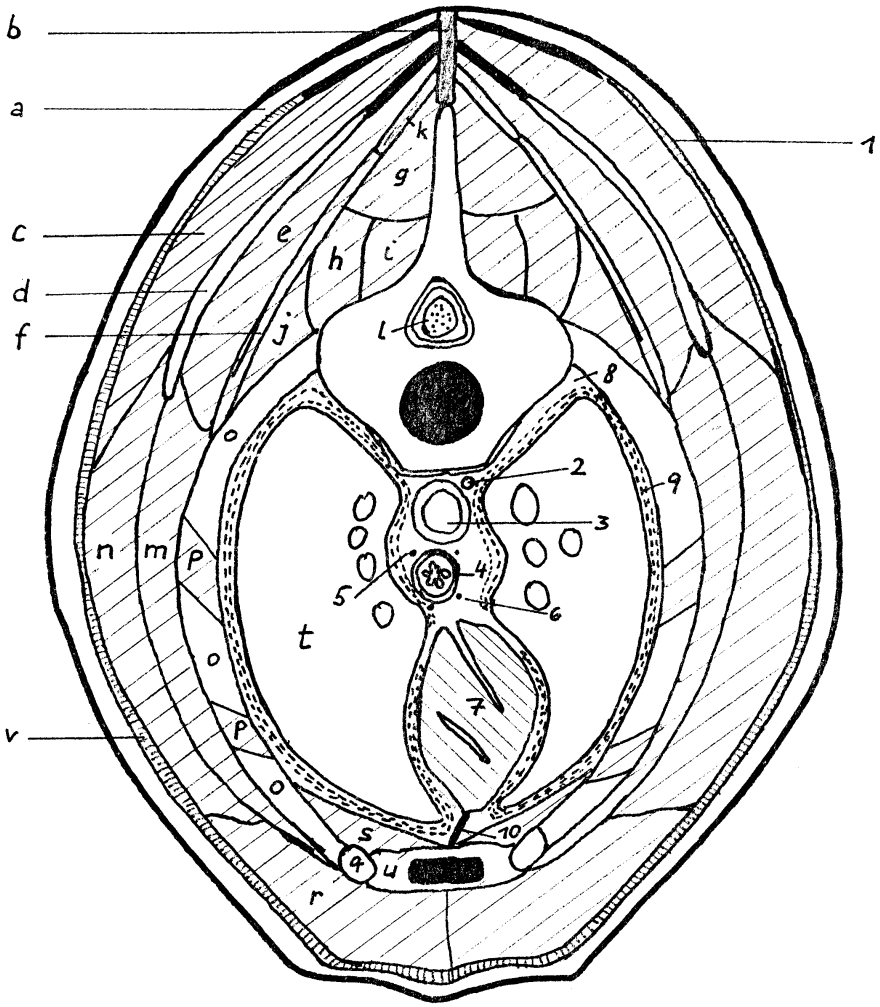
The thoracic part of the esophagus is continueing caudally the cervical part and extends from the thoracic inlet cranially till to the Hiatus esophageus of the diaphragm caudally.

It is absolutely and relatively shorter than the cervical

Fig. 7 Cross-section through the thorax of a buffalo-fetus (CRL = 53 cm) at the level of the 5th rib

Cranial view - schematic representation

a	Cutis
b	Funiculus nuchae
c	M. trapezius, Pars thoracica
d	Cartilago scapulae
e	M. rhomboideus thoracis
f	Mm. spinalis thoracis et semispinalis thoracis
g	M. longissimus thoracis
h	M. iliocostalis thoracis
i	M. multifidus thoracis
j	Mm. levatores costarum
k	Lamina nuchae
l	Medulla spinalis
m	M. serratus ventralis thoracis
n	M. latissimus dorsi
o	5th rib
p	Mm. intercostales externi et interni
q	Cartilago costalis
r	M. pectoralis transversus
s	M. transversus thoracis
t	Lung
u	Sternum
v	M. cutaneus trunci
1	Fascia trunci superficialis
2	V. azygos sinistra
3	Aorta thoracica
4	Esophagus
5	Truncus vagalis dorsalis
6	Truncus vagalis ventralis
7	Heart
8	Fascia endothoracica
9	Pleura parietalis et Pleura pulmonalis
10	Ligg. sternopericardiaca



part (table 1). It measures about 7,5 cm in the buffalo-fetus of CRL 39 cm and 17,8 cm in the buffalo-fetus of 94 cm CRL (full term fetus).

The relative part of the total length of the esophagus is 48,07 % in the buffalo-fetus of 39 cm CRL and 46,48 % in the buffalo-fetus of 94 cm CRL (full term fetus).

The diameter of the thoracic part of the esophagus differs (table 2). At the thoracic inlet it is narrowest and resembles the cervical part. At the base of the heart it becomes a little wider and at the level of the Hiatus esophageus more wider, roughly reaching the dimensions of the pharyngo-esophageal junction.

Thus the esophagus of the buffalo offers to us as a caudally widening musculo-membranous tube with dilated ends.

From the thoracic inlet the esophagus is running caudally. It passes dorsally the cranial, middle and caudal mediastinal spaces. At the base of the heart (level of the 5th thoracic vertebra) the thoracic part of the esophagus forms its third curvature, which is dorsally convex. The aorta causes at the level of the base of the heart a displacement of the esophagus to the right side of the median plane. Leaving the base of the heart the esophagus curves ventrally and caudally to reach the Hiatus esophageus at the level of the 11th thoracic vertebra.

The relations of the thoracic part of the esophagus were found to be the following:

<u>At the level of the thoracic inlet</u> (fig. 6): Dorsal: The retropharyngeal space, the left longus colli muscle with

prevertebral fascia. Dorsolateral: Stellate ganglion. Lateral: Left costocervical trunk, vertebral artery, thoracic roots of the brachial plexus. Ventral: Lobus intermedius and Lobus thoracicus of the thymus, costocervical vein. Ventrolateral: The left vagus nerve.

At the level of the base of the heart (fig. 7): Ventral: Trachea and common brachiocephalic trunk, ventral vagal trunk. Dorsal: Dorsal vagal trunk, thoracic aorta, left azygos vein. Laterally: At the beginning still the left thoracic lobe of the thymus, then the mediastinal as also the right palmonary pleura and right lung.

At the level of the Hiatus esophageus:

Dorsal: Truncus vagalis dorsalis and Lnn. mediastinales caudales. Ventral: Truncus vagalis ventralis. Lateral: Mediastinal pleura of the caudal mediastinum.

Abdominal part: A distinct abdominal part of the esophagus is found till to the stage of a full-term fetus. Later on, after parturition it can be practically neglected, due to the rapid increasing development of the rumen.

As abdominal part is that part of the esophagus understood which extends from the Hiatus esophageus to the Atrium ruminis. It is absolutely and relatively short, measuring 0,4 - 0,7 cm in buffalo-fetuses of CRL 39 cm and 94 cm and representing 2,57 % - 1,84 % of the total length of the esophagus in fetuses of the same stages.

Table 1

Length of the esophagus and of its individual portions

	CRL/days /years	total length of esophagus	length of cervical part absolute	length of cervical part relative	length of thoracic part absolute	length of thoracic part relative	length of abdominal part absolute	length of abdominal part relative
buffalo-fetus	39 cm	15,6 cm	7,7 cm	49,36 %	7,5 cm	48,07 %	0,4 cm	2,57 %
"	44 cm	16,5 cm	8,5 cm	51,52 %	7,7 cm	46,67 %	0,3 cm	1,81 %
"	51 cm	22,5 cm	11,4 cm	50,67 %	10,6 cm	47,11 %	0,5 cm	2,22 %
"	53 cm	23 cm	11,5 cm	50,00 %	11,0 cm	47,82 %	0,5 cm	2,18 %
"	57 cm	26,8 cm	13,5 cm	50,37 %	12,5 cm	46,64 %	0,8 cm	2,99 %
"	61 cm	27,3 cm	14,2 cm	52,01 %	12,5 cm	45,79 %	0,6 cm	2,20 %
"	68 cm	30 cm	15,3 cm	51,00 %	14,0 cm	46,67 %	0,7 cm	2,33 %
"	94 cm	38 cm	19,5 cm	51,32 %	17,8 cm	46,84 %	0,7 cm	1,84 %
calf	20 days	55 cm	- +)	- +)	- +)	- +)	-+)	- +)
"	30 days	57 cm	- +)	- +)	- +)	- +)	- +)	- +)
adult	3 years	82 cm	- +)	- +)	- +)	- +)	- ++)	- ++)
"	8 years	96 cm	- +)	- +)	- +)	- +)	- ++)	- ++)

+) from technical reasons it was not possible to obtain datas from this portion of the esophagus

++) an abdominal part is practically absent in adult buffaloes (considerable development of the rumen)

Table 2

Diameter of the esophagus at its individual portions
(completely isolated, relaxed and not extended esophagus) formaline fixed

	CRL/days /years	over the larynx	at the thoracic inlet	over the base of the heart	just cranial to the Hiatus esophageus
buffalo-fetus	39 cm	3,82 mm	3,18 mm	3,18 mm	3,50 mm
"	44 cm	3,98 mm	3,18 mm	3,50 mm	3,82 mm
"	51 cm	5,57 mm	4,78 mm	5,10 mm	5,41 mm
"	53 cm	5,73 mm	5,09 mm	5,09 mm	5,73 mm
"	57 cm	6,36 mm	5,73 mm	5,73 mm	6,05 mm
"	61 cm	7,01 mm	5,73 mm	5,73 mm	6,05 mm
"	68 cm	7,96 mm	5,73 mm	6,05 mm	6,37 mm
"	94 cm	8,20 mm	7,32 mm	7,32 mm	7,96 mm
calf	20 days	11,14 mm	-	9,90 mm	10,50 mm
"	30 days	11,78 mm	-	10,50 mm	11,14 mm
adult	3 years	24,53 mm	-	22,93 mm	23,89 mm
"	8 years	30,89 mm	-	29,30 mm	30,25 mm

5. Histological studies on the esophagus of the Egyptian Water buffalo during its ontogenetic development

For matter of convenience the esophagus was divided into the following three portions

1. pharyngo-esophageal junction,
2. cervical part,
3. thoracic part.

The description of the results will be laid down in such a manner, that firstly qualitative and quantitative aspects of the individual esophageal portions are considered for all stages and after this the entire esophagus with its three portions for a certain ontogenetic stage.

Part I: Qualitative aspects

Pharyngo-esophageal junction

Tunica mucosa

Lamina epithelialis: The esophageal lumen is irregular quadrilateral or stellate in outline (fig. 8 and 9). In buffalo fetuses of CRL 9 - 67 cm the Lamina epithelialis consists of a superficial layer and a deep layer (fig. 8-11). The superficial layer varies in thickness due to the increasing number of cell layers with increasing age (CRL 9 cm = 4 layers, CRL 25 cm = 7 - 8 cell layers, CRL 36 cm = 9 - 10 cell layers). The cells are polyhedral in shape, relatively

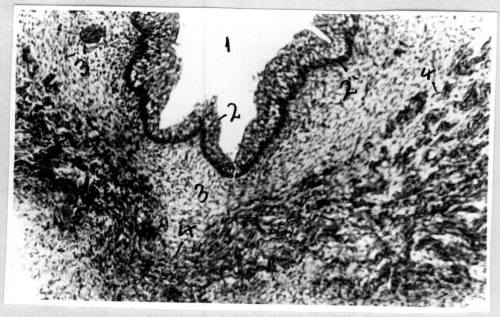


Fig. 8 Cross-section through the pharyngo-esophageal junction of a buffalo-fetus (CRL = 9 cm)

H&E stain. Obj.: 5; Ocular 10

1	Lumen of the esophagus
2	Lamina epithelialis, superficial layer
2'	Lamina epithelialis, deep layer
3	Lamina propria mucosae / Tela submucosa
3'	Glandulae esophageae in the Lamina propria mucosae / Tela submucosae
4	Tunica muscularis

large, have a faint cytoplasm and a relatively large ovoid to spherical nucleus, which may be placed centrally or at the luminal pole of the cell. Some top layer cells are binucleated. Cell borders are distinctly visible (fig. 10 and 11).
From CRL 94 cm (full term fetus) the superficial cell layers become more solidified and compressed, thus assuming a condition similarly found in adult specimens (fig. 12). The cytoplasm is distinct eosinophilic with H&E.
Generally the stratified squamous epithelium of the pharyngo-esophageal junction in buffalo fetuses is not keratinized. The keratinization occurs after birth. First symptomes of this process are seen in fetuses of CRL 67 cm. A top layer of cells becomes flattened, and the cytoplasm appears pinkish with H&E (fig. 10 and 11). In CRL 94 cm-buffalo-fetuses these layers are increased to two (fig. 12). Correspondingly their nuclei are also flattened. Among our studied material firstly in buffalo calves of 20 days of age keratinization of the top cell layer of the superficial layer was observed. The keratinization process was found to be extremely elaborated in 3 years old adult buffaloes. With VAN GIESON the cornified layer is contrasted in colour with the Stratum spinosum and Stratum granulosum.
The <u>deep layer</u> of the Lamina epithelialis consists of one row of darker stained cuboidal or columnar cells with still darker stained spherical to columnar cell nuclei. These cells are deployed in one smooth line till a CRL of 94 cm (fig. 8 - 12), i.e. till birth no symptoms of papillary formation could be observed. This will occur later on, synchronously with

Fig. 9 Cross-section through the pharyngo-esophageal junction of a buffelo-fetus (CRL = 25 cm)
H&E stain. Obj.: 5; Ocular 10

1	Lumen of the esophagus
2	Lamina epithelialis, superficial layer
2'	Lamina epithelialis, deep layer
3	Lamina propria mucosae / Tela submucosa
3'	Lamina propria mucosae / Tela submucosa, its darker zone rich in cells
3"	Lamina propria mucosae / Tela submucosa, its lighter zone, poorer in cells
3"'	Glandulae esophageae in the Lamina propria mucosae / Tela submucosa

the keratinization (calf). Only a soft and slight undulation of the basal cell layer line can be stated.

