POSTNATAL DEVELOPMENT OF UPPER DIGESTIVE TRACT IN THE DUCK

By

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THESIS

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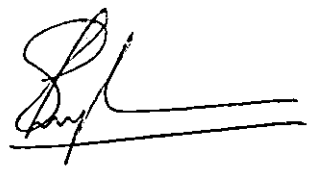
Dedicated to

my husband and parents

DECLARATION

I hereby declare that this thesis entitled 'POSTNATAL DEVELOPMENT OF UPPER DIGESTIVE TRACT IN THE DUCK' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.



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Certified that this thesis entitled 'POSTNATAL DEVELOPMENT OF UPPER DIGESTIVE TRACT IN THE DUCK' is a record of research work done independently by Smt. Shyla Paulose under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to her.

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CONTENTS

ABBREVIATIONS USED

H & E	:	Haematoxylin and Eosin
PAS	:	Periodic Acid Schiff's reagent
PTAH	:	Phosphotungstic Acid Haematoxylin
AF	:	Aldehyde Fuchsin
HCl	:	Hydrochloric acid
C.S.	:	Cross section
L.S.	:	Longitudinal section
Fig.	:	Figure

LIST OF TABLES

LIST OF FIGURES

Fig. No.	Description
20	Section of the tongue showing fungiform papilla. 120 days - H & E. X 160.
21	Tongue epithelium at the middle part showing many taste buds - 90 days H & E. X 250.
22	Taste buds in middle part of tongue. H & E. X 400
23	Section of the posterior part of the tongue (75 days). H & E. X 160.
24	Length and width of laryngeal mound at different ages
25	Section of the pharynx (8 days). Trichrome. X 50
26	Section of the choanal slit (180 days). H & E. X 50
27	Section of the infundibular slit showing lymphocytic aggregations beneath the epithelium (45 days). H & E. X 160.
28	Section of the pharynx (8 days). Trichrome. X 160.
29	Section of the laryngeal mound (45 days). PTAH. X 160.
30	Viscera of duck (90 days) female.
31	C.S. of the cervical oesophagus (8 days) H & E. X 160.
32	C.S. of posterior part of cervical oesophagus showing folds with a pointed apex (8 days). H & E. X 50.
33	Section of the anterior part of the cervical oesophagus showing lymphocytic aggregations around glands (75 days). H & E. X 160.
34	C.S. of the cervical oesophagus showing two layers of muscles in the tunica muscularis (8 days). H & E. X 50.
35	Section of mucosal fold of thoracic oesophagus (75 days). H & E. X 160.

Fig. No.	Description
36	Oesophageo-proventricular junction (150 days). H & E. X 160.
37	Mucosal crypt epithelium of the oesophageal tonsil showing intraepithelial lymphocytes (30 days). H & E. X 250.
38	Lumen of the crypt showing lymphocytes and cell debris (30 days). H & E. X 200.
39	Oesophageal tonsil showing connective tissue septa around the nodules (150 days). H & E. X 160.
40	Proventricular mucosa (8 days). H & E. X 200.
41	Lamina propria of the proventriculus showing simple tubular glands and strands of smooth muscles mixed up with the connective tissue (75 days). Van-Gieson's staining. X 250.
42	Proventricular glands lined by dark and light stained cells (8 days). H & E. X 250.
43	Proventricular glands (8 days). H & E. X 200.
44	C.S. of the proventriculus (22 days). Van Gieson's staining. X 250.
45	Weight of gizzard at different ages.
46	Weight of gizzard as % of body weight at different ages.
47	Section of the lateral wall of the gizzard showing the arrangement of muscle fibres (45 days). Trichrome. X 160.
48	Section of the gizzard showing attachment of muscle layer to the tendon layer (45 days). Trichrome. X 50.
49	Section of craniodorsal sac of gizzard showing two layers of muscles (180 days). H & E. X 50.
50	Section of the caudoventral sac of the gizzard showing two layers of muscle with a thin layer of muscle at the lower part of the submucosa (60 days). PTAH. X 50.
51	Gizzard glands (75 days). H & E. X 50.

Fig. No.	Description
52	Gizzard glands (75 days). H & E. X 200.
53	Gizzard glands (60 days). PTAH. X 400.
54	Gizzard glands (60 days). PTAH. X 160.
55	Gizzard glands (45 days). PAS. X 160.
56	Gizzard glands (45 days). Trichrome. X 250.
57	Gizzard lining (45 days). H & E. X 200.
58	Gizzard gland and lining of the caudoventral sac (60 days). PTAH. X 50.
59	Gizzard gland and lining (45 days). Van Gieson's staining. X 160.
60	Gizzard gland and lining (45 days). Trichrome. X 160.
61	Gizzard gland and lining (45 days). Aldehyde Fuchsin. X 160.
62	Gizzard glands (75 days). H & E. X 160.
63	Section of gizzard-duodenal junction (22 days). H & E. X 50.
64	Gizzard-duodenal junction showing lymphocytic aggregation (120 days). H & E. X 50.
65	Section of the duodenal villi (45 days). Trichrome. X 400.
66	Angiogram of the head and neck.
67	Angiogram of the body - lateral view.

Introduction

INTRODUCTION

The domestic duck Anas platyrhyncos domesticus was derived through domestication of Mallard, Anas platyrhyncos, native to Europe, Asia, North Africa and North America. Ducks have a long history as established members of the farmer's livestock.

India has secured a place of prominence in the poultry map of the world coming within the top 13 poultry producing countries. However, the status of ducks in our country, either for egg production or meat, has virtually remained static during the last one and a half decades as compared to the phenomenal progress in chicken rearing.

Ducks in our country are mainly maintained for egg production and spent ducks and surplus drakes are the only source of duck meat. Ducks are second to chicken as far as table egg production is concerned. In India ducks are mainly distributed in the eastern and southern States, of which West Bengal occupies the first place and Kerala the sixth. According to the 1982 census, the duck population in Kerala was 5.3 lakhs which is 3.5% of the State's poultry population.

The agro-climatic environment and the wide stretching coastal belt form a natural gift to Kerala State which is ideal for duck rearing. Duck farming in Kerala is found to be a remunerative enterprise, since it does not require

elaborate housing, necessitates only low capital investment, brings quick return from outlay.

Nearly a dozen breeds of ducks are available, of which Khaki Campbell and Indian Runner are important laying types and Aylesbury and Pekin are good table breeds.

It is well known that management practices of any particular species of animal or bird depend entirely on the structure and functions of various parts of the body. Corresponding to diverse adaptive variations in types of nutrition, the individual parts of the digestive tract vary extensively in form and functions. The feeding practice and the food stuff vary greatly between domestic fowl and the duck. A comprehensive knowledge on the structure of the digestive tract of duck is a necessary prelude for the proper understanding of their functional peculiarities. A perusal of the available literature reveals that there has not been a systematic and detailed study on the structure and development of gastrointestinal tract of duck. Hence, the aim of the present experiment is an endeavour to carry out morphological and histological studies on the upper digestive tract in the duck at various stages of postnatal development.

Review of Literature

REVIEW OF LITERATURE

Hallsworth and Coates (1962) in their study on the internal volumes of different parts of the alimentary tract of fowl and goose observed that the gut capacities increased rapidly reaching a maximum in relation to body weight within the first fortnight after hatching. At 16 weeks, the capacity of alimentary canal had almost the same relation to body weight as in the adult. Crompton and Walters (1979) studied the growth of the alimentary tract of male domestic fowls, from the dry weight of the whole and component parts of the tract, from hatching to 10 weeks of age. Baranyiova et al. (1983) found that the greatest live body mass increase was in the fifth week in White Pekin ducks while during the third week of post hatch the actual mass of whole gastrointestinal tract recorded the maximum rate of growth. In the order of decreasing contribution to the growth of gastrointestinal tract, intestine predominated over gizzard while the contributions of oesophagus, crop and proventriculus were negligible.

The gross and microscopic anatomy of the digestive system of the fowl have been studied by Calhoun (1954), Bradley and Grahame (1960), Hill (1971), Ziswiler and Farner (1972), Hodges (1974) and McLelland (1975). Das et al. (1965) have given an insight into the comparative anatomy of the digestive system of the domestic duck.

The tongue of domestic duck has been reported to be spatula shaped with a median groove on the dorsal surface and a smooth prominence near the root. There were two rows of caudally directed pointed papillae at the root of the tongue demarcating the limit of the oral cavity (Das et al., 1965). The histological structure of the tongue of duck had been investigated by Biswal and Das (1967) and Rao and Hafeezuddin (1988). Biswal and Das (1967) observed the presence of fungiform papillae on the tongue of duck and fibrocartilages on either side of the entoglossal bone contrary to the observation of Rao and Hafeezuddin (1988) who could not observe true fungiform papillae. There has been considerable controversy as to whether or not the fowl possesses a sense of taste. While Calhoun (1954) and Bradley and Grahame (1960) could not locate taste buds in the tongue of fowl, Kare et al. (1957) and Gentle (1971a) reported a remarkably good sense of taste in fowls. Lindenmaier and Kare (1959); Saito (1966) and Gentle (1971b) estimated about 30-70 taste buds in the chicken, they being glandular buds associated with the duct of salivary gland and consisted of sustentacular and gustatory cells with a taste pore. Gentle (1971b) found that taste buds in chicken were formed of a single type of columnar cells. Biswal and Das (1967) did not observe any taste buds in the tongue of domestic duck. Contrary to this observation Rao and Hafeezuddin (1988) observed few taste buds in the root of the tongue.

Large number of Herbst's corpuscles and ganglion cells were observed in the tongue of domestic duck by Biswal and Das (1967). In addition, Rao and Hafeezuddin (1988) have reported the presence of Grandry's corpuscles. The anterior and posterior lingual glands of domestic fowl consisted of branched tubular glands which opened into a common cavity from which a duct led to the mouth cavity (Calhoun, 1954). The cytology of the secretory cells and the physiological cycle of secretion has been described at length by Chodnick (1948). In duck, the salivary glands consisted of a single row of tubuloalveolar holocrine mucous glands (Biswal and Das, 1967; Rao and Hafeezuddin, 1988).

The pharynx of domestic duck was directly continuous with the hard palate and had many small caudally directed papillae. However, the papillae at the pharyngeo-oesophageal junction were not well developed (Das et al., 1965). Later works of McLelland (1975) revealed the presence of a well defined transverse row of caudally directed papillae at the junction with the oesophagus. The pharynx was lined by a thick non-cornified stratified squamous epithelium and its thickness decreased towards the oesophageal junction in fowl (Hodges, 1974) and in duck (Rao and Hafeezuddin, 1987b). Lymphocytic infiltration in the tunica propria in the region of the auditus laryngis, with some subepithelial lymph nodules, was regarded as the pharyngeal tonsil in fowls (Calhoun, 1954). Occurrence of Herbst's corpuscles (Trautmann and

Feibiger, 1957; McLelland, 1975) and taste buds (Lindenmaier and Kare, 1954) has been established in the pharynx of fowl. Densely arranged branched tubuloalveolar PAS-positive glands were observed in the submucosa of duck pharynx (Rao and Hafeezuddin, 1987b). Beneath the floor of the pharynx there were large bundles of striated muscle fibres associated with the hyoid bone and the base of the tongue in fowls (Hodges, 1974).

According to Das et al. (1965) the auditus oesophagi of domestic duck was very wide, the lumen of the oesophagus was wide, and at the thoracic inlet constricted. They have further observed that the mucosal folds were prominent in the cervical part. The general morphology of the mucous gland cells and the nature of the secretory granules in the oesophageal glands of newly hatched chicks have been described by Allenspach and Jerry (1971). The light and electronmicroscopic studies on the glands of the oesophagus and crop of various domestic and wild birds showed that there was no relationship between the structure of the three oesophageal segments and type of feed consumed (Feder, 1972). The oesophageal glands of duck were simple tubuloalveolar glands (Das and Biswal, 1967; Rao and Hafeezuddin, 1987a) and holocrine in nature (Das and Biswal, 1967). Mucous glands were found in the wall of the crop of duck (McLelland, 1975) and in the crop channel of chicken (Nickel et al.,

1977). The muscularis mucosa was composed of longitudinal smooth muscle fibres which showed thickenings at the base of the mucosal folds, the thin submucosa containing blood vessels and lymphocytes and the tunica muscularis consisting of inner thick circular and outer thin longitudinal smooth muscle fibres (Calhoun, 1954; Bradley and Grahame, 1960; Hodges, 1974). Rao and Hafeezuddin (1987a) observed that the muscularis mucosa and submucosa were absent in duck and the tunica muscularis consisted of an outer circular and an inner longitudinal layer of smooth muscle fibres. However, Das and Biswal (1967) observed longitudinal layer of muscularis mucosa and only a thick layer of circular smooth muscle in the outer musculature of oesophagus of domestic duck. McLelland (1975) has described the crop of duck as a spindle shaped enlargement just cranial to the thoracic inlet whereas Das et al. (1965) had opined that crop was absent in the duck. The lymphoid tissue designated as oesophageal tonsil has been reported at the oesophago-proventricular junction by various workers in chicken (Calhoun, 1954; Hodges, 1974) and in duck (McLelland, 1975; Nickel et al., 1977). In addition, in chicken Calhoun (1954) observed diffuse and nodular lymphoid tissue throughout the oesophagus except in the crop.