Lamina propria mucosae / Tela submucosa

Both are forming one common layer because the Lamina muscularis mucosae is usually absent in this portion of the esophagus. This result will also not be changed by the fact that every now and then few smooth muscle cell may occur between the Lamina propria mucosae and submucosa as in the CRL 9 cm-fetus, in which few smooth muscle cells could be observed at the lateral aspects of the pharyngo-esophageal junction, but all the other specimens did not show a Lamina muscularis mucosae. Despite of the absence of the latter one the Lamina propria mucosae / submucosae can be subdivided into two zones in the buffalo fetuses. The first one appears more darker due to its rich cellular content and aggregation of collagenic and elastic fibers (first ones in the CRL 25 cm stage) and is directed to the Lamina epithelialis and lumen (fig. 9); the second one is much more lighter because of the depletion of connective tissue cells and fibers; it is directed to the Tunica muscularis (fig. 9). Beside its rich cellular content the Lamina propria / mucosa is filled with many blood vessels (venous plexus)(fig. 11). These are more numerous in the zone directed to the Lamina epithelialis than in the outer one. Gradually the richness of connective tissue cells is replaced by connective tissue fibers in buffalo specimens of higher ontogenetic development. Thus in the 20 days old calf it is much more fibrous than in the

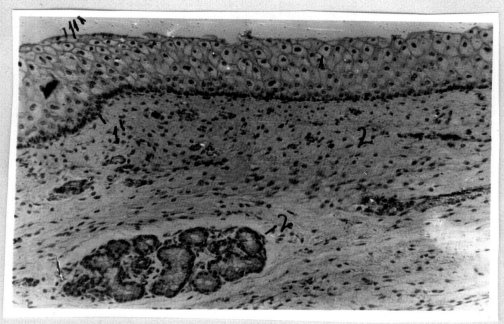


Fig. 10 Cross-section through the pharyngo-esophageal junction of a buffalo-fetus (CRL = 67 cm)
H&E stain. Obj.: 5; Ocular 10

1	Lamina epithelialis, superficial layer
1'	Lamina epithelialis, deep layer
1"	Lamina epithelialis, flattened top cell layer
2	Lamina propria mucosae / Tela submucosa
2'	Glandulae esophageae

CRL 94 cm-buffalo-fetus and in all other younger stages.
The Lamina propria / submucosa of the adult buffalo is characterized by dense irregular connective tissue, enriched by many blood vessels.
The ontogenetic development of the Lamina propria / submucosa is not only featured by the increase of collagenous and elastic fibers (f.e. CRL 94 cm stage) on account of the connective tissue cells, but also by the elaboration of the papillary body, which is firstly observed by us in post-partum-specimens (calf 20 days of age).
The pharyngo-esophageal junction of buffalo contains the esophageal glands (Glandulae esophageae). In fetuses of CRL 9 cm they are visible as spherical epithelial masses in the Lamina propria / submucosa (fig. 8). As epithelial sprouts they projected from the esophageal epithelium into the surrounding mesenchyme mass. Solid epithelial strands connecting the esophageal epithelium with these glandular epithelial primordia remember still to this process. In these slides the esophageal glands are rare in number (fig. 8 and 9), much more were seen in buffalo fetuses of CRL 36 cm. Furthermore it can be stated that at this stage the former solid strands are canalized to become the excretory ducts of the esophageal glands. But the glandular end-pieces were seen still solid, not hollowed.
In buffalo fetuses of CRL 67 cm and 94 cm this canalization of the excretory ducts is more distinct than in earlier stages (fig. 12). The cell nuclei of the epithelial glandular cells become pushed to the periphery (cellular base), thus

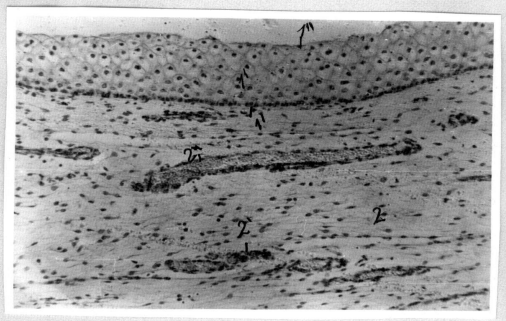


Fig. 11 Cross-section through the pharyngo-esophageal junction of a buffalo-fetus (CRL = 67 cm)

H&E stain. Obj.: 5; Ocular 10

1	Lamina epithelialis, superficial layer
1'	Lamina epithelialis, deep layer
1"	Lamina epithelialis, flattened top cell layer
2	Lamina propria mucosae / Tela submucosa
2'	Lamina propria mucosae / Tela submucosa, vascular plexus

gaining a similarity with mucous glands. The glandular end-pieces show narrow lumina, surrounded by highly columnar cells with basally situated nuclei (fig. 10).
The later ontogenetic development of the esophageal glands is characterized by multiplication of their end-pieces till they form a relatively compact layer of mucous glands (calf 20 days of age). Interesting are their topical relations insofar that they are not exclusively found in the Tela submucosa, but also between bundles of striated muscle fibers belonging to the Tunica muscularis.

Tunica muscularis: It is already early developed. A roughly circularly running layer of striated muscle fibers is found already in buffalo fetuses of CRL 9 cm (fig. 8). In CRL 14 cm a spiral arrangement becomes already clear. Inside, the muscle fibers are coursing sometimes circularly, sometimes but longitudinally. At least two layers are present, separated by intermuscular connective tissue, which is rich in blood vessels. The thickness of the Tunica muscularis is increasing with advancing age. In the 3 years old adult buffalo the Tunica muscularis is the thickest part of the entire esophageal wall. First elastic fibers between the muscle bundles could be seen in the CRL 36 cm-fetus.

Tunica adventitia: It is early developed and resembles in its development in a certain regard to the Lamina propria / submucosa. It is firstly more cellular, later on more fibrous and richly fitted by blood vessels and nerves. As dense irregular connective tissue it fixes the esophagus in its junction with the pharynx to the neighbourhood.

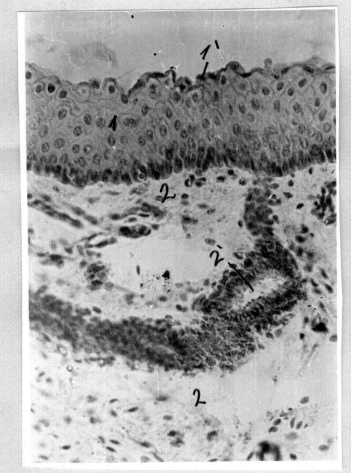


Fig. 12 Cross-section through the pharyngo-esophageal junction of a buffalo-fetus (CRL = 94 cm)

H&E stain. Obj.: 20; Ocular 5 : 1K

1	Lamina epithelialis
1'	Lamina epithelialis, flattened top cell layers
2	Lamina propria mucosae / Tela submucosa
2'	Canalized excretory duct of the Glandulae esophageae

Cervical part of the esophagus

Tunica mucosa

Lamina epithelialis: The cross-section of the cervical part of the esophagus has the shape of the letter H (fig. 13). Similar to the pharyngo-esophageal junction the epithelium of the cervical part is firstly thin and increases with increasing age. Thus the Lamina epithelialis, which is principally composed of a superficial layer and a deep layer (fig. 15), has 1 - 2 layers of large, polyhedral cells with pale pinkish cytoplasm and a more or less luminally disposed nucleus, at the stage of 9 cm CRL (fig. 13). The same is practically to observe in buffalo fetuses at stages of 14 cm CRL (fig. 14) and 17 cm CRL. Unsignificantly, only one layer has been added to the former ones. A considerable change is to state from 25 cm CRL. In comparison to the previous fetal stages the Lamina epithelialis is now absolutely thicker (3 - 5 cell layers). This push continues to the following stages. In fetuses of 36 cm CRL the superficial layer of the Lamina epithelialis comprises now 5 - 8 cell layers in thickness (fig. 15), combined with a qualitative change, which is featured by the occurrence of the first flattened cells in the top epithelial layer. The 67 cm CRL fetus shows a tremendous increase of the superficial layer which is found to be 7 and 40 cell layers. In the 94 cm CRL the superficial layer is loosing its loosely arranged state of large polyhedral cells and is replaced by compressed, solidified, strongly eosinophilic cells as already described in the

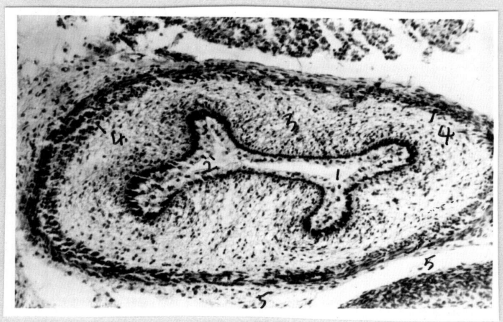


Fig. 13 Cross-section through the cervical part of the esophagus of a buffalo-fetus (CRL = 9 cm)
H&E stain. Obj.: 10; Ocular 5 : 1K

1 H - shaped lumen
2 Lamina epithelialis
3 Lamina propria mucosae / Tela submucosa
4 Tunica muscularis
5 Tunica adventitia

pharyngo-esophageal junction. During the fetal development no keratinization of the stratified squamous epithelium of the cervical part could be observed. This occurs after birth. Thus in the calf of 20 days of age the superficial layer is keratinized. Of course has the cornified layer not the same strength like in adult buffaloes, it comprises only three cell layers of flattened cells with shrinked, darkly stained, pyknotic cell nuclei. The Stratum corneum is contrasting in colour to the other, distally following layers, which consist of further 3 - 4 circularly arranged cell layers, followed from cells of the Stratum spinosum showing here a more perpendicular deployment. The highest degree of keratinization is found in the cervical esophageal part of the adult buffalo. The cornified layer is made up of 4 layers of cornified squamous cells in which the pyknotic cells are still visible. With VAN GIESON it contrasts with a more brownish colour from the Strata granulosum and spinosum. The latter ones are formed about 17 cell layers.

The deep layer consists always of one cell layer during the entire phase of the ontogenetic development (fig. 15). The cells are columnar ones with same shaped nuclei, which contain spot-like scattered heterochromatine as also one or two nucleoli. They rest on a basement membrane, which is especially distinctly visible after H&E stain. The basal cell layer is a completely smooth line till to the end of the fetal period. After birth the papillary formation is introduced by waving this line in a wide, spacious manner. This is replaced by short intervalled projecting papilla from the Lamina

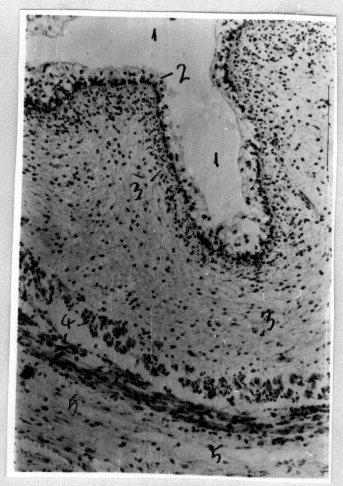


Fig. 14 Cross-section through the cervical part of the esophagus of a buffalo-fetus (CRL = 14 cm)

H&E stain. Obj.: 10; Ocular 5 : 1K

1	Esophageal lumen
2	Lamina epithelialis
3	Lamina propria mucosae / Tela submucosa
3'	Broader strip of smooth muscle cells forming later on the Lamina muscularis mucosae
4	Tunica muscularis
5	Tunica adventitia

propria in adult buffaloes.

Lamina propria mucosae:

Till the stage of CRL 14 cm the Lamina propria mucosae is blending without any line of demarcation with the submucosa (fig. 13 and 14). It has the typical fetal characteristics: it is rich in cells, especially in the neighbourhood of the Lamina epithelialis. The collagenic and elastic fibers are still less developed and very fine. At the CRL 14 cm fetus the cells become aggregated in a broader line, paralleling the Lamina epithelialis. This is to a certain degree then condensed at the CRL 17 cm fetus, and more distinct recognizable as Lamina muscularis mucosae.
It is not so rich in blood vessels than the pharyngo-esophageal junction.

Lamina muscularis mucosae:

On the contrary to the pharyngo-esophageal junction the cervical part of the esophagus possesses a Lamina muscularis mucosae, but this not from the very beginning, but from the stage of CRL 14 cm, long time after the Tunica muscularis has already been established (fig. 14). Its formation is going on in different steps. Firstly a broader strip of smooth muscle cells becomes visible in the Lamina propria mucosae (CRL 14 cm) (fig. 14). Their cytoplasm is not demonstratable by H&E and VAN GIESON, thus making apparent only the nuclei, giving the image of a very cellular Lamina propria mucosae. Later on this strip becomes narrowed and

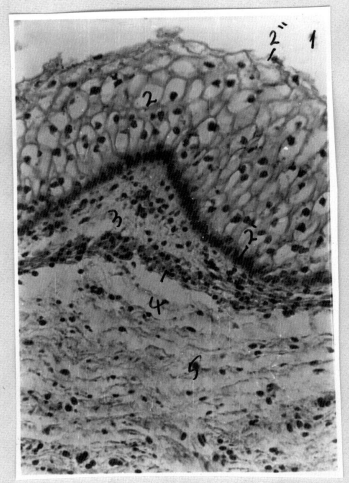


Fig. 15 Cross-section through the cervical part of the esophagus of a buffalo-fetus (CRL = 36 cm)
H&E stain. Obj.: 20; Ocular 5 : 1K

1	Esophageal lumen
2	Lamina epithelialis, superficial layer
2'	Lamina epithelialis, deep layer
2"	Lamina epithelialis, flattened top cell layer
3	Lamina propria mucosae
4	Lamina muscularis mucosae
5	Tela submucosa

condensed, but the cytoplasm of these cells can still not be detected (17 cm CRL). The final step is then the appearance of the cytoplasm of the smooth muscle cells, facilitating the aggregation of them to a definite Lamina muscularis mucosae (CRL = 36 cm) (fig. 15).

Tela submucosa:

As mentioned before there is only a Lamina propria mucosae/submucosa till to the stage of CRL 14 cm (fig. 13 and 14), after this both become separated on the reason of formation of the Lamina muscularis mucosae (fig. 15). The submucosa is more fibrous than the Lamina propria. Collagenous and elastic fibers (first appearance at the 25 cm CRL stage) are lattice-shape-like arranged, containing a high number of blood vessels of different caliber.
Esophageal glands were never found in the cervical part.

Tunica muscularis:

This is already early developed, long before the Lamina muscularis mucosae is found. We have already in CRL-9cm-fetuses observed a two-layered Tunica muscularis, spirally arranged (fig. 13). It reflects the requirement of a transportation function in the esophagus already now. In the following stages (fig. 14) of the ontogenetic development the increase in thickness, absolutely and relatively, is clearly to recognize, but the complicated spiral course is maintained, i.e. sometimes the inner layer is longitudinal, and the outer circular and vice versa. VAN GIESON stain elucidates

clearly that both are separated by sufficient intermuscular connective tissue, filled with blood vessels and nerves. As in the pharyngo-esophageal junction also in the cervical part the muscular tissue is of the striated or striped variety.

Tunica adventitia (fig. 13 and 14):
It shows the known structure, i.e. more or less loose connective tissue, anchoring the esophagus to the neighbouring structures. Collagenous and elastic fibers form a lattice-shaped network, containing a lot of nutrient structures as blood vessels and nerves. It is less cellular than the Lamina propria mucosae and Tela submucosa.