According to Das et al. (1965) the proventriculus of domestic duck was cylindrical with uniform diameter and a wide opening into the gizzard. In chicken, the proventriculus was elongated, spindle shaped with wide and

macroscopically visible papillae on its mucosal surface (McLelland, 1975). The mucous membrane of the duck proventriculus presented numerous small papillae containing the openings of proventricular glands (Kolda and Komarek, 1958). Both in fowl and duck, the surface epithelium of the mucosa consisted of columnar cells with basal nuclei and contained supranuclear mucin granules (Aitken, 1958; Das and Biswal, 1967 and Hodges, 1974). According to Horvath (1974) the lining epithelium of the proventricular lumen and the glandular epithelium of proprial glands were similar in structure to the superficial mucin secreting cells of the mammalian stomach. The simple tubular glands beneath the surface epithelium in fowls was studied by Calhoun (1954). Bradley and Grahame (1960) have suggested hydrochloric acid (HCl) production from these glands. Das and Biswal (1967) reported that the cleft between the folds of mucous membrane in duck proventriculus contained crypt-like simple tubular glands with spherical cells with large basal nuclei. The lamina propria, in addition to connective tissue fibres contained diffuse and aggregated lymphoid tissue in fowl (Calhoun, 1954; Hodges, 1974) and in duck (Das and Biswal, 1967). Calhoun (1954) found muscular bundles between the gland lobules as well as internal to the glands and considered a diffuse muscularis mucosa consisting mainly of the inner longitudinal muscle layer lying external to the glands but also stretching in folds between them whereas Bradley and

Grahame (1960) considered small bundles of longitudinal fibres lying internal to the glandular masses as the diffuse muscularis mucosa in fowl. In duck proventriculus, the muscularis mucosa was made up of thick longitudinally running smooth muscle layer lying external to the glands and the fibres were especially well developed at the base of the interglandular septa but did not penetrate into them (Das and Biswal, 1967). The proventricular glands of the fowl were simple tubular glands grouped together into lobules each converging to a common cavity in the centre of the lobule, the openings converging to the surface of ducts, each duct opening at the apex of small papillae (Calhoun, 1954; Aitken, 1958; Bradley and Grahame, 1960). In duck, the proventricular glands in the lamina propria were unilobular compound tubuloalveolar glands, the tubules being arranged radially around a central sinus which opened into the lumen of the proventriculus by a duct (Das and Biswal, 1967). Surrounding each lobule in fowl was a connective tissue septum consisting of collagen and elastic fibres together with sparse muscle fibres and containing blood vessels and nerves (Calhoun, 1954). The epithelial cells lining the duct and the central cavity were identical with those of mucous glands and the number of granules decreased on passing within the glands (Aitken, 1958). The proventricular glands of the fowl were lined by simple epithelium consisting of cells which made contact with the adjacent

cells towards their bases and had a dentate appearance (Chodnick, 1947; Calhoun, 1954; Aitken, 1958). According to Das and Biswal (1967) the unilobular compound tubulo-alveolar glands were lined with cuboidal epithelial cells resting upon a thin basement membrane and the duct and the sinus were lined with the same type of epithelium as the mucosa. Toner (1963) studied the fine structure of the sub-mucosal gland cells of the proventriculus of fasting and histamine treated fowls. The resting cell was cuboidal or low columnar with the apex of cell rounded and bulging into the lumen of the gland. The free surface was smooth without microvilli and there were infoldings of the basal cell membrane at intervals. The apical cytoplasm was packed with cytoplasmic vacuoles. The free surface of the histamine treated cell was straight with long bulbous microvilli and the basal infoldings were more elaborate. Wight (1975) observed considerable amount of lipids in the oxyntico-peptic cells of the proventriculus of fasted chicken. The tunica muscularis of the proventriculus consisted of inner circular and outer longitudinal layers of smooth muscle in fowl (Batt, 1924; Calhoun, 1954) and in duck (Das and Biswal, 1967). According to Bradley and Grahame (1960); Nickel et al. (1977) and Czarnecki (1977), the tunica muscularis consisted of three layers viz., thin inner and outer longitudinal layers and a thick middle circular layer of smooth muscles.

According to Das et al. (1965) the gizzard of the domestic duck was located entirely to the left of the median plane and its musculature was distinctly developed to form a dorsal and ventral ridge whereas at its cranial and caudal ends, the musculature was ill defined and the mucosa was strongly adherent to the musculature. The gizzard of the chicken was shaped like a biconvex lens with a greater cranio-caudal diameter (McLelland, 1975). The tendon layer of the gizzard of fowl consisted of closely packed collagen fibres and was thickest at the tendinous aponeurosis which was free of any muscle (Bradley and Grahame, 1960; Hodges, 1974). Calhoun (1954) observed in fowls, fibrocartilage at the junction of the smooth muscle and tendon layer and Bradley and Grahame (1960) reported striated muscle at the keel of the gizzard. Das and Biswal (1967) observed two layers of smooth muscles in the lateral wall of the gizzard in ducks. Bennett and Cobb (1969) showed that the smooth muscle of the gizzard was extensively arranged into interlocking bundles separated by connective tissue and the Auerbach's plexus lay close to the outer surface of the gizzard immediately under the serosa. The connective tissue septa between the muscle bundles were arranged at right angles to the adjacent bundles and the muscle bundles formed an angle with the tendon layer in chicken (Gabella, 1985). The intermediate muscles of the chicken blind sacs consisted of inner longitudinal and outer circular layers of smooth muscles (McLelland, 1975). The

muscularis mucosa was absent in the fowl (Calhoun, 1954) and in duck (Das and Biswal, 1967). The submucosa consisted of a dense layer of connective tissue containing collagen fibres, blood vessels and nerve plexuses (Calhoun, 1954); Das and Biswal (1967) had designated this layer as the stratum compactum.

The gizzard glands have been described by various workers as the protruding lamellae of the gland cells forming single elongated crypts which terminate as either single or branched tubular glands (Chodnick, 1947 and Calhoun, 1954). The simple glandular tubules were found lined by cuboidal cells (Aitken, 1958; Eglitis and Knouff, 1962 and Toner, 1964) in fowl and numerous branched tubular glands lined with columnar cells opening into the gizzard lumen between the folds of the epithelium (Das and Biswal, 1967) in duck. The gizzard glands were lined mainly by the chief cells and few basal and intermediate cells in fowl (Toner, 1964).

The surface epithelium of the gizzard was simple columnar (Calhoun, 1954). The cells were taller than the chief cells which were low columnar. The apical surface of the surface epithelium appeared tending to bulge into the lumen, the nucleus being irregular in shape and an increase in depth of staining on passing from the base to the top of the pit (Chodnick, 1947 and Toner, 1964). It further showed two distinct zones on Haematoxylin and orcein staining - a basal

basophilic zone including the nucleus and a distal zone which is faintly eosinophilic (Eglitis and Knouff, 1962). The columnar cells covering the free surface and lining the upper part of the gland tubule contained granules which were stained with mucicarmine, PAS and aldehyde fuchsin and metachromatic with celestin blue and methylene blue (Aitken, 1958). The chief cell granules and the material in the gland lumen were specifically stained by PTAH stain in fowl (Toner, 1964). The substance in the gland lumen gave positive carbohydrate reaction and this was absent from the chief cell granules (Aitken, 1958; Eglitis and Knouff, 1962 and Toner, 1964). Eglitis and Knouff (1962) considered that the gizzard lining consisted of arrays of vertical columns and a matrix produced by the surface cells in horizontal laminations. Toner (1964) demonstrated filamentous structure of the intraglandular secretions and the mode of formation of the gizzard lining in fowl. The chemical nature of the gizzard lining has been worked out and it is said to be keratohyalin (Bradley and Grahame, 1960; Calhoun, 1954); or a hard keratin similar to hair (Aitken, 1958) or koilin (Hoffmann and Pregl, 1907); or a carbohydrate-protein complex of mucoprotein variety (Eglitis and Knouff, 1962) or a protein unlike keratin (Webb and Colvin, 1964).

The gizzard-duodenal junction was delineated by a constriction of the muscularis mucosa, forming a fold of the muscularis and the tunica propria in fowl (Hodges, 1954).

Brunner's glands were reported at this junction by Calhoun (1954), Bradley and Grahame (1960) and Farner (1960). Hodges (1974) reported a narrow zone of tubular glands between the gizzard and the duodenum, homologus to the mammalian Brunner's gland. Presence of globular leucocytes in the duodenal villi had also been reported in fowl by Clara (1926); Greulich (1949); Toner (1965); Holman (1968) and Colvin et al. (1974).

Materials and Methods

MATERIALS AND METHODS

Seventy-two ducklings belonging to the White Pekin breed were used for the present study. They were selected randomly from a single hatch and reared in the University Poultry Farm under the same conditions of feeding and management. Soon after the hatch, the ducklings were sexed, numbered and transferred to a brooder in which artificial light was provided. After one month, they were transferred to the litter floor system of management. The birds were allowed to feed ad libitum on water and proprietory diet.

On the first, 8th, 15th, 22nd, 30th, 45th, 60th, 75th, 90th, 120th, 150th and 180th days, six birds each (3 males and 3 females)were selected from the group for experimental observations. These birds were starved overnight and their body weights were recorded. The birds were then slaughtered by pithing and severing the spinal cord at the level of occipito-atlantal articulation. They were exsanguinated by cutting jugular veins without disturbing the cervical oesophagus. The length of the bills, the length and width of the hard keratin and width of the upper bill at the level of nostrils were measured using a vernier caliper.

The birds were dissected and the topography of the upper digestive tract such as the position and relationship of the oesophagus and crop, proventriculus and gizzard were noted. The upper digestive tract starting from the tongue

The diameters of different rggions, viz., the cervical oesophagus (cranial, middle and caudal), crop (junction of cervical oesophagus, middle and junction of thoracic oesophagus), thoracic oesophagus (cranial, middle and caudal), proventriculus (anterior, middle and posterior) and gizzard (cranio caudal, dorsoventral and thickness) were measured using a vernier caliper. The tract was divided into tongue, pharynx, oesophagus and crop, proventriculus and gizzard. The gizzard was opened by a longitudinal incision and its contents were removed, washed in normal saline and mopped. The weights of these organs were recorded using a monopan balance.

Representative samples of the different regions were removed and fixed in formol-saline, Bouin's fluid, and neutral buffered formalin. The tissues were processed and paraffin sections of 5 um thickness were taken. The sections were stained with Harris' haematoxylin and Eosin for general histoarchitecture. Besides this, the following special stains were also used.

No.	Parameter	Fixation	Method	Source
1	Collagen fibres	Bouin's fluid/ Formol saline	Van-Gieson's	Drury and Wallington (1967)
2	Elastic fibres	"	Verhoeff's Method	"
3	Mucins	"	Periodic Acid Schiff's reaction (PAS)	"

Results

RESULTS

Body weight

The body weights of the White Pekin ducks used for this study are shown in Table 1. The maximum body weight of 2023.3 ± 53.64 g was recorded at 150 day old ducks and thereafter a reduction was noticed in 180 days (Fig. 2).

Mouth cavity

The broad and oval epidermal bills enclosed the mouth cavity.

Upper bill (Fig.3).

It was long and wide covering partly the premaxillary and nasal bones. The external nares were partly closed. Rounded tip of the upper bill had a spatula shaped hard keratin, limited to a small median part while the rest of the bill was soft and wax-like. One-day-old ducklings showed a small cone shaped raised egg tooth on the hard keratin near its tip. A ventral median whitish line was present on the dorsal part of the hard keratin which was absent in the ducks aged 45 days and above.

The length and width of the upper bill and hard keratin are shown in table 2. The length showed a progressive increase from 15.8 mm to 75 mm and width from 8 mm to 27.6 mm upto 180 days of age (Fig.4). The hard keratin also showed a relative increase in length (5.7 mm to 14 mm) and width (5 mm to 11.6 mm).

The ventromedial edge of the upper bill possessed a row of blade like lamellae with narrow free medial surface. In one-day-old ducklings these lamellae were very small with less interlamellar space. The lamellae showed a gradual change in size, width and interlamellar space with advancing age. In the 15-day-old ducklings, the lamellae became distinct blades and the mean value of lamellae was found to be 45 pairs.