Thoracic part of the esophagus

Tunica mucosa

Lamina epithelialis:
The cross-section of the esophagus has the shape of the latter H in the CRL 9 cm stage as also described in the pharyngo-esophageal part and cervical part (fig. 16). Later on the number of folds increases with advancing age.
The Lamina epithelialis is thinner than that in the pharyngo-esophageal junction, but comparable to that of the cervical part. Principally it is composed of a superficial layer and a deep layer (fig. 16 and 17). The former one is built

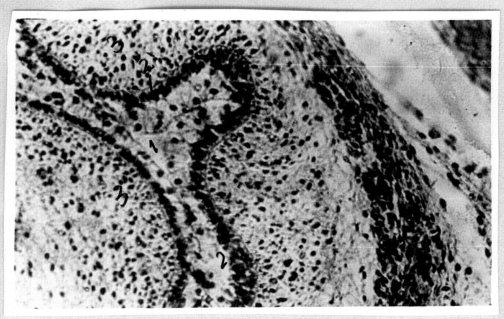


Fig. 16 Cross-section through the thoracic part of the esophagus of a buffalo-fetus (CRL = 9 cm)

H&E stain. Obj.: 20; Ocular 5 : 1K

1 Esophageal lumen
2 Lamina epithelialis, superficial layer
2' Lamina epithelialis, deep layer
3 Lamina propria mucosae / Tela submucosa

up by two layers of large, polyhedral cells, relatively deprived of cytoplasm and thus appearing slightly pink in colour. The basal or deep layer contains columnar cells with the same shaped nuclei, deployed in one smooth line, resting on a basement membrane, distinctly visible with H&E. The thickness of the Lamina epithelialis is roughly the same at the stage of CRL 14 cm and starts then to increase. Thus at the stage of CRL 17 cm it consists already of 3 cell layers, at CRL 25 cm of five and at CRL 67 cm of about ten. The structure of the polyhedral cell is - lightmicroscopically seen - unchanged to a stage of 36 cm CRL. After this the large polyhedral cells become rearranged. This rearrangement includes firstly a more proximo-distal distension of them and secondly a decrease in size due to the greater number of cells (CRL 67 cm). In buffalo-fetuses of CRL 67 cm the cells of the superficial layer of the Lamina epithelialis are clearly smaller and more densely packed. The top layer cells are now flattened. But no symptoms of keratinization could be observed, even not in the full-termed buffalo-fetus of CRL 94 cm (fig. 18). Here as in the pharyngo-esophageal part and cervical part the superficial epithelium is changing to another quality insofar, as it becomes here firm, solid and compressed. The upper two cell layers contain proximo-distally flattened nuclei. They become cornified in calves (calf 20 days of age). Striking is the absolute smoothness of the epithelial surface in the thoracic part, not known from the pharyngo-esophageal and cervical part. Distinctly elaborated is the keratinization

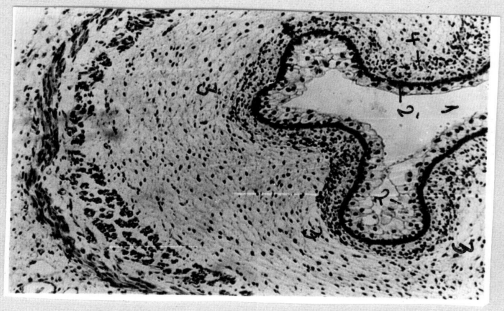


Fig. 17 Cross-section through the thoracic part of the esophagus of a buffalo-fetus (CRL = 14 cm)
H&E stain. Obj.: 10; Ocular 5 : 1K

1 Esophageal lumen
2 Lamina epithelialis, superficial layer
2' Lamina epithelialis, deep layer
3 Lamina propria mucosae / Tela submucosa
4 Aggregation of smooth muscle cells becoming later on the Tunica muscularis mucosae

process at the stratified squamous epithelium of adult buffaloes. The Stratum corneum is here relatively strong. The cells of it contain very small, thin, fusiform or rod-like and extremely pyknotic nuclei. The cornified layer comprises about 6 - 7 layers.

What the deep layer of the Lamina epithelialis concerns, it is to state, that it is formed by cuboidal and columnar cells with spherical or columnar nuclei, arranged in one row. This gets its first alteration at the stage of post-partal subjects. First symptoms of a spacious undulation could be observed in calves of 20 days of age, the distinct papillary-body-formation in adult buffaloes.

Lamina propria mucosae:

In the early fetal stages, investigated by us, a Lamina muscularis mucosae was absent, and the Lamina propria mucosae is blending with the submucosa without any line of demarcation (fig. 16 and 17). The common Lamina propria/ submucosa is in general quite cellular, but still more distinct in areas related nearer to the epithelium. It gets more fibrous peripherally. Primordia of glands are completely absent. The richness of cells increases at certain sites of the Lamina propria indicating the later formation of the Lamina muscularis mucosae (CRL 14 cm) (fig. 17). The following stages are characterized by a further elaboration of the Lamina muscularis mucosae (fig. 18).

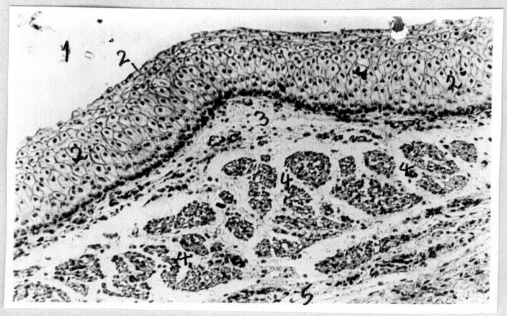


Fig. 18 Cross-section through the thoracic part of the esophagus of a buffalo-fetus (CRL = 94 cm)
H&E stain, Obj.: 10; Ocular 5 : 1K

1	Esophageal lumen
2	Lamina epithelialis
2'	Lamina epithelialis, flattened top cell layer
3	Lamina propria mucosae
4	Lamina muscularis mucosae
5	Tela submucosa

Lamina muscularis mucosae:

As mentioned before the first indications of its appearance can be dated back lightmicroscopically to the stage of 14 cm CRL (fig. 17). Among the numerous connective tissue cells and scarce connective tissue fibers smooth muscle cells are developing. But their cytoplasm is still not demonstrable by H&E or VAN GIESON. Thus the morphological substrate of the Lamina muscularis mucosae remains an aggregation of cell nuclei in the Lamina propria till to the stage of 36 cm CRL. In the fetuses of CRL 36 cm it was first time possible for us to see the Lamina muscularis mucosae clearly developed, i.e. the cytoplasm of the smooth muscle cells became visible and the smooth muscle cells themselves attached to each other, thus forming a complete Lamina muscularis mucosae. After completion of it, the Lamina propria mucosae results only as a relatively narrow strip projecting into the Lamina epithelialis as papillary bodies after birth (from calves 20 days of age till adult buffaloes).

The characteristic feature of the thoracic part is the extremely strong development of the Lamina muscularis mucosae; it is here much stronger than in the cervical part of the esophagus (fig. 18).

The smooth muscle cells are arranged in bundles which show a longitudinal course.

The thickness of the Lamina muscularis mucosae in calves of 20 days of age and in adult buffaloes in twice of the Lamina propria mucosae.

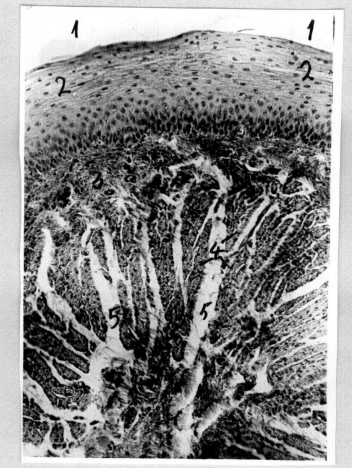


Fig. 19 Cross-section through the thoracic part of the esophagus of an adult buffalo

VAN GIESON stain. Obj.: 10; Ocular 5 : 1K

1 Esophageal lumen
2 Lamina epithelialis
3 Lamina propria mucosae
4 Lamina muscularis mucosae
5 Tela submucosa

Tela submucosa:

An independent and clearly separated Tela submucosa is present from the fetal stage of CRL 14 cm (fig. 17). Prior to this only a common Lamina propria mucosae/submucosa can be observed. On the contrary to the Lamina propria it is less cellular, but contains more delicate collagenous and elastic fibers, lattice-like arranged. About the border between them several blood vessels are located.
In all stages can be observed that the submucosa becomes absolutely and relatively narrower due to the stronger development of the Tunica muscularis. Sometimes it has only the same breadth like the Lamina propria mucosae and even the Lamina muscularis mucosae is appearing stronger than the submucosa.
Esophageal glands were always absent, in all fetal stages, as also in calves and adult buffaloes.

Tunica muscularis:

It is already early developed, as also seen in the pharyngo-esophageal junction and cervical part, long before the Lamina muscularis mucosae makes it appearance. Thus the striated musculature forms already two layers at the CRL 9 cm stage. Both are spirally arranged, the inner one is running longitudinally, the outer circularly and vice versa. Extremely thick becomes the Tunica muscularis already in CRL 36 cm-fetuses and remains in this relation till to the adult buffaloes. In the latter ones it is the thickest layer of the thoracic esophageal wall and the spiral course of the

striated muscle fibers is quite complicated. Near the submucosa the muscle bundles show a more circular course, followed by a very distinct circular course and finished by a more oblique longitudinal course.

Tunica adventitia/serosa:

The final layer of the thoracic esophageal wall forms a more or less loose connective tissue, consisting of numerous collagenous and elastic fibers embracing several blood vessels and nerves. Externaly this loose connective tissue, forming the mediastinal fibrosa, is covered by one layer of mesothelium representing the mediastinal pleura.

Part II: Quantitative aspects
(fig. 20 - 28)

The orientating measurements revealed some interesting facts, which are explained in the accompanying tables and figures.

Among all three parts of the esophagus the pharyngo-esophageal junction is permanently the strongest. It takes a very rapid development and reaches with 7,135 mm the peak in the adult buffalo. The cervical and thoracic parts change in their significance. Till to a CRL of 36 cm the former one follows the pharyngo-esophageal junction in strength of the wall, from a CRL of 67 cm the thoracic part. The latter one starts slowly in the development, together with the cervical part, but later on (from CRL 36 cm) it shifts to the developmental speed of the pharyngo-esophageal junction.

The individual layers of the esophageal wall let miss the clear and straight forward development like the total thickness. But also here interesting trends are to comment.

The quantitative development of the Lamina epithelialis differs only insignificantly in the individual parts of the esophagus. In all parts it begins somewhat slow, continues in this manner till birth and speeds up in postnatal subjects (fig. 20).

The cervical part has often the thinnest Lamina epithelialis (CRL 9 cm, 14 cm, 17 cm, 25 cm, 67 cm, calf and adult buffalo).

The growth of the Lamina propria mucosae/submucosa is

offering no new aspects; it is steadily increasing in thickness. Clearer becomes this trend from CRL 25 cm, when a distinctly developed Lamina muscularis mucosae is present. The thickness of the Lamina propria is greater in the cervical part (fig. 21 + 22).

The Lamina muscularis mucosae takes from CRL 25 cm a relatively speedy development, being always thicker in the thoracic part (fig. 23).

The growth curve of the Tela submucosa resembles somewhat to the Lamina propria mucosae, but with the difference that this time the thoracic part has the thicker submucosa (fig. 24).

The Tunica muscularis develops relatively slow from CRL 9 cm to CRL 36 cm, after this the growth rate increases significantly. It is always thickest in the pharyngo-esophageal junction, mostly weakest in the cervical part. Its share in the total wall of the esophagus is increasing from 22,77 % in the CRL 14 cm-stage to 86,51 % in the buffalo-calf (fig. 25). Similar are the trends at the cervical and thoracic parts.

Table 3

Quantitative development of the esophagus in buffalo

Buffalo fetuses CRL	pharyngo-esophageal junction total thickness of the wall	cervical part total thickness of the wall	thoracic part total thickness of the wall
9 cm	363 µm (0,363 mm)	149 µm (0,149 mm)	213 µm (0,213 mm)
14 cm	439 " (0,439 mm)	432 " (0,432 mm)	309 " (0,309 mm)
17 cm	564 " (0,564 mm)	399 " (0,399 mm)	373 " (0,373 mm)
25 cm	796 " (0,796 mm)	480 " (0,480 mm)	458 " (0,458 mm)
36 cm	1299 " (1,299 mm)	906 " (0,906 mm)	890 " (0,890 mm)
67 cm	1884 " (1,884 mm)	1568 " (1,568 mm)	2383 " (2,383 mm)
94 cm	2805 " (2,805 mm)	2246 " (2,246 mm)	2392 " (2,392 mm)
calf	5971 " (5,971 mm)	2913 " (2,913 mm)	3089 " (3,089 mm)
adult buffalo	7135 " (7,135 mm)	4852 " (4,852 mm)	6701 " (6,701 mm)

1 µm = 0,001 mm

Table 4/a

Quantitative development of the esophagus in buffalo (absolute)

Buffalo fetuses CRL	pharyngo - esophageal junction		
	Lamina epithelialis	Lamina propria mucosae/submucosa	Tunica muscularis
9 cm	52 µm	149 µm	162 µm
14 cm	31 "	308 "	100 "
17 cm	54 "	366 "	144 "
25 cm	71 "	490 "	235 "
36 cm	110 "	599 "	590 "
67 cm	111 "	585 "	1188 "
94 cm	69 "	1008 "	1728 "
calf	112 "	693 "	5166 "
adult	259 "	1854 "	5022 "

1 µm = 0,001 mm

Table 4/b

Quantitative development of the esophagus in buffalo (absolute)

Buffalo fetuses CRL	cervical part				
	Lamina epithelialis	Lamina propria mucosae	Tela submucosa	Lamina muscularis mucosae	Tunica muscularis
9 cm	23 um	95 µm		-	31 µm
14 cm	29 "	331 "		-	72 "
17 cm	36 "	261 "		-	102 "
25 cm	66 "	21 um	207 um	25 um	161 "
36 cm	109 "	29 "	329 "	34 "	405 "
67 cm	102 "	65 "	720 "	60 "	621 "
94 cm	78 "	69 "	990 "	38 "	1071 "
calf	107 "	95 "	1080 "	137 "	1494 "
adult	344 "	220 "	1152 "	139 "	2997 "

1 µm = 0,00 1 mm

Table 4/c

Quantitative development of the esophagus in buffalo (absolute)

Buffalo fetuses CRL	thoracic part				
	Lamina epithelialis	Lamina propria mucosae	Tela submucosa	Lamina muscularis mucosae	Tunica muscularis
9 cm	25 µm	151 µm		-	37 µm
14 cm	29 "	230 "		-	50 "
17 cm	33 "	266 "		-	74 "
25 cm	67 "	15 µm	176 µm	29 µm	171 "
36 cm	86 "	19 "	324 "	38 "	423 "
67 cm	117 "	49 "	882 "	129 "	1206 "
94 cm	57 "	60 "	1170 "	124 "	981 "
calf	124 "	68 "	990 "	215 "	1692 "
adult	268 "	146 "	1026 "	167 "	5094 "

1 µm = 0,001 mm

Table 5/a

Quantitative development of the esophagus in buffalo (relative)

Buffalo fetuses CRL	pharyngo - esophageal junction		
	Lamina epithelialis	Lamina propria mucosae/submucosa	Tunica muscularis
9 cm	14,32 %	41,06 %	44,62 %
14 cm	7,07 %	70,16 %	22,77 %
17 cm	9,57 %	64,89 %	25,54 %
25 cm	8,92 %	61,56 %	29,52 %
36 cm	8,46 %	46,12 %	45,42 %
67 cm	5,89 %	31,05 %	63,06 %
94 cm	2,46 %	35,94 %	61,60 %
calf	1,88 %	11,61 %	86,52 %
adult	3,63 %	25,98 %	70,39 %