Lower bill (Fig. 5).

The lower bill was smaller than the upper bill except in one-day-old ducklings in which the upper and lower bills were nearly equal in length (Fig. 4). It extended on the dentary bones of the mandible. The hard keratin at the tip of the lower bill was more rounded. The central median whitish line reached only upto its caudal half. The hard keratin showed an increase in length (4.6 mm to 13.5 mm) and width (4.7 mm to 10.7 mm) upto 180 days of age.

The dorsolateral edge of the lower bill presented a dorsal row of lamellae extending from its tip towards the angle of the bill. These lamellae were short, their dorsal edges being directed laterally and they had a rounded dorsal surface. These lamellae were smaller in size in comparison to the lamellae of the upper bill and the mean number was observed to be 74 pairs.

The lateral surface of the bill close to the dorsal

lamellae, had a lateral row of larger blade-like lamellae with sharp dorsal edges and the mean number was found to be 52 pairs. These lamellae on the posterior 1/3rd of the bill were rounded and smooth.

A ridge separating the dorsal and lateral lamellae extended dorsolaterally from the angle of the mouth towards the tip and was narrow rostrally and wide caudally.

Palate.

The rostral part of the palate ventral to the premaxillary bones were strongly concave. The mucous membrane formed a longitudinal median ridge, continued caudally by four wide-based papillae, arranged in a line in most birds and in pairs in some birds, one pair in line with the ridge and the caudal pair side by side. On either side of the median ridge rostrally were the openings of the maxillary glands.

Choanal slit.

The choanal slit was relatively short. The wide caudal part was larger than the narrow rostral part. The mucous membrane at the edges of the slit was thickened and had thin pointed caudally directed papillae.

A transverse row of thin pointed, caudally directed papillae extended on each side of the midline from the edge of the choanal slit at the junction of the narrow and wide parts. The papillae were better developed at the wider part

of the slit and were arranged in several irregular longitudinal rows, close to the slit.

A transverse ridge somewhat in the middle of the narrow part of the choanal slit demarcated the caudal upper limit of the oral cavity. Transverse rows of caudally directed papillae on the caudal end of the tongue demarcated the lower limit of the oral cavity. The average length of the choanal slit increased from 7.6 mm at one-day-old to 27.8 mm at 180 days of age (Table 3).

The proportions of anterior and posterior part of the choanal slit are shown in Fig. 6. Lateral to the wider part of the choanal slit, many small openings of the pharyngeal salivary glands were seen.

Tongue

Gross observations (Fig. 5).

The tongue was long and spatula shaped. The rostral extremity was thin and had a depression on its middle part. Dorsal surface of the tongue had a median longitudinal groove which did not extend to the full length of the tongue, but it stopped a little in front of the middle third of the tongue. On either side of the median longitudinal groove in the middle third of the tongue longitudinal rows of small papillae which converged caudally with a nodular enlargement on either side were seen and then continued caudally with a wide ridge of mucous membrane in the caudal third of the tongue. The

lateral edges of the ridge also had small papillae and it covered a small portion of the dorsal surface of the tongue. This ridge extended laterally and were directly continuous with the raised dorsal surface at the root of the tongue. Lateral to the longitudinal rows of papillae and the ridges were many wide based short papillae.

Lateral margins of the caudal half of the tongue presented tough, straight, wide based conical papillae numbering about five on each side and united by fine papillae. This was continued rostrad by two rows of papillae which looked like fins of fishes. The dorsal row consisted of large conical papillae connected by fine papillae. The ventral row was composed of only the finer type. The ventral surface presented a median ridge and at its tip a triangular eminence corresponding to the depression on the dorsal surface was observed. Rostral to the frenum linguae two prominences were also observed.

Close to the base of the tongue were two transverse rows of caudally directed papillae. The largest ones were seen close to the midline except in day-old ducklings in which the papillae were of equal size.

The skeleton of the tongue was formed by the median entoglossal bone. A narrow hyaline cartilage was present at the rostral part and the cornual processes were absent (Fig. 7).

The weight and length of the tongue at different ages are shown in Table 4. The weight of the tongue increased about 13.6 times from 0.142 ± 0.003 g in day old to 1.937 ± 0.056 g in 30 day-old birds. Thereafter the increase was at a slower rate upto the age of 75 days. A maximum weight of 6.07 ± 0.202 g was recorded at 150 days of age (Fig. 8). The contribution of tongue to body weight was 0.71% at 8th day and decreased progressively to 0.37% at 180 days of age.

The length of the tongue increased progressively from 1.5 ± 0.03 cm at one day old to 6.0 ± 0.18 cm at 180 days. The rate of increase was maximum between 22-30 days after hatching and thereafter the increase was at a slower rate. The weight of the tongue was related positively with its length (r = 0.9934) and body weight (r = 0.9863).

Histology.

Epithelium.

The tongue of the domestic duck was lined by stratified squamous epithelium. The epithelium was thicker on the dorsal surface compared to the ventral surface (Table 5 and Fig. 9). The epithelium at the tip of the tongue and lateral edges were keratinised.(Fig. 10). The thickness decreased towards the posterior part on both surfaces. The thickness of the epithelium varied in different age groups and regions (Table 5). The dorsal surface was irregular whereas the ventral surface was smooth. The superficial layer of the

epithelium showed strong propensity to slough off. The stratum cylindricum was thick and consisted of very long columnar cells in day-old ducklings. The cells of the stratum granulosum showed many granules in their cytoplasm from eight days of age.

Numerous long narrow dermal papillae projecting into the stratum granulosum of the epithelium contained fine connective tissue fibres and capillaries (Fig.11). These dermal papillae lined by columnar cells gave a fern-like appearance. In day-old ducklings, the dorsal epithelium had few small dermal papillae which were lacking in the ventral epithelium. At eighth day they were observed on both sides and by 15th day, dermal papillae were well formed on both sides. A proportionate increase in the number of dermal papillae with thickening of the epithelium was noticed. They were more on the dorsal epithelium. In adult ducks the dermal papillae were wider and fewer in number especially at the middle and caudal part of the tongue where it had a follicular nature (Fig. 12).

Lamina propria.

Lamina propria was well developed in the body and root of the tongue and composed of collagen and few elastic fibres, and rich in adipose tissue. Towards the anterior part the lamina propria was thin. It was rich in blood vessels, nerve trunks, sensory nerve endings and lymphocytes. Longitudinal blood sinuses were also observed. Strips of fibrocartilage

were observed in the middle part of the tongue (Fig. 13). The lymphocytes occurred both in aggregated and diffuse forms especially beneath the deeper layers of the epithelium.

Eventhough the tongue of the duck was bulky, the striated muscles were scanty. They were observed in the caudal part, majority being arranged longitudinally around the entoglossal bone but few fibres were arranged transversely and obliquely (Fig. 14).

Herbst's corpuscles (Fig. 15).

Large number of Herbst's corpuscles were observed in the lamina propria close to the deeper layers of the epithelium. They were numerous at the base of the barbs and other papillae. In the anterior part of the tongue they occurred mostly as single and in the body and root as groups of two to five large corpuscles. They were oval shaped lamellated corpuscles consisting of an outer layer of concentrically arranged lamellae containing fibroblasts and an inner layer of dense lamellae. In the middle of the inner layer there were two rows of flattened elongated nuclei containing an axis cylinder in between the two rows. The diameter of the corpuscles varied from 40 um to 95 um.

Tactile corpuscle (Fig. 16).

Few tactile corpuscles were observed in the lamina propria beneath the epithelium of the body and root of the tongue, mostly near the Herbst's corpuscles. In shape they

resembled a fir cone with a thin connective tissue capsule containing transversely arranged tactile cells and spiral nerve fibres. The average diameter of this corpuscle ranged from 53 um to 80 um.

Grandry's corpuscles (Fig. 17).

Grandry's corpuscles were observed in the lamina propria at the anterior and middle part of the tongue, on either side of the median groove dorsal to the entoglossal cartilage. They had two to four vesicular tactile cells in the centre with a lamellated collagenous capsule. The inner lamellae were compact and closely arranged whereas the outer lamellae were loosely arranged. Close to the corpuscle there were nerve bundles and blood vessels. They were more or less oval in shape and the width ranged from 160 um to 200 um and length from 460 um to 530 um.

Numerous encapsulated spherical bodies were observed in the dermal papillae, close to the stratified squamous epithelium near the Herbst's corpuscles. They consisted of two to four horizontally oriented columnar like cells with a granular cytoplasm. The nucleus was spherical, vesicular and with a distinct nucleolus (Fig. 16).

Several ganglion cells were observed in groups of two to seven in the lamina propria beneath the epithelium near the Herbst's corpuscles.

The nerve supply was extensive especially on the dorsal

part of the tongue where two large myelinated nerve trunks were also observed in addition to the smaller branches.

The central part of the tongue was occupied by the entoglossal bone which was continued rostrally by an oval dorsoventrally flattened hyaline cartilage which reached upto the tip of the tongue. In the middle portion of the tongue, the cartilage was more or less circular in outline. At the posterior part of the tongue, the entoglossal bone was thin and wide and showed a ventral concavity. It formed a sinovial hinge with rostral basibranchial bone at the root of the tongue.

Ossification of the cartilage started from the posterior part by eight days of age. But the tip of the cartilage remained cartilagenous even upto the age of 180 days.

Lingual papillae.

Three types of papillae were observed on the tongue of domestic duck, namely, filiform papillae, 2. conical papillae and 3. fungiform papillae.

Filiform papillae (Fig. 18).

These papillae were arranged in two rows on the lateral edges of the tongue. Dorsal row of papillae was long and pointed and consisted of an external layer of thick keratinised stratified squamous epithelium and an inner core of lamina propria. The stratum corneum extended over the tips of the barbs as horny spines. The ventral row of papillae

was smaller than the dorsal row and spatula shaped. Few secondary papillae arose from the base of the primary papillae. The lamina propria of the barb did not enter into the secondary papillae.

Conical papillae (Fig. 19).

Few broad cone shaped papillae were present at the lateral edges of the caudal 2/3rd of the tongue. It had an external layer of thick keratinised stratified squamous epithelium and an inner core of lamina propria rich in blood vessels and nerve endings.

Fungiform papillae (Fig. 20).

A few wide based papillae covered by comparatively thin stratified squamous epithelium with thick keratin layer were observed on the body of the tongue. It had an extensive core of lamina propria rich in blood vessels, Herbst's corpuscles and tactile corpuscles. Taste buds were not observed on this papillae.

Taste buds (Fig. 21 and 22).

Large numbers of taste buds were observed in the middle and posterior part of the tongue. They were oval in shape and measured 105-130 um length and 80-105 um width. Each bud consisted of an aggregate of elongated nucleated cells stained pale with eosin. The taste pore was very small. Taste hairs were not observed.

Lingual glands (Fig. 23).

The anterior lingual glands were observed on the dorsolateral aspect of the body and the posterior lingual glands on the ventrolateral aspect of the root of the tongue. They composed of masses of compound tubuloalveolar glands. An entire gland was formed from varying numbers of units, each unit comprising many tubules opening into a common cavity and possessing a common duct. Salivary glands were surrounded by a connective tissue capsule mainly formed of collagen fibres and few elastic fibres. Blood vessels and nerves were present within the capsule. From the capsule septa invaded and formed interlobular connective tissue which surrounded groups of tubules. Smooth muscle fibres were not observed in the capsule and interlobular septa. The glandular tubules were lined by single row of tall columnar mucous cells with basal spherical nucleus and basophilic foamy cytoplasm. The glands were holocrine in nature and the lumen contained cell debris and secreted material. Different phases of the secretion process were observed.

The duct from the basic units of the gland was lined by tall columnar cells. The larger duct was lined by nonsecretory stratified cuboidal epithelium and opened through the stratified squamous epithelium of the tongue to the oral cavity. The glands were highly PAS positive.

Pharynx

Gross observations.

Roof (Fig. 3).

The length and weight of the pharynx and the thickness of the epithelium (at the roof) are shown in tables 6 and 7. The weight of the pharynx increased 8.6 times in 30 days from 0.237 ± 0.03 to 2.049 ± 0.115 g with its greatest contribution to body weight at 8th day. The length of the pharynx increased 2.2 times in 30 days of age.

The mucous membrane of the roof of the pharynx had small caudally directed papillae which at the junction with the oesophagus formed a well defined transverse row. Caudal to the choanal slit was a narrow opening, the infundibular slit which lead into the tuber cinerium into which the two eustachian tubes opened.

Floor (Fig. 5).