Table 5/b

Quantitative development of the esophagus in buffalo (relative)

Buffalo fetuses CRL	cervical part				
	Lamina epithelialis	Lamina propria mucosae	Tela submucosa	Lamina muscularis mucosae	Tunica muscularis
9 cm	15,44 %	63,76 %		-	20,81 %
14 cm	6,71 %	76,62 %		-	16,67 %
17 cm	9,02 %	65,42 %		-	25,56 %
25 cm	13,75 %	4,37 %	43,13 %	5,21 %	33,54 %
36 cm	12,04 %	3,20 %	36,31 %	3,75 %	44,70 %
67 cm	6,51 %	4,15 %	45,92 %	3,83 %	39,60 %
94 cm	3,47 %	3,08 %	44,08 %	1,69 %	47,68 %
calf	3,67 %	3,26 %	37,08 %	4,70 %	51,29 %
adult	7,09 %	4,53 %	23,74 %	2,86 %	61,78 %

Table 5/c

Quantitative development of the esophagus in buffalo (relative)

Buffalo fetuses CRL	thoracic part				
	Lamina epithelialis	Lamina propria mucosae	Tela submucosa	Lamina muscularis mucosae	Tunica muscularis
9 cm	11,74 %	70,89 %		-	17,37 %
14 cm	9,39 %	74,43 %		-	16,18 %
17 cm	8,85 %	71,32 %		-	19,84 %
25 cm	14,63 %	3,28 %	38,43 %	6,33 %	37,34 %
36 cm	9,66 %	2,14 %	36,40 %	4,27 %	47,53 %
67 cm	4,91 %	2,06 %	37,01 %	5,41 %	50,61 %
94 cm	2,38 %	2,50 %	48,92 %	5,18 %	41,02 %
calf	4,01 %	2,20 %	32,05 %	6,96 %	54,78 %
adult	4,00 %	2,18 %	15,31 %	2,49 %	76,02 %

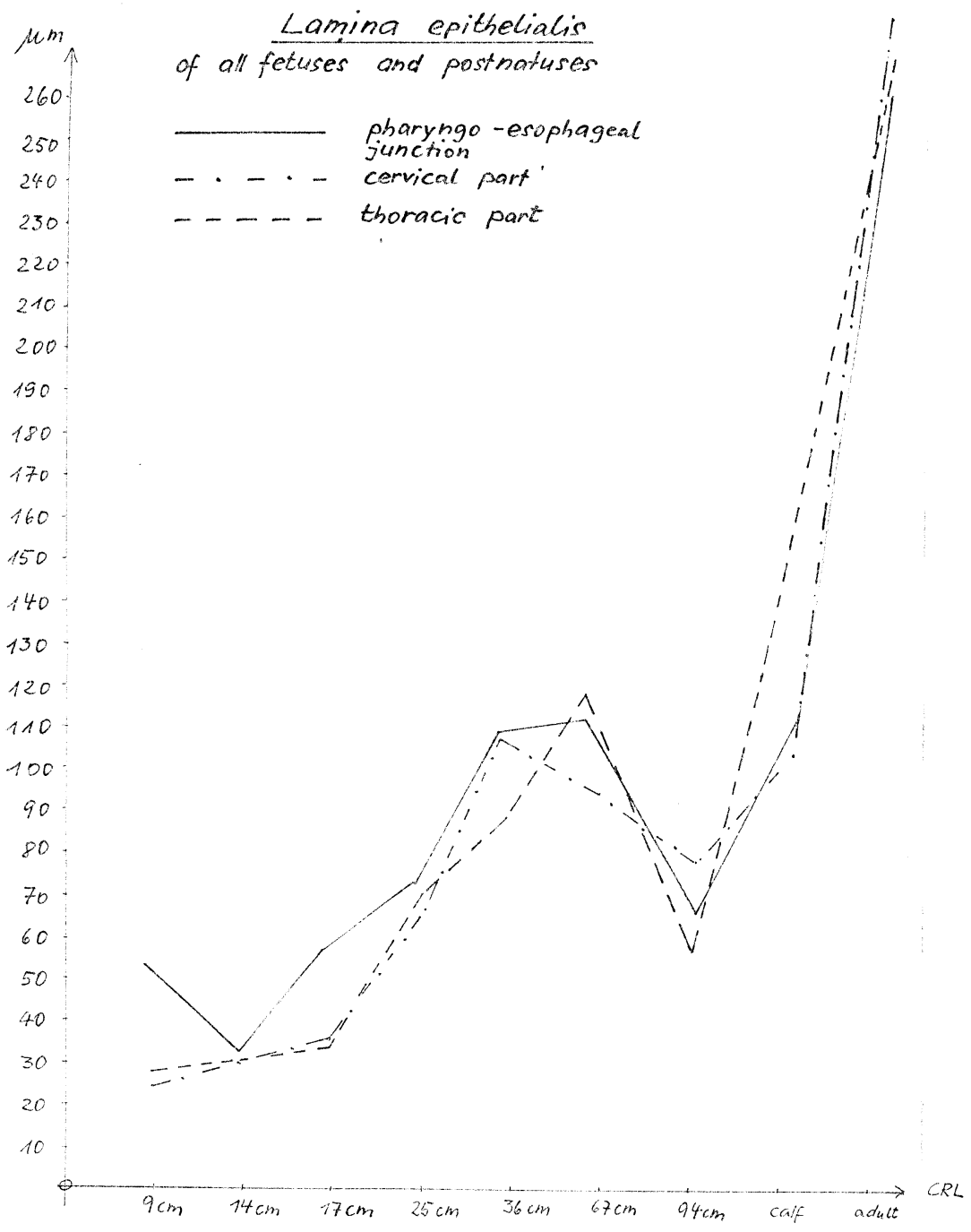


Fig. 20

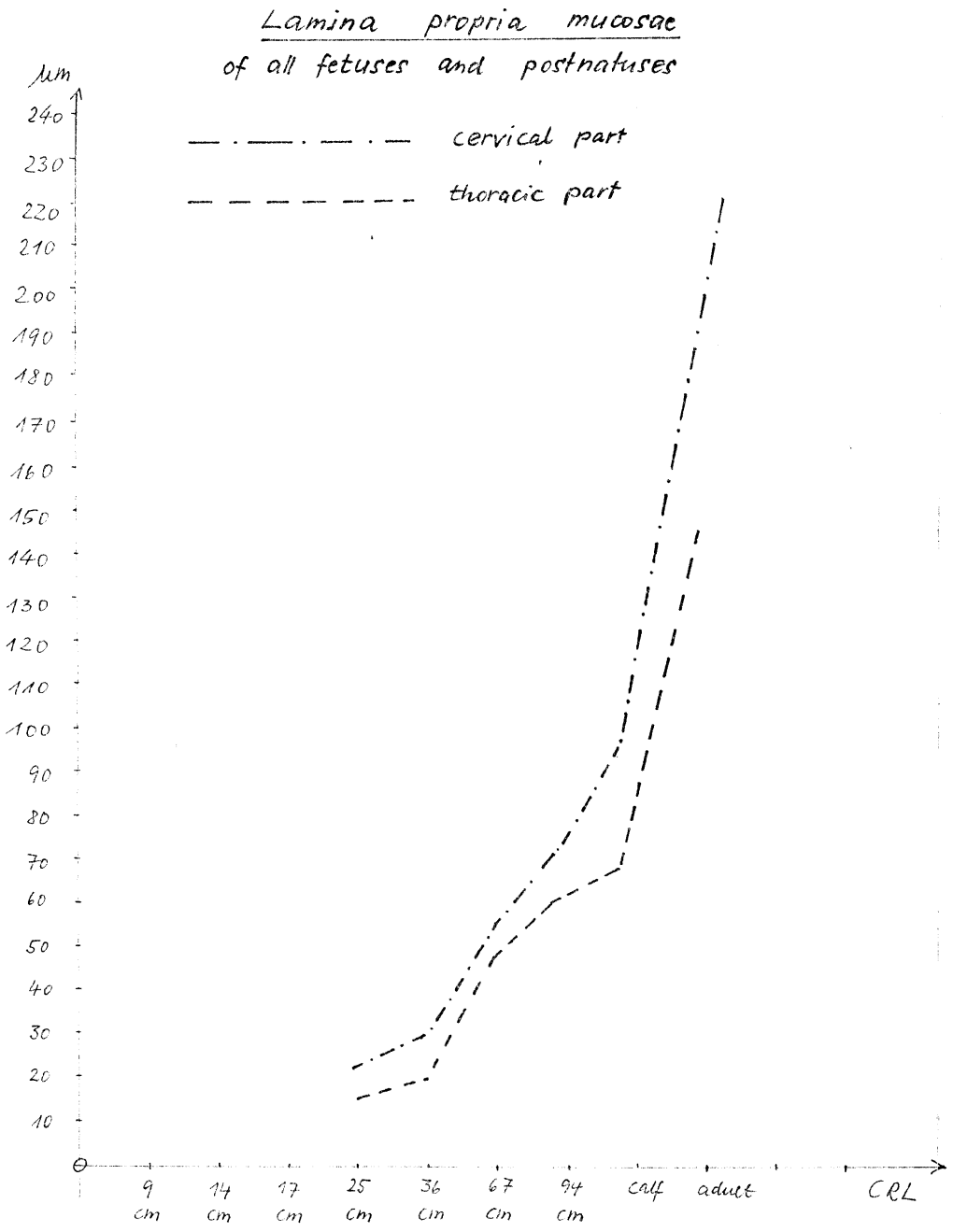


Fig. 21

Lamina propria-mucosae / tela submucosa
pharyngo-esophageal junction
of all fetuses and postnatuses

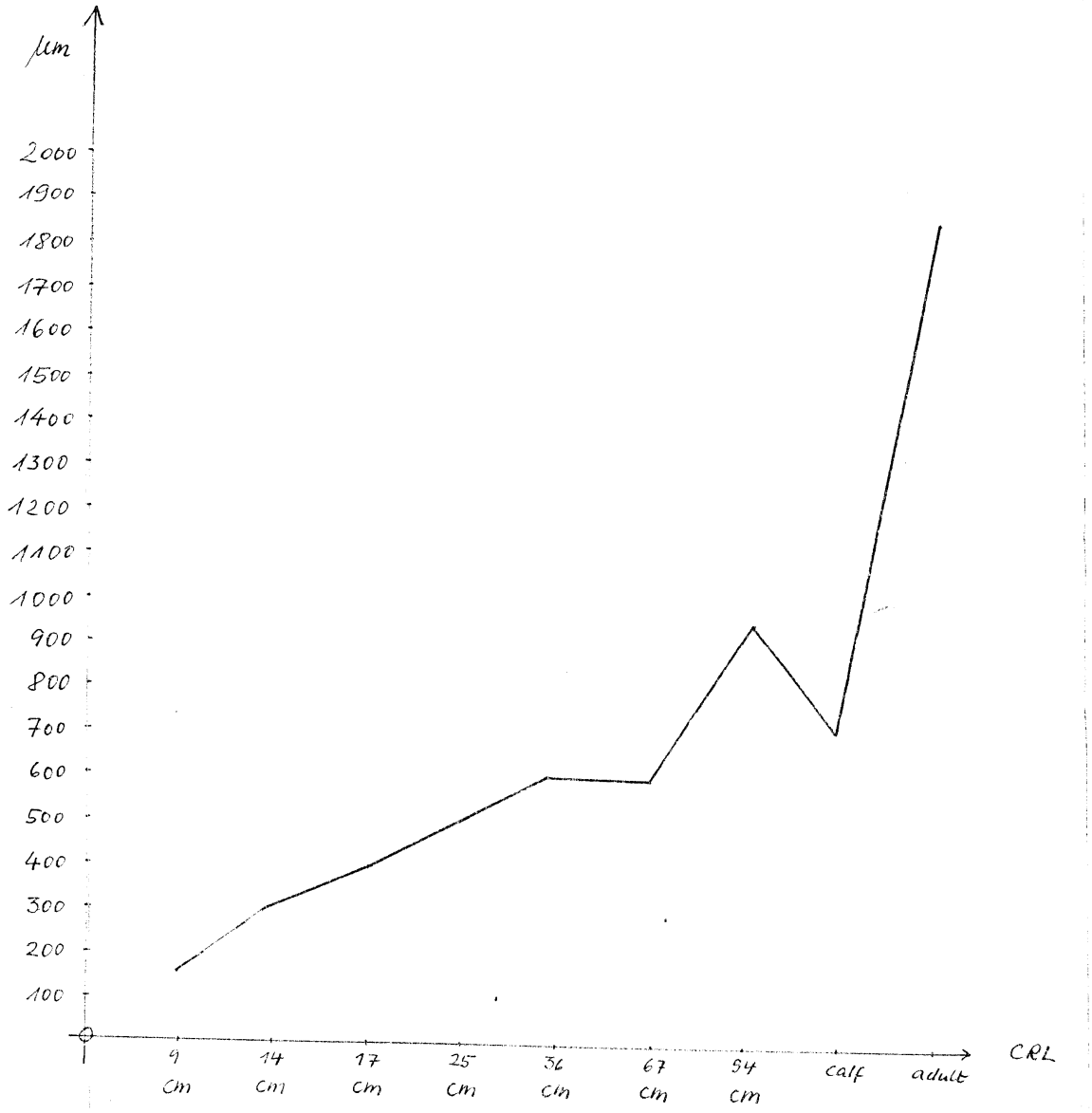


Fig. 22.