Caudal to the base of the tongue, two pharyngeal papillae bearing numerous small papillae were present. The laryngeal mound was located in the floor of the pharynx. This was elongated, lozenge shaped and it blended smoothly with the pharyngeal floor. A transverse line of caudally pointed papillae was present at the caudal end of the inlet. A series of large caudally pointed papillae were observed in the midline caudal to the inlet. The rest of the mound caudal to the inlet had small caudally directed papillae

scattered over it. The rim of the inlet had one sagittal row of very small papillae. Rostral to the laryngeal fissure, few openings of the salivary glands were observed. The laryngeal mound of the ducklings showed an increase in length (6.3 mm to 27.8 mm) and width (3.8 mm to 14.3 mm) in day-old to 180 days of age (Fig. 24). Angle of the pharynx and lateral surface of the caudal part of the laryngeal mound also had very small openings of the salivary glands.

Histology.

Roof (Fig. 25).

The roof of the pharynx was lined by stratified squamous epithelium. The stratum corneum was relatively thick. The thickness of the epithelium decreased towards the junction with the oesophagus (Table 7). The epithelium was thin compared to the floor of the pharynx. The surface of the epithelium was rough and the superficial layers showed strong propensity to slough off. The dermal papillae were scanty and contained fine connective tissue fibres and capillaries. In oblique sections, they were represented as spaces containing red blood corpuscles. Many caudally directed, conical, pointed papillae with distinct lamina propria and covered by keratinised epithelium were observed on the mucosa. The mucous membrane was folded at the lateral angles of the pharynx.

The margin of the choanal slit was lined by stratified squamous epithelium on its external and internal surface.

The internal surface in addition contained many simple alveolar glands of holocrine nature. The glandular epithelium was formed of taller columnar cells with basal spherical nuclei. The ducts of the gland opened separately at the surface of slit through the surface epithelium. Within the choanal slit, a cavernous tissue covered by pseudostratified ciliated columnar epithelium was observed (Fig. 26). Numerous simple alveolar mucous glands of holocrine nature were observed within the epithelium. Several endothelial lined spaces contained blood cells, smooth muscle fibres and elastic fibres were present in the cavernous tissue. Lymphocytes were diffusely arranged below the epithelium.

The infundibular slit was lined by stratified squamous epithelium which was thickened at the edges of the slit bearing caudally directed pointed papillae. Lymphocytic aggregations were present beneath the epithelium (Fig. 27).

Lamina propria was composed of collagen and few elastic fibres, many blood vessels and nerves. Abundant lymphocytic aggregations were observed beneath the epithelium, especially at the choanal slit and infundibular slit and also in the submucosa close to the glands. Lymphocytes were also observed in diffuse forms. This lymphoreticular tissue formed the pharyngeal tonsil.

Herbst's and Grandry's corpuscles were not observed. Muscularis mucosa was absent.

Densely arranged branched tubuloalveolar mucous glands were observed in the submucosa. The connective tissue formed a capsule around the glands and contained blood vessels and nerves. The glands were lined by tall columnar cells with basal, spherical or angular nuclei. The glandular lumen was narrow, the duct lumen was large and lined a short distance by columnar cells and opened through the stratified squamous epithelium to the pharyngeal cavity. The lumen contained secretory materials and cell debris. The medial and lateral palatine glands were situated around the choanal slit and the ducts opened lateral to the choanal slit. The sphenopterygoid glands were present around the infundibular slit and the ducts opened lateral to the infundibular slit.

Below the glands, longitudinally oriented striated muscles were observed.

Floor.

The floor was lined by stratified squamous epithelium and had numerous pointed caudally directed papillae with a keratinised epithelium.

The laryngeal mound was covered by stratified squamous epithelium with numerous pointed caudally directed papillae covered by keratinised epithelium (Fig. 28). The inlet of the larynx was a narrow slit supported on either side by the arytenoid cartilages. The inlet was continued caudally by the laryngeal fissure, a narrow groove which extended to the

caudal group of papillae. The epithelium of the fissure was stratified squamous and had two large papillae bearing a few small papillae at its posteriormost end.

At the inlet, the stratified squamous epithelium changed abruptly into pseudostratified ciliated columnar epithelium with numerous simple tubular or alveolar mucous glands (Fig. 29). These glands were PAS positive. The length of the cilia ranged from 13 um to 26 um.

Lamina propria was thin and composed of collagen and elastic fibres, blood vessels and nerves. Lymphocytes occurred in nodular and diffuse forms. Lymphocytic nodules were observed at the transitional zone where the stratified squamous epithelium changed into pseudostratified ciliated columnar and also at the ventral median ridge of the cricoid cartilage.

Submucosa contained the laryngeal salivary glands (cricoarytenoid glands). The connective tissue of the submucosa formed a thin capsule around the glands. These glands were highly PAS positive similar to other salivary glands. At the anterior part of the larynx, they were smaller in size and just lateral to the arytenoid cartilages. At the middle part of the laryngeal mound, the glands were larger and situated more towards the lateral side of the arytenoid cartilage. At the level of the laryngeal fissure, few glands were observed just beneath the epithelium and the ducts opened into the fissure.

Glands at the angle of the pharynx were smaller and duct from each gland opened separately into the pharyngeal cavity.

The intrinsic muscles of the larynx were observed in the submucosa. The superficial intrinsic muscle was thick and longitudinally oriented under the mucosa which caused the roundness of the laryngeal mound. The deep intrinsic muscle was thin, vertically oriented and embracing the inlet of the larynx. Posterior to the inlet, the ends of the cricoid cartilage were connected by a transversely oriented striated muscle.

The cartilages of the larynx,were four in number. The cricoid cartilage was semicircular in cross-section and had a dorsal median prolongation. The paired arytenoid cartilages flanked the laryngeal inlet. The procricoid was dorsal and median in position. From eight days of age, they showed signs of ossification.

Oesophagus

Gross observations.

The oesophagus connected the pharynx to the proventriculus and was divided into the longer cervical part, the crop and the short thoracic part. The length, weight and diameter of the oesophagus at different ages and regions are shown in tables 8, 9, 10 and 11. The weight of the oesophagus and crop increased 55 times in 60 days from

0.225 ± 0.011 to 12.405 ± 0.534 g. The rate of increase was greatest between 45 and 60 days and the contribution to the body weight was a maximum of 1.2% at 8th day of age.

The length of the oesophagus increased 3.15 times at a progressive rate upto 30 days of age and thereafter the increase was at a slower rate and at 180 days of age the length of oesophagus was 32.33 ± 0.945 cm.