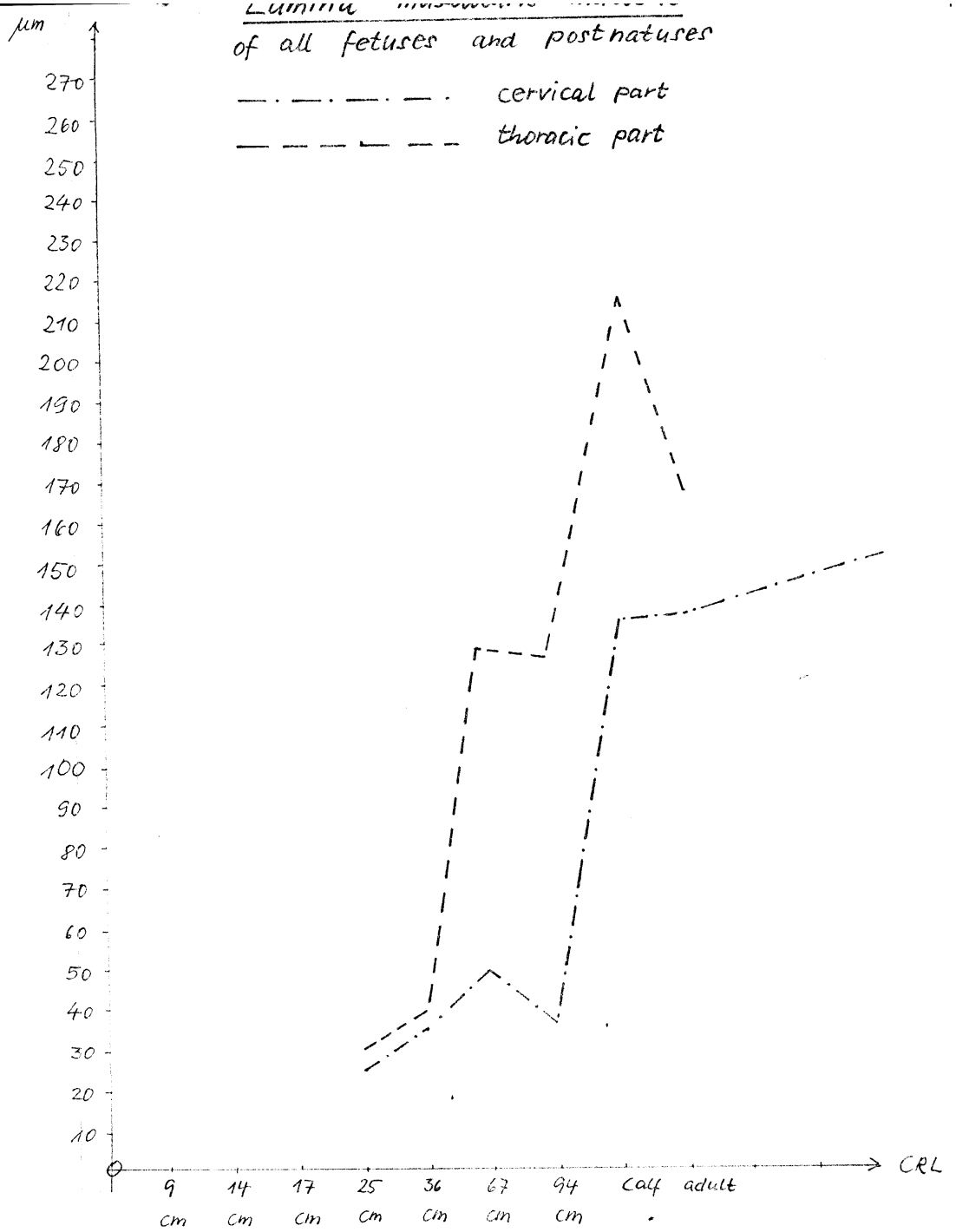


Fig. 23

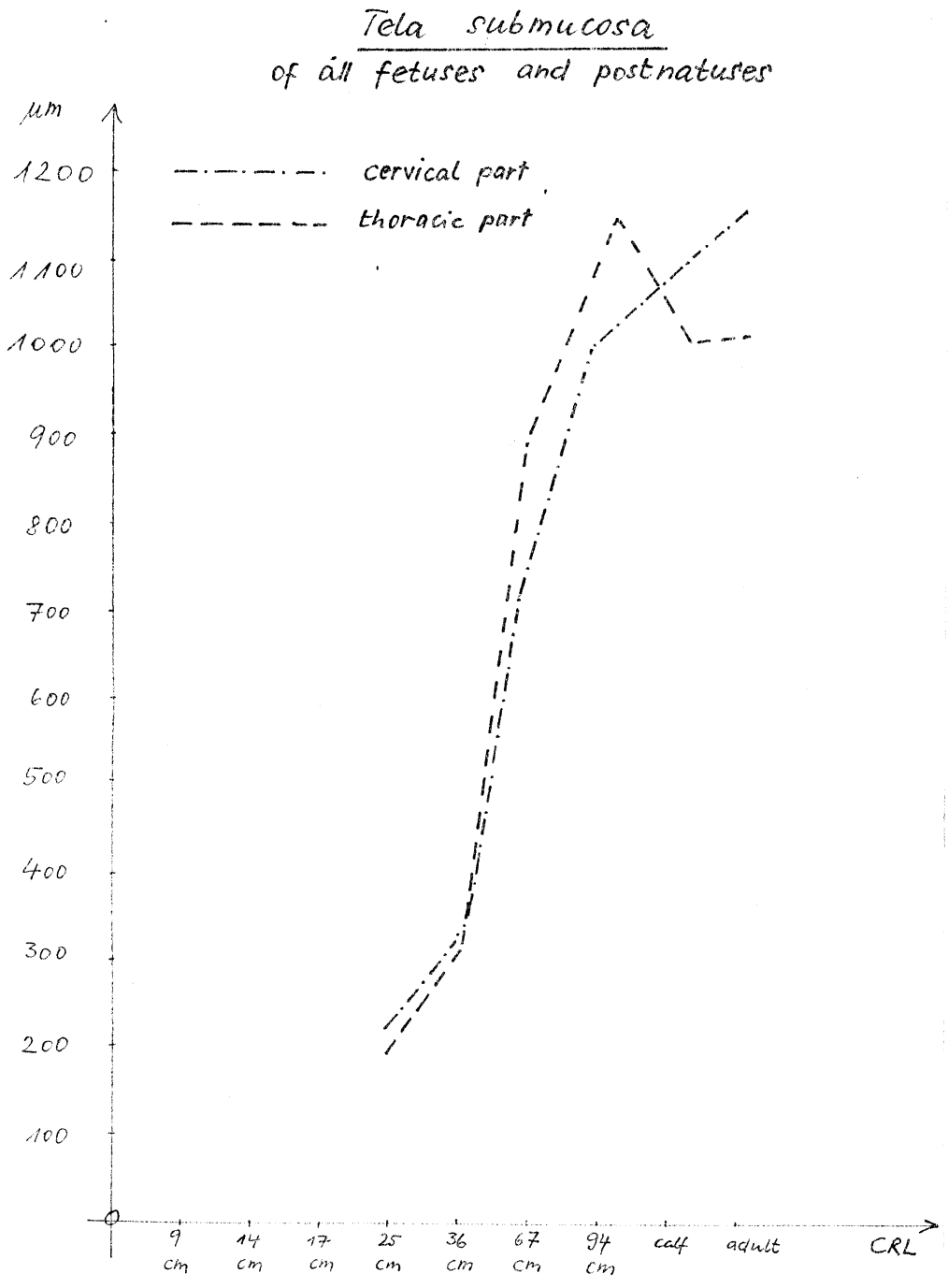


Fig. 24

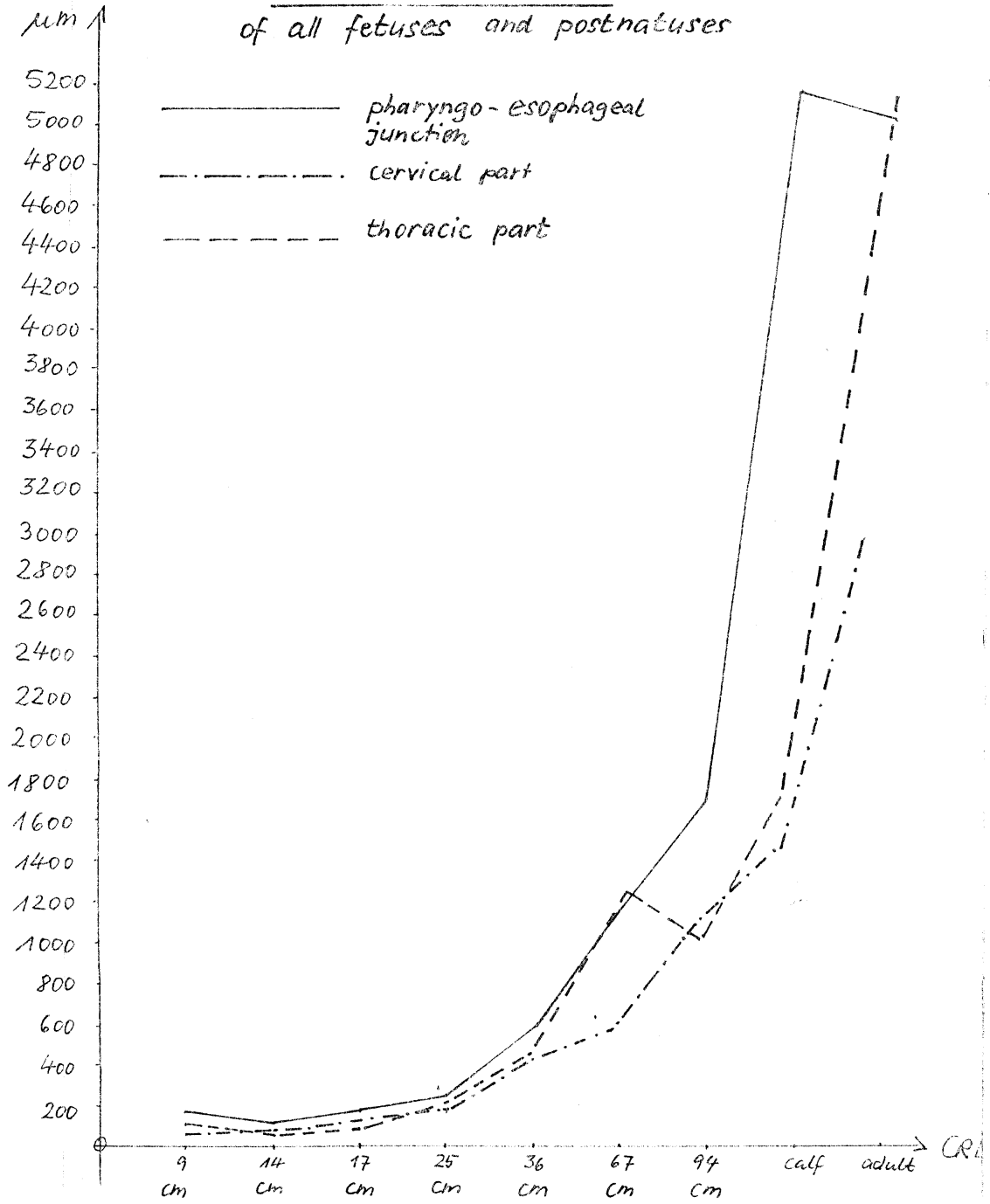


Fig. 25

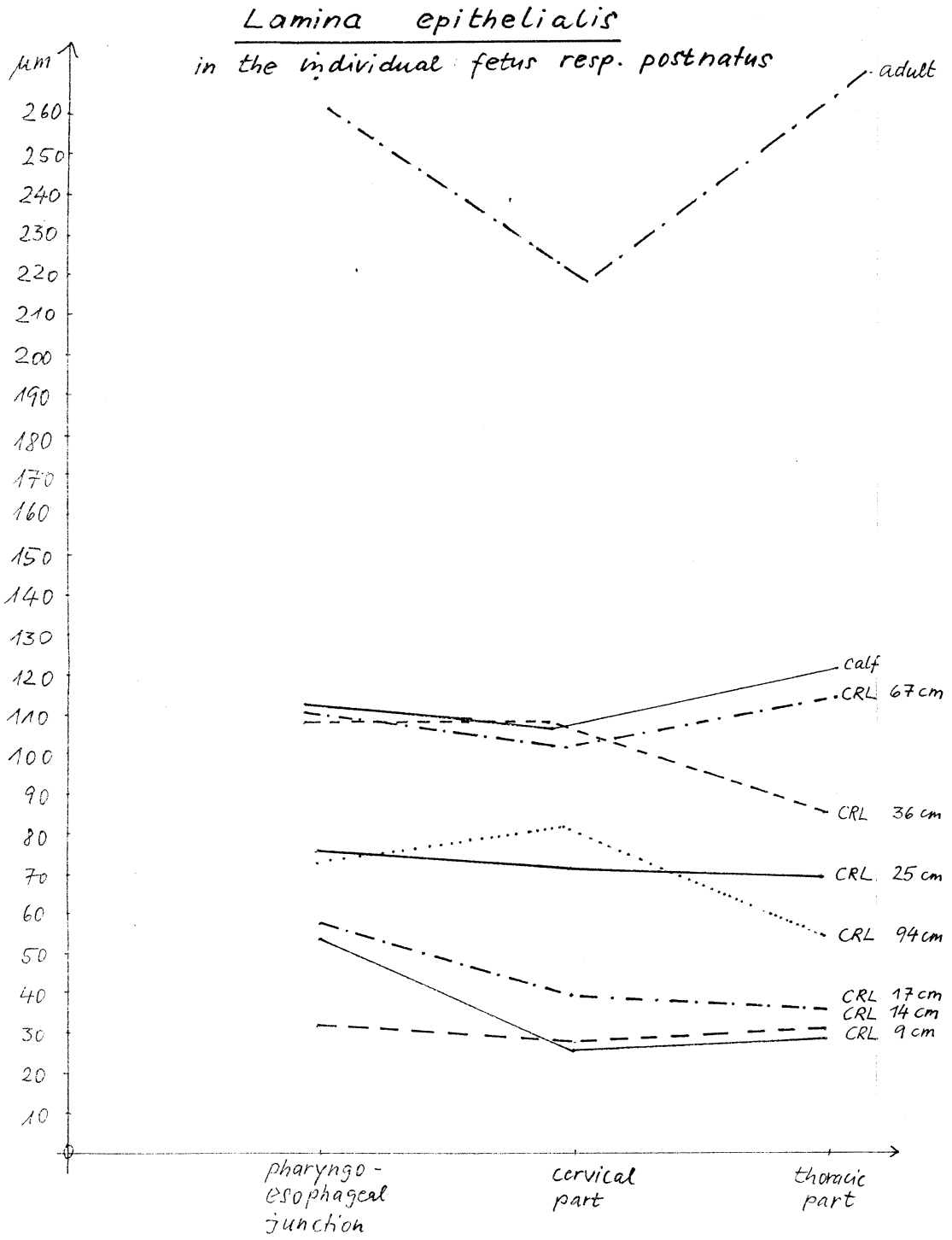


Fig. 26

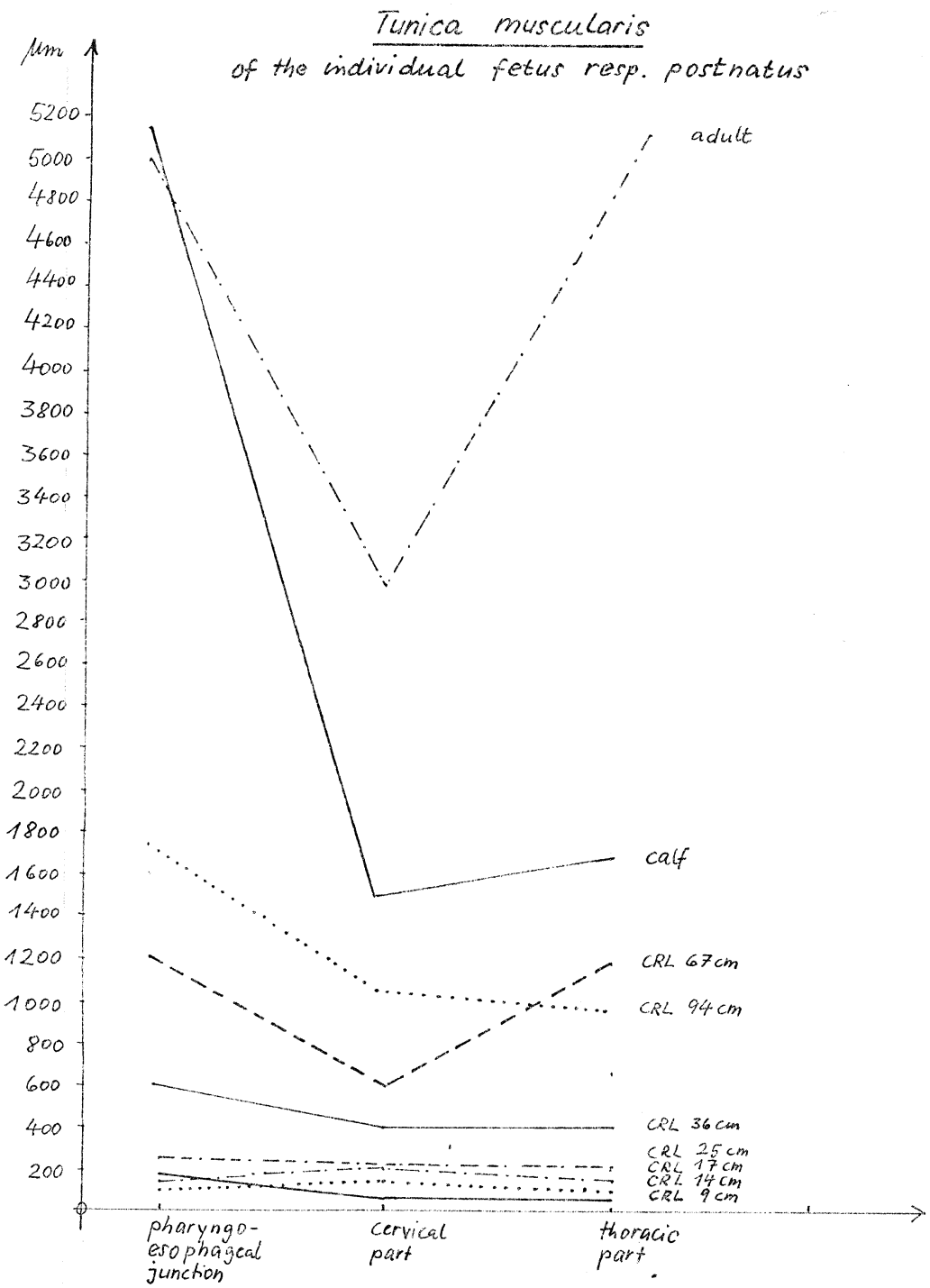


Fig. 27

Development of the total thickness of the esophageal wall

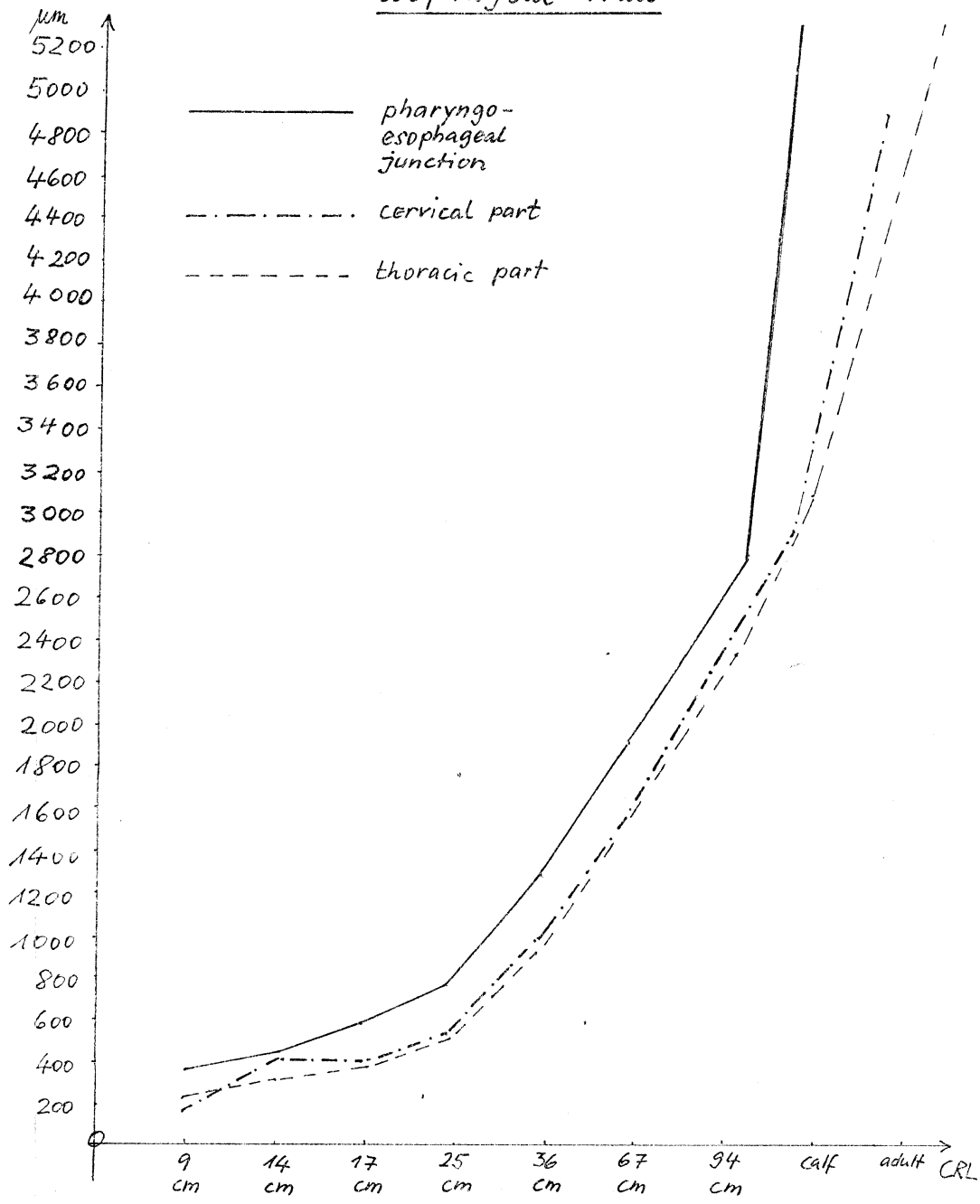


Fig. 28

Part III: Main qualitative micromorphological criteria of the esophagus of the Egyptian Water buffalo in the different developmental stages

Buffalo - fetus of 9 cm CRL

Pharyngo-esophageal junction (fig. 8):

The lumen is irregular in outline. The epithelium is stratified and consists of a superficial and a deep layer. The thinnest part has 4 layers of cells, the thickest 23 layers. The shape of the basal cells is cuboidal to columnar. Very few epithelial outgrowths into the Lamina propria/submucosa are clearly visible.

The Lamina propria mucosae is extremely cellular and very rich in blood vessels.

First indications of a Lamina muscularis mucosae occur at the lateral sides of a cross-section through the esophagus. Thus the submucosa is exactly a Lamina propria/submucosa. This is less cellular than the Lamina propria and contains voluminous empty vessels. The cells have a total mesenchymal appearance.

The Tunica muscularis is present and the inner circular layer is to a certain extent well developed.

Cervical part (fig. 13):

The lumen has the shape of the letter H. The superficial epithelial layer of the stratified epithelium consists of

1 - 2 layers of polyhedral cells, the nuclei of which are at the luminal pole. The cells of the basal layer are densely packed and columnar in shape.
The Lamina muscularis mucosae is absent, thus occurring only a Lamina propria/submucosa. This is quite cellular, especially at the region of the Lamina epithelialis.
Esophageal glands are absent.
The submucosa is more fibrous than the Lamina propria.
The Tunica muscularis is distinctly developed and divided into an inner and outer layer, spiralling around each other.
The Tunica adventitia is rather developed and consists of connective tissue fibers and fusiform fibroblasts.

Thoracic part (fig. 16):
The lumen is very narrow, but has also in the cross-section the outlines of the letter H.
The Lamina epithelialis is thinner than that of the pharyngo-esophageal junction and of the cervical part. The superficial cell layer has only one, maximally two layers of large polyhedral cells, meanwhile the basal cell layer is composed of smaller, columnar cells, densely packed.
The Muscularis mucosae is absent.
The Lamina propria mucosae/submucosa is slightly cellular near the Lamina epithelialis, less in the submucosal region.
Esophageal glands are absent.
The Tunica muscularis is present. The two spirally arranged layers are clearly recognizable.
The Tunica adventitia is made up of loosely arranged

connective tissue.

Buffalo - fetus of 14 cm CRL

Pharyngo-esophageal junction:

The esophageal lumen has still the outline of the letter H.
The number of epithelial cell layers has not increased in comparison to the buffalo-fetus of 9 cm CRL.
Superficial and deep cell layers are still distinct.
The basement membrane is even.
The Lamina propria mucosae is rich in cells. The parts near to the epithelium are much more cellular than the peripheral parts.
The muscularis mucosae is still absent. By this reason the submucosa has merged with the former to the Lamina propria/ submucosa.
The Tunica muscularis consists of a sometimes longitudinally, a sometimes circularly arranged layer or of spirally arranged layers of muscle fibers.
The adventitia resembles the submucosa. Less cellular and less fibrous, but rich in blood vessels and nerves.

Cervical part (fig. 14):

The Lamina epithelialis is still bilayered. The superficial layer comprises 1 - 3 cell layers, the basal one one layer of densely arranged columnar cells, stained deeply bluish.
The basement membrane is straight and even.

The Lamina propria mucosae is extremely cellular and can be understood as the first indication of the occurrence of a Lamina muscularis mucosae.
The Tunica muscularis and Tunica adventitia are both well developed. Structurally there are no new findings.

Thoracic part (fig. 17):
In comparison to the other parts, the Lamina epithelialis appears relatively thin.
The Lamina muscularis mucosae becomes indicated by the richly distributed cells in the Lamina propria. On the contrary to this, the submucosa is less cellular. The border between the Lamina propria and the submucosa is demonstrated by a line of blood vessels in between them.
The Tunica muscularis is well developed, two-layered, but not very strong.

Buffalo - fetus of 25 cm CRL

Pharyngo-esophageal junction (fig. 9):
The esophageal lumen is irregular in outline, due to the presence of several longitudinal folds.
The number of cell layers of the stratified squamous epithelium has increased considerably. The superficial layer has 7 - 8 cell layers. These cells are large and polyhedral. Their nuclei are often located centrally. In the top cell layer as also in the basal cell layer binucleated cells are

observable.

The basement membrane is distinct and even.

The Lamina propria mucosae has different zones, more or less furnished with connective tissue cells and fibers.

Primordia of the esophageal glands are clearly visible in the more cellular and less fibrous part of the propria.

The Tunica muscularis consists of two layers which are spirally arranged. First time nerve cells could be detected in the intermuscular layer.

The Tunica adventitia is slightly fibrous and also cellular.

Cervical part:

The esophageal lumen becomes much more folded than in the former embryological stages.

The Lamina epithelialis becomes absolutely thicker (3 - 5 cells), and a superficial and a deep layer are still to differentiate.

The Lamina muscularis mucosae is present and appears as a cellular belt in the Lamina propria, formed by nuclear aggregations. Esophageal glands are absent.

The Tunica muscularis is made up of two layers of striated muscle fibers, in between of which vessels are clearly found, as also between the Tunica muscularis and the adventitia.

The Tunica adventitia shows its usual structure and is relatively thick.

Thoracic part:

The outline of the lumen of the thoracic part is more irregular, due to the occurrence of more mucosal folds.
The number of the epithelial cell layers has increased.
The superficial layer of the Lamina epithelialis contains till to five layers of very loosely packed, large, polyhedral cells. The Lamina muscularis mucosae appears still as a granular line, because the cytoplasm of the smooth muscle cells are not yet demonstrable by H&E stain.
The thickness of the Tunica muscularis has considerably increased. It is two-layered and spirally arranged.
The adventitia is offering no new aspects.

Buffalo - fetus of 36 cm CRL

Pharyngo-esophageal junction:

The Lamina epithelialis has further increased in thickness. The superficial layer is made up of 9 - 10 cells. These are polyhedral and more or less binucleated. The deep layer consists of one row of ovoid cells with a clear nucleolus or more nucleoli. The basal cells are resting on an evenly stretched basement membrane.
The Lamina propria mucosae is still cellular, but already more fibrous than before. It is blended with the submucosa, because of the want of the Lamina muscularis mucosae.
Relatively many esophageal glands in the propria/submucosa

are found. The epithelial outgrowths forming the later glandular end-pieces appear often solid, but canalized ducts become already visible.
The Tunica muscularis is fully developed and made up of spirally arranged striated musculature.
The Tunica adventitia is offering no new aspects.

Cervical part (fig. 15):
The number of epithelial cell layers has clearly increased (5 - 8 cells in thickness). Striking is the fact that the top layer cells become flattened.
Also it is characteristic that the Lamina muscularis mucosae is now appearing as a proper one. The cytoplasm of the smooth cells becomes now demonstrable by H&E, thus letting disappear the granular structure in the younger fetal stages.
The smooth muscle cells are longitudinally arranged.
The Tunica muscularis is characterized by a further increase of the striated musculature.
The adventitia is unchanged.

Thoracic part:
As at the pharyngo-esophageal junction and the cervical part also the thoracic part is characterized by an increase of the number of epithelial cell layers. The cells themselves become more proximo-distally distended.
The Lamina propria mucosae is relatively narrow, but the Lamina muscularis mucosae clearly developed. The smooth muscle cells now are filled with cytoplasm, demonstrable by

H&E. The submucosa is narrow on account of the Tunica muscularis which appears extremely thick. The latter one is bi-layered and both layers are spirally arranged.
The Tunica adventitia offers no new aspects.

Buffalo - fetus of 67 cm CRL

Pharyngo-esophageal junction (fig. 10 + 11):
The Lamina epithelialis is made up of two layers, a superficial and a deep one. The superficial one consists of 7 cell layers of polyhedral cells, the cytoplasm of which is light and the nucleus mostly spherical and often situated to the luminal side. The top layer cells are flattened. The deep layer is deployed in one line and no papillary formation is to observe.
The Lamina propria/submucosa is still relatively cellular, but becomes more fibrous peripherally.
Near the basement membrane many blood vessels and glands are visible. The excretory ducts are canalized. The nuclei of the columnar or pyramidal glandular epithelial cells are pushed to the periphery, but not yet flattened. The glandular lumen is still small. The glands aggregated in clumps and resemble mucous end-pieces.
The Tunica muscularis is composed of an internal circular and outer longitudinal layer of striated muscle fibers, spirally arranged. The adventitia offers no new aspects.

Cervical part:

In the Lamina epithelialis of this part a considerable increase in the number of cells of the superficial layer is visible (generally 7 layers, maximally 40 layers).
The Lamina muscularis mucosae is a thin, continuous bandlike structure.
The submucosa is rich in blood vessels.
From the Tunica muscularis, the inner - here longitudinally running layer - is much stronger than the outer one.
The adventitia is characterized by a rich content of nerves.

Thoracic part:

This part approaches already very much to the adult structure.
The esophageal lumen appears much folded. The number of cell layers in the Lamina epithelialis has increased to ten.
The cells are now smaller than before and more densely packed. The top layer cells are flattened and the basal cells become more cuboidal with rounded nuclei. From the basal layer to the top layer the cells increase steadily in size.
All nuclei are generally centrally located.
The Lamina propria mucosae is narrow and dense.
The Lamina muscularis mucosae is composed of longitudinally running bundles of smooth muscle cells.
The submucosa is broad and covered by numerous blood vessels.
The Tunica muscularis has considerably increased in thickness and it is clearly to subdivide into two layers, spirally running and subdivided by loose connective tissue.

Buffalo - fetus of 94 cm CRL (= full term fetus)

Pharyngo-esophageal junction (fig. 12):
The stratified squamous epithelium is more solidified. The cytoplasm of the epithelial cells is eosinophilically stained. The top layer is formed by two layers of flattened cells, which contain corresponding flattened nuclei. The basal cells are more cuboidal in shape with spherical nuclei. The basement membrane is still stretched and even or begins to become slightly undulated indicating firstly the approaching papillary formation.
The Lamina propria mucosae is made up of lightly appearing loose connective tissue with few smooth muscle cells. Peripherally from it aggregations of esophageal glands are found, which show a mucous appearance. The lumen of the glandular endpieces is moderately wide and the epithelial cell nuclei are pushed to the periphery. The excretory ducts are lined by a layer of cuboidal cells.
Submucosa, Tunica muscularis and adventitia offer no new aspects in comparison to the foregoing fetal stage.

Cervical part:
The Lamina epithelialis is made up of about 6 cell layers. The epithelial cell borders are pronounced, the cell nuclei are rounded and centrally located.
The Lamina propria mucosae shows no specific features.
The Lamina muscularis mucosae is found as a thin strip,

discontinuous and disintegrated into several individual pieces. The submucosa is richly developed and filled with blood vessels. By this, it facilitates a maximal folding of the mucosa. The Tunica muscularis is very thick, made up of 2 layers of striated muscle fibers, roughly spirally or predominantly longitudinally arranged.
The adventitia has no new features.

Thoracic part (fig. 18):
The Lamina epithelialis is solid and firm and includes about 5 cell layers, from which the upper two ones show flattened nuclei. The superficial layer cells are polyhedral, meanwhile the basal ones are cuboidal. Keratinization can not be detected. The Lamina propria mucosae is less cellular than in the younger fetal stages.
The Lamina muscularis mucosae is distinctly stronger and more continuous than in the cervical part and in the buffalo-fetus of 67 cm CRL. The submucosa is well developed and filled by numerous blood vessels.
The Tunica muscularis is distinctly separated into two layers. The inner layer is here the longitudinal one, the outer the more oblique or circular one. But this changes more often in the entire course.
The intermuscular layer consists of loose connective tissue with vessels and nerve plexuses.

Buffalo - calf, 20 days of age

Pharyngo-esophageal junction:

The Lamina epithelialis of the buffalo-calf is characterized by some new features. First time, a Stratum corneum can be observed. Thus keratinization in our cases occurs after birth, between full term of pregnancy and 20 days of age post parturition. It is made up of 3 - 4 cell layers.
Furthermore, first time a papillary formation of the epithelium becomes visible. Epithelial plugs project more or less deeply into the Lamina propria mucosae. From Stratum basale to Stratum granulosum about 8 cell layers are included.
The Lamina propria mucosae is much more fibrous than in the fetal stages. Numerous fibroblasts, fibrocytes, collagenic fibers, blood vessels and excretory ducts of esophageal glands are found. Corresponding to the epithelial plug formation also the Lamina propria mucosae shows a papillary formation.
A Lamina muscularis mucosae is absent in this part of the esophagus.
In the Lamina propria mucosae/submucosa the esophageal glands are located. They form a thick layer of mucous glands. Interesting are their relations to the striated musculature of the Tunica muscularis. Sometimes the glands are exactly found between the muscle bundles.
The Tunica muscularis as also the adventitia offer no new aspects.

Cervical part:

The Lamina epithelialis of the cervical part is formed by a keratinized stratified squamous epithelium. Of course the cornified layer is not so strong as in the adult buffaloes. The Stratum corneum is followed by 3 - 4 layers of cells, which are horizontally disposed as the former ones and the basal cell layer, which is perpendicularly arranged.
A papillary formation of the Lamina propria mucosae is also present here; corresponding to the epithelial plugs, and also present as at the pharyngo-esophageal junction, but only in a slight undulating manner. The main component of the Lamina propria consists of dense, irregularly arranged collagenic fibers.
The Lamina muscularis mucosae is only at certain locations clearly visible and of moderate thickness.
The Tunica muscularis appears to be considerably thick.
About the adventitia no new findings are to be reported.

Thoracic part (fig. 19):

Striking for the thoracic part of the esophagus is its extensive foldings.
The Lamina epithelialis consists of a keratinized stratified squamous epithelium. In contrast to the remaining parts of the esophagus it appears at its surface completely smooth.
The keratinization of the epithelium is not so distinct as at the pharyngo-esophageal junction or at the cervical part.
The epithelial plug formation is either only slightly

pronounced or even absent.
The Lamina propria mucosae is relatively narrow.
The Lamina muscularis mucosae is of a surprising thickness in the thoracic part. It comprises about twice of the thickness of the Lamina propria mucosae.
Submucosa, Tunica muscularis and adventitia offer no new aspects.

Adult buffalo, 3 years of age

Pharyngo-esophageal junction:
The Lamina epithelialis consists of a keratinized stratified squamous epithelium. Its cornified layer comprises about 8 cell layers. Well developed interpapillary pegs anchor the epithelium to the Lamina propria mucosae.
The Lamina propria is strong, made up of dense irregular connective tissue which is filled by collagenic fibers, enriched by blood vessels.
The pharyngo-esophageal junction contains in this animal a Lamina muscularis mucosae, probably due to the to far caudal sampling. It is distinctly developed.
The submucosa is of the same breadth as the Lamina propria mucosae, but is not so densely filled by irregularly arranged collagenic fibers. The esophageal glands occur as classical mucous glands.
The Tunica muscularis is the thickest part of the entire

esophagus. It is of considerable thickness, made up of transversely and longitudinally arranged striated musculature, subdivided by intermuscular connective tissue, which in adult specimens is clearly developed.

Cervical part:

The Lamina epithelialis is a keratinized stratified squamous epithelium. The Stratum corneum s. mortificatum consists of 4 layers of cells which contain still their pyknotic nuclei. The Strata spinosum and granulosum comprise totally 17 layers. The basal cells are columnar with the alike shape of their nuclei.

Interpapillary pegs dip deeply into the Lamina propria mucosae, which in an alternating manner sends the corresponding number of connective tissue papillae into the Lamina epithelialis.

The Lamina propria is structured densely and filled with irregularly arranged collagenic fibers, connective tissue cells and blood vessels.

The Lamina muscularis mucosae is distinctly elaborated and contains bundles of longitudinally arranged smooth muscle cells.

The submucosa has the usual structure.

The Tunica muscularis is composed of two layers, separated by a thinner layer of intermuscular connective tissue. The inner layer runs circularly, the outer one longitudinally.

Thoracic part:

The keratinized stratified squamous epithelium bears a strong cornified layer. The cells contain still pyknotic nuclei, which are very small, thin, fusiform or rod-like. They form about 6 - 7 layers. The basal layer is composed of columnar cells, arranged as distinct interpapillary pegs.

The Lamina propria mucosae is dense and packed by collagenic fibers.

The Lamina muscularis mucosae is clearly developed.

The submucosa appears here denser and narrower than in the remaining parts of the esophagus. It is densely packed by connective tissue fibers.

The Tunica muscularis is the thickest part of the wall of the esophagus. The striated muscle fibers have a spiral course.

The adventitia offers no new aspects.

6. Discussion

This study gives a comprehensive survey on the morphology of the esophagus in buffalo.

The anatomy and histology of the late prenatal, as well as the early and late postnatal periods of its development are studied in detail.

From our kind of approach, we expect profund connections and insights in problems concerned with this scientific subject.

A lot of new data on the buffaloe's esophagus we could obtain.

First, we are able to add new findings of quantitative and qualitative changes in the esophagus of the buffalo in Egypt to the quantitative results gained by TAHER, MOUSTAFA and BERG (1969) concerning this subject. In summing up, we would like to state that the developmental changes are practically concentrated to the mucosa and the musculature, which is in accordance with the reports of SENGAR and SINGH (1969) on the prenatal development of the esophagus of the Indian buffalo.

Embryologically and gross anatomically, it can be confirmed that also the growth of the esophagus follows the known principles of development. With increasing age, it increases in length, i.e. from 15,6 cm in the 39 cm CRL fetus (= 151 days of gestation) to 96 cm in the adult buffalo. In calf of 20 days it measures about 55 cm in length.

This is of some importance for the applied anatomy, because we can conclude from this f.e. the length of a probang to be applied by practicians or clinicians for the treatment of gastrointestinal disorders a.s.o. in buffalo calves and adults.

The studies also revealed that about 50 % and more of the length of the esophagus are covered by its cervical part, followed by the thoracic part and finally by the abdominal part in fetus and calf.

Of no less importance is of course the diameter of the esophagus, often cause of obstruction of the esophagus. Basing on our applied method of measuring the pharyngo-esophageal junction proved to be the widest part of the esophagus, during the entire period of fetal and postnatal development we studied (from 151 days of gestation to adult age). In calf it measures about 11 - 12 mm (unextended), in adult buffaloes 25 - 30 mm (unextended). Also these datas provide clear limits for the diameter of instruments being applied in this region by practicians and clinicians.

The narrowest part of the buffaloe's esophagus is found at the level of the thoracic inlet and over the base of the heart, which is in good accordance with practical observations. But it is to keep in mind that these differences are not clear cut and considerable.

Just cranial to the Hiatus esophageus the diameter of the esophagus widens again, but reaches not the dimensions of the pharyngo-esophageal junction (table 2).

Comparable measurements to ours we did not find in the literature, but individual datas are given by SENGAR and SINGH (1970). They describe the absolute length of the esophagus of the Indian buffalo as to be 98,72 ± 0,92 cm, what is in good accordance with our results (= 96 cm). Also the value given by RAGHAVAN (1964) we can consider as corresponding to ours. He reports the absolute length of the esophagus in the same animal as to be 0,75 - 1 m.

Compared with the ox we can observe that the bovine esophagus is of similar length (90 - 105 cm, HABEL, 1975) like that of the buffalo, but concerning the share of the individual parts there are contradictious opinions. On the contrary to us HABEL (1975) found the cervical part shorter (42 - 49 cm from 90 - 105 cm), than the thoracic part (48 - 56 cm from 90 - 105 cm). Regarding the diameter we could not find any datas.

Finally we want to emphasize HABEL's (1975) statement regarding the unreliability of the measurements of the diameter of the esophagus because of its dilatability in the living state. To avoid this we have used only formaline-fixed specimens.

Regarding the position of the esophagus there are practically no changes during the early and late prenatal phase as also in the early and late postnatal period.

In all developmental stages the initial part of the esophagus is found over the larynx. At the level of the atlanto-axial joint it descends gradually from the dorsal surface to the left side of the trachea. At the level of the 4th cervical

vertebra this shift of position is finished and the cervical part is now found completely at the left side of the trachea. The thoracic part passes dorsally the cranial, middle and caudal mediastinal spaces, forms at the base of the heart (level of the 5th thoracic vertebra) the third curvature of the esophagus (= dorsally convex). From the heart it curves ventrally and caudally to reach the Hiatus esophageus at the level of the 11th thoracic vertebra. A distinct abdominal part of the esophagus is found till to the stage of the full-term fetus.

According to the descriptions of WILKENS and ROSENBERGER (1957), RAGHAVAN (1964), KOCH (1970), DYCE and WENSING (1971), BERG (1973, 1974) and HABEL (1975) on the bovine esophagus, we can confirm to have found a similar position and similar relations of the esophagus in the buffalo.

Quite new are our observations on the retropharyngeal space, which is practically neglected in the veterinary gross anatomical literature till now. But this structure has a practical significance.

As a result from our studies we can state that the Spatium retropharyngeum is also present in all investigated stages of the Egyptian buffalo and extends from the pharyngo-esophageal junction to the dorsal mediastinal space. It is filled by loose connective and fat tissue. It gets practical significance because of its continuance from the pharynx to the thoracic cavity and by this of the possibility of spreading of septic processes in it (fig. 3, 4, 5, 6).

Our histological studies have proven the esophagus of the Egyptian Water buffalo as to be a typical tubular organ composed of a Tunica mucosa with a Lamina epithelialis, Lamina propria mucosae and Lamina muscularis mucosae, a Tela submucosa, a Tunica muscularis and a Tunica adventitia/serosa. The presence of the Lamina muscularis mucosae characterizes the esophagus as a typical digestive organ (SOBOTTA and HAMMERSEN, 1976).

According to SENGAR and SINGH (1969) and MICHEL (1977) the Lamina epithelialis develops from a single layer of epithelial cells to a stratified squamous epithelium. This we have also observed among our specimens, in which the least number of epithelial layers were found to be two (CRL 9 cm).

SENGAR and SINGH (1969) describe for the early fetal stage of 50 days in the Indian buffalo a well developed epithelium resting on a basement membrane and which is covered by a single layer of squamous cells. It is to consider that our earliest stage is 19 days older than that of SENGAR and SINGH (1969), i.e. the monolayer stage of the esophageal epithelium in the Egyptian Water buffalo is according to our studies prior to the CRL 9 cm-stage (= 69 days).

MICHEL (1977) reports that the epithelium of the esophagus is increasing so much that the lumen may be obstructed. This can be confirmed by our studies. We have seen that the lumen at least partially was occluded by epithelial masses (pharyngo-esophageal junction of buffalo-fetus 9 cm CRL).

WILLIAMS and WENDELL-SMITH (1976) describe the same phenomenon in man. There with the descent of the heart and diaphragm, the part of the foregut between the pharynx and diaphragm elongates rapidly to form the esophagus. The elongation is accompanied by a temporary obliteration of its lumen followed by recanalisation and differentiation of a stratified squamous epithelium.

The quantitative histological studies revealed a continuous increase in the thickness of the esophageal wall. Among the three portions of the buffaloe's esophagus the pharyngo-esophageal junction is the thickest, followed by the thoracic part. The thinnest part is the cervical part, which again has also clinical importance (= perforation of esophagus). The reasons for this we consider as follows:

The thickest wall at the pharyngo-esophageal region of the buffalo esophagus is caused by the presence and activity of the pharyngeal muscles. The thinnest wall of the cervical part of the esophagus is to discuss in intimate association to the fact, that the esophagus here is surrounded by many cervical muscle, which act on the esophageal wall and on its content, reliefing in this manner the activity of the Tunica muscularis with the result of being not so strongly developed. The again increased wall of the thoracic part of the esophagus may have its reason of the lacking of a surrounding musculature. The Tunica muscularis is depending on itself and has consequently to be thicker than in the cervical part.

In all portions of the esophagus (pharyngo-esophageal junction, cervical part and thoracic part) the Lamina epithelialis increases absolutely (52 um - 69 days of gestation - to 259 um - adult buffalo = pharyngo-esophageal junction; 23 um - 69 days of gestation - to 344 um - adult buffalo = cervical part; 25 um - 69 days of gestation - to 268 um - adult buffalo = thoracic part) with increasing age (table 4) but decreases relatively with increasing age (table 5).

Till 155 days of gestation (= CRL 36 cm) the connective tissue (Lamina propria mucosae and Tela submucosa) is the dominating tissue in the fetal esophagus of the buffalo. That means till here it is still far away from its proper function of transporting food, because this function is clearly associated to a distinct development of the musculature. But from the 155th day of gestation the situation begins to change as the muscular tissue gains now the dominance and the definite function of the esophagus becomes established.

DIDIO (1975) characterizes the Tunica muscularis as being responsible for the movements of the walls, as these acts on the contents of the esophagus. The action of the walls on the contents may be compression or propulsion, Circular musculature may block the entrance or exit of the cavity of an organ.

From all esophageal portions generally we found the absolutely and relatively strongest Tunica muscularis in the pharyngo-esophageal junction, not in the thoracic part

(table 4 and 5).

We agree with DELLMANN and BROWN (1976) that in all animals the inner circular layer of the esophagus thickens toward the stomach in all animals. Also in the buffalo this trend is distinctly developed.

The Tunica muscularis of the buffaloe's esophagus has the tendency to be arranged as individual muscle bundles, meanwhile the smooth musculature (Lamina muscularis mucosae) tends to be continuous, forming extensive layers. This is in accordance with DIDIO (1975).

The Lamina muscularis mucosae, which is absent in the pharyngo-esophageal junction of the buffaloe's esophagus, is composed of longitudinally arranged smooth muscle cells forming a belt around the Lamina propria mucosae and Lamina epithelialis. In direction from the cervical portion to the Hiatus esophageus it is steadily increasing in thickness. First appearance of the Lamina muscularis mucosae of the cervical and thoracic part in the buffalo fetus was observed at the CRL of 14 cm (92 days of gestation). Here it presents a circularly disposed wider belt of slightly concentrated smooth muscle cell nuclei. The second stage in the formation of this Lamina muscularis mucosae is the narrowing of the above mentioned belt and the increasing concentration of the smooth muscle cell nuclei, without the cytoplasm being demonstrable by H&E. The final stage is then the linkage of all cell nuclei by increasing amount of cytoplasm.

In the esophago-gastric transition the Lamina muscularis mucosae is considerably thickened and may assist the spincter

muscle in closing the entrance of the stomach (DIDIO 1975). This is also to assume for the esophagus of the buffalo. The loose Tela submucosa permits the Tunica mucosa to form longitudinal folds when the esophagus is contracted and these folds in turn allow marked distention (HABEL 1975).

Esophageal glands occur only in the region of the pharyngo-esophageal junction. The first solid glandular epithelial sprouts are seen in the propria/submucosa of buffalo-fetuses with 9 cm CRL (69 days of gestation). They are located ventrally and laterally in the wall of the esophagus. Later on first the excretory ducts become canalized and finally the glandular end-pieces (CRL 67 cm or 225 days of gestation). The esophageal glands of the buffalo are of predominant mucoid character.

7. Summary

In 14 buffalo-fetuses, 2 buffalo-calves and 2 adult buffaloes the oesophagus was studied anatomically and in 7 buffalo-fetuses, 1 buffalo-calf and another adult buffalo histologically.

By this, the development of the early and late prenatal in addition to the early and late postnatal stages were covered.

The position of the esophagus is unchanged during all the developmental stages. At the pharyngo-esophageal junction, it lies dorsal to the larynx, at the cervical part, on the left of the trachea, at the thoracic part dorsal to the trachea.

The length, the diameter and the thickness of the esophageal wall are increasing with increasing age. The length of the esophagus in the adult buffalo is about 96 cm, in the buffalo-calf about 55 cm. The diameter is about 31 mm in the adult buffalo and about 12 mm in the buffalo calf.

The esophagus of the buffalo can be divided into a pharyngo-esophageal junction, a cervical, thoracic and an abdominal portion. The latter one occurs only till the time of parturition. It then disappears successively due to the increasing development of the rumen of the calf.

The cervical part is the longest and narrowest part among all and at the same time it has the thinnest wall. This may be related to the fact that the cervical part is surrounded by muscles which act on the esophageal wall. The thickest wall

is found at the pharyngo-esophageal junction, due to the presence of the pharyngeal musculature here. The widest part is also the pharyngo-esophageal junction, followed by the thoracic part.

The Lamina epithelialis consists of a keratinized stratified squamous epithelium in the adult buffalo. In the fetus there is firstly only one epithelial layer and its number is increasing with increasing age. Keratinization occurs about or immediately after parturition. Interpapillary-peg-formation, anchoring the epithelium to the Lamina propria occurs after birth.

The Lamina muscularis mucosae is absent at the pharyngo-esophageal junction, present in the cervical and thoracic part. It occurs firstly at CRL 14 cm stage and increases steadily in thickness. The thickest Lamina muscularis mucosae is found in the thoracic part of the esophagus of the adult buffalo.

Esophageal glands occur only at the ventral and lateral wall of the pharyngo-esophageal junction. First epithelial sprouts projecting from the Lamina epithelialis into the Lamina propria/submucosa are seen at the CRL 9 cm stage. They increase in number with increasing age. Later on first the excretory ducts become canalized (CRL 67 cm) and finally the solid glandular epithelial sprouts (CRL 94 cm). The esophageal glands are of predominating mucous character.

The Tunica muscularis consists of a circularly and a longitudinally arranged layer of striated musculature which are spirally arranged. The circular layer increases in thickness

toward the thoracic part.

The Tunica adventitia is a connective tissue of loose texture at the pharyngo-esophageal junction and in the cervical part. At the thoracic portion it is surrounded by mediastinal pleura.

8. References

ABDEL RAOUF, M. and M.A. EL NAGGAR (1968): Biometry of the Egyptian Buffalo foetus. J.Vet.Sci. 5, 37 - 43.

BANCROFT, J.D. and A. STEVENS (1977): Theory and practice of histological techniques. Churchill Livingstone - Edinburgh, London and New York.

BERG, R. (1973): Angewandte und topographische Anatomie der Haustiere. VEB Fischer Jena.

BERG, R. (1974): Angewandte und topographische Anatomie der Haustiere. Ferdinand Enke. Stuttgart.

BERG, R., EL-S. TAHER and M.S. EL DIN M. MOUSTAFA (1969): Comparative studies on the prenatal growth of the brain, thymus, stomach and esophagus in the camel (Camelus dromedarius) and Egyptian Water Buffalo (Bos /Bubalus/ bubalis L.). Zbl.Vet.Med., A, 16, 659 - 663.

COCKRILL, W.R. (1974): The husbandry and health of the domestic buffalo. FAO, Rom.

DELLMANN, H.-D. and BROWN, E.M. (1976): Textbook of Veterinary Histology. Lea & Febiger. Philadelphia.

DIDIO, L.J.A. (1975): General splanchnology. In: GETTY, R.: SISSON and GROSSMAN's The Anatomy of the Domestic Animals. Vol.I Saunders, Philadelphia. London. Toronto.

DYCE, K.M. and C.J.G. WENSING (1971): Essentials of bovine anatomy. Lea & Febiger. Philadelphia.

EL AYAT, M.A. (1977): Morphological studies on the arterial and venous blood vessels in the heard region of the buffalo in Egypt (Bos bubalis L.). Ph.D. thesis Cairo University.

HABEL, R.E. (1975): Ruminant. Digestive system. In: GETTY, R.: SISSON and GROSSMAN's The anatomy of the domestic animals. 5th edition. Saunders Co. Philadelphia. London. Toronto.

HARRIS, H.F. (1900): On the rapid conversion of haematoxylene into haematin in staining reactions. J.app.Micr. 3, 777. Cited after BANCROFT, J.D. and STEVENS, A.

KOCH, T. (1970): Lehrbuch der Veterinär-Anatomie. Band II. 2. Aufl. VEB Fischer Jena.

KRAHMER, R., SCHRÖDER, L. and MICHEL, G. (1976): Anatomie der Haustiere. Hirzel Leipzig.

MICHEL, G. (1977): Kompendium der Embryologie der Haustiere. 2. Aufl. VEB Fischer Jena,

MULLER-BOTHA, G.S. (1962): The gastro-esophageal junction. Churchill London.

RAGHAVAN, D. (1964): Anatomy of the ox. Indian Council of Agricultural Research. New Dehli.

SENGAR, O.P.S. and S.N. SINGH (1969): Studies on the digestive system of ruminants. Part I: Development of foregut and compound stomach in buffalo, Bos bubalis L. Agra Univ.J.Res. 18, 17 - 84.

SENGAR, O.P.S. and S.N. SINGH (1970): Studies on the digestive system of ruminants. Part III: Structure of the foregut in buffalo, Bos bubalis L. Agra Univ.J.Res. 19, 43 - 64.

SENGAR, O.P.S. and S.N. SINGH (1971): Studies on the digestive system of ruminants. Part VII: Biometry of the digestive system in buffalo, Bos bubalis L. Agra Univ.J.Res. 20, 73 - 80.

SOBOTTA/HAMMERSEN (1976): Histology. Urban-Schwarzenberg. München - Berlin - Wien.

TAHER, EL-S.; MOUSTAFA, M.S.EL DIN M., BERG, R. (1969): Prenatal growth of some organs in the Egyptian Water buffalo (Bos/ Bubalus/bubalis, L.). Relation between body weight and brain, thymus, stomach and esophagus weights. Zbl.Vet.Med., A, 16, 529 - 535.

TIWARI, G.P. (1978): A note on the microanatomy of esophagus of buffalo (Bubalus bubalis).
Indian J. Animal Science 48, 401 - 403.

VAN GIESON, J. (1889): Laboratory notes of technical methods for the nervous system.
New York Med.J. 50, 57.
Cited after: BANCROFT, J.D. and STEVENS, A.

VSHIVTSEVA, V.V. (1970): Afferent innervation of the intramural ganglia in the esophagus of adult sheep.
Dokl.Akad.Nauk. (SSSR) 190, 983 - 986.

WAKURI, H. and MUTO, K.I. (1972): The fine structure of the cattle esophageal gland with a special reference to the myoepithelial cells.
Kitasato Arch.Exp.Med. 45, 45 -50.

WEIGERT, C. (1898): Über eine Methode zur Färbung elastischer Fasern.
Zbl.allg.path.Anat. 9, 289.
Cited after: BANCROFT, J.D. and A. STEVENS.

WILKENS, H. and ROSENBERGER, G. (1957): Betrachtungen zur Topographie und Funktion des Oesophagus hinsichtlich der Schlundverstopfung des Rindes.
DTW 64, 393 - 396.

WILLIAMS, WENDELL-SMITH, TREADGOLD (1976): Basic Human Embryology. 2nd edition. ELBS - Pitman Medical. London.

YAP, E.E. and MAALA, C.P. (1973): Some observations of the esophagus of the philippine carabao (Bos bubalis). Philipp.J.Vet.Med. 11, 6 - 15.

ملخص عربي

اشتملت هذه الدراسات التى تناولت التركيب التشريحى والهستولوجى لمرئ الجاموس المصرى فى المرحلة الجنينيه ومرحلة ما بعد الولاده على فحص عشر جنينا ، عجلين وجاموستين بالغتين لدراستهم تشريحيا ، كما فحص سبعه اجنه وعجل وجاموسه بالغه للدراسه الهستولوجيه .

وجد من خلال هذه الدراسات أن الوضع الطبيعى للمرئ لايتغير خلال مختلف مراحل التطور فى العمر . يقع الاتصال المرئ البلعومى على السطح العلوى للحنجره والجزء المنقى منها يقع على الجانب الايسر للقصبه الهوائيه .

وجد ايضا انه بتطور العمر يزداد كل من طول وقطر وسمك الجدار المرئ يبلغ طول المرئ فى الجاموس البالغ حوالى ٩٦ سم وفى العجل حوالى ٥٥ سم . يبلغ قطر المرئ حوالى ٣١ مم فى الجاموس البالغ وحوالى ١٢ مم فى العجل . يمكن تقسيم المرئ الى الاجزاء التاليه :

جزء يشمل الاتصال المرئ البلعومى ، جزء عنقى ، جزء صدرى ، وجزء بطنى يتلاشى وجوده عند الولاده لزياده نمو الكرش فى العجل .

يعتبر الجزء المنقى هو اطول اجزاء المرئ واقلهم سمكا مما قد يكون نتيجه لضغط المضلات المنقيه على هذا الجزء ، وجد ان جدار الجزء المرئ البلعومى هو الاكثر سمكا على الاطلاق وهذا يرجع الى وجود المضلات البلعوميه فى هذه المنطقه .

وهذا الجزء علاوه على سمك جداره يتميز بانه اكثر الاجزاء اتساعا يتلوه الجزء الصدرى للمرئ .

تتكون الصفيحه الطلائيه لجدار المرئ فى الجاموس البالغ من خلايا حرشفيه عديده الطبقات ذات سطح متقرن . اما فى المراحل الجنينيه فانها تبدأ بطبقه واحده من الخلايا سرعان ما تزداد فى التعدد تباعا بزياده العمر وقد لوحظ ان عليه التقرن تبدأ عقب الولاده مباشره او بعدها بفتره وجيزه .

يبدأ ظهور الصفيحة الطلائية الاساسية فى الاجنه التى يبلغ طولها حوالى ١٤ سم وتزداد تدريجيا فى السمك بزياده العمر . وقد وجد ان هذه الصفيحه المطليه لا توجد فى الجزء المرئ البلعومى ولكنها موجوده بالجزء المنقى والصدرى من المرئ ويبلغ سمكها اقصاه فى الجزء الصدرى فى الجاموس البالغ .

توجد الغدد فى الاتصال المريء البلعومى فى الجزء بين البطنى والجانبى وتزداد هذه الغدد فى العدد بزيادة العمر وهى بوجه عام مخاطية الافراز

تتكون الطبقة العضلية من حزم دائرية وطولية مرتبة بطريقة حلزونية وتزداد الطبقة الدائرية فى السمك فى الجزء الصدرى للمريء .

يحاط كل من : الجزء المريئى البلعومى والجزء العنقى بطبقة غير كثيفة من الانسجة الضامة اما الجزء الصدرى فانه يحاط بالغشاء البللورى .

رسالة

على

دراسات تشريحيه و هستولوجيه على مرئ الجاموس أثناء التطور الجنيني

مقدمه

من

السيد عيسى غانى حسن (بكالريوس العلوم الطبيه البيطريه)
سنة ١٩٧٧

للحصول على

درجة الماجستير فى العلوم الطبيه البيطريه

(تشريح)

تحت أشراف:

الأستاذ الدكتور/ رولف برج

الدكتور/ أنور محمد على قاسم (مشرف مساعد)

قسم التشريح و الهستولوجيا و الأجنه

بكلية الطب البيطرى (أدفينا)

جامعة الاسكندريه

١٩٨٠