Cervical oesophagus.

The cervical oesophagus originated from the pharynx and was located in the midline dorsal to the trachea and larynx to which it was closely attached by connective tissue. Caudal to the fifth cervical vertebra, it inclined to the right side of the neck between the right jugular vein, vagus nerve and thymus dorsally and trachea ventrally. The auditus oesophagi was very wide and the lumen was more dialatable. The mucosa of the oesophagus showed many longitudinal folds. The cervical oesophagus showed a progressive increase in length from 3.25 ± 0.056 cm to 9.75 ± 0.54 cm upto 180 days of age. But a slight reduction was noticed at 120 days of age (Table 8).

Crop.

Immediately cranial to the thoracic inlet, the oesophagus showed a spindle shaped enlargement. In day-old ducklings it was not very distinct. As age advanced, the crop extended upto the level of bifurcation of the trachea (Fig. 30). The

wall of the crop was thick as that of the oesophagus but showed more number of longitudinal folds. Most of this oesophageal mucosal folds abruptly ended at the cranial part of the crop, but few extended throughout the length of the crop and even continued into the thoracic oesophagus. It was also observed that there were mucosal folds which were confined to the crop itself. The length of the crop increased progressively from 1.03 ± 0.076 cm at day-old to 14.67 ± 0.357 cm at 180 days of age (Table 8).

Thoracic oesophagus.

Thoracic oesophagus started at the bifurcation of the trachea (syrinx) and extended caudally dorsal to the trachea and base of the heart. It passed caudally dorsal to the cranial border of the left lobe of liver. Caudal to the third vertebral rib, it was found between the cranial thoracic air sacs extending to the medial surface of the left lobe of liver. Dorsally and ventrolaterally it was covered by cervical and clavicular air sacs. The thoracic oesophagus was shorter in length compared to the cervical oesophagus (Table 8).

The diameter at various regions of the oesophagus showed that the anteriormost part of the cervical oesophagus had greater diameter compared to other parts, barring crop, in all age groups of birds studied (Table 10). The average diameter of the cervical oesophagus was more than that of thoracic oesophagus (Table 11).

Histology.

The structure of the oesophagus anterior and posterior to crop was similar.

Cervical oesophagus (Fig. 31).

Cervical oesophagus showed about 6-7 primary and secondary longitudinal mucosal folds. The lumen was wider. The folds were broad and short with a rounded end at the anterior part whereas in the posterior portion the lumen was encroached by the longer folds with a pointed end (Fig. 32).

The mucosa was lined by a nonkeratinised stratified squamous epithelium with an irregular surface and it showed strong propensity to slough off. The thickness of the epithelium decreased towards the posterior part of the cervical oesophagus and ranged from 53 um to 226 um from day-old to 180 days of age. In day-old ducklings, the stratum cylindricum consisted of single layer of tall columnar cells. Dermal papillae were more at the anterior part.

The dense layer of lamina propria was composed of collagen fibres, many blood vessels and lymph vessels. Numerous oesophageal mucous glands were also observed (Fig.33). The glands were numerous at the auditus oesophagi. In day-old ducklings, they were simple tubular glands. By 8th day, the gland increased in size, number and became branched tubular. The tubules were lined by tall columnar cells with basal flat nucleus and acidophilic foamy cytoplasm. The tubules

opened into a central cavity from which it was drained by a wider duct. In the duct, the epithelium was low columnar to cuboidal and then changed to squamous epithelium which passed through the lining epithelium of the oesophagus and opened into the oesophageal lumen. The connective tissue of the lamina propria formed capsule around the glands and contained blood vessels. The lymphoid tissue occurred both in diffuse and aggregated forms just beneath the epithelium and frequently around the glands (Fig. 33).

Muscularis mucosa was absent. Submucosa was very thin and contained submucosal plexus.

The tunica muscularis consisted of inner longitudinal and outer circular layer of smooth muscle fibres (Fig. 34). The inner longitudinal muscle showed thickenings at the base of mucosal folds. In day-old ducklings this muscle entered a short distance into the folds in the anterior part of the oesophagus. Compared to the circular muscle, the thickness of the longitudinal muscle layer was one-third at the anterior part, half at the middle portion and half to one-third at the posterior part. The circular muscle layer was thick and composed of different fasciculi. Between the two muscle layers there was a thin layer of connective tissue containing blood vessels and nerve plexus. The thickness of the tunica muscularis increased with advancing age as well as towards the posterior part of the cervical oesophagus.

The outermost layer of tunica adventitia was consisted of very loose connective tissue with many blood vessels, nerves, adipose tissue and lymphatics.

The structure of the crop was similar to that of cervical oesophagus. The longitudinal mucosal folds averaged about ten numbers and were long and pointed in the middle part of the crop. Lateral branching of the longer folds were also observed.

The crop was lined by stratified squamous nonkeratinised epithelium and the thickness was reduced towards the posterior end. The thickness of the epithelium increased as age advanced and ranged from 40 um to 200 um. The epithelium was smooth in day-old ducklings. By eight days the epithelial surface became irregular with desquamation of surface epithelial cells. By 15 days, many microscopic papillae appeared on the surface epithelium. Basal layers of the epithelium were more basophilic. Dermal papillae were wider and fewer in day-old ducklings. As age advanced, the dermal papillae became thin, deeper and more in number.

The lamina propria was thin, dense, composed of collagen fibres and continued into the mucosal folds. Few simple tubular glands at one day old became branched tubular by eight days of age. The lymphoid tissue occurred both in diffuse and aggregated forms and more in the middle zone of the crop especially around the glands. Many heterophils were

also observed in the lamina propria. The connective tissue formed capsule around the glands.

The muscularis mucosa and submucosa were absent. The tunica muscularis consisted of inner longitudinal and outer circular layer of smooth muscle fibres. The longitudinal muscle showed thickenings at the base of the folds. The thickness was half of that of circular muscle layer upto eight days of age and from 15 days onwards, the thickness was only one-third of that of circular muscle.

Outer circular muscle was divided into three to four bundles which were separated by thin layer of connective tissue containing blood vessels. The inner longitudinal and outer circular layer of smooth muscles were separated by a thin connective tissue layer containing blood vessels and nerve plexuses.

The thickness of the tunica muscularis increased with age and ranged from 130 um to 600 um.

outermost layer of tunica adventitia contained loose connective tissue with blood vessels and nerves.

Thoracic oesophagus.

The structure of the thoracic oesophagus was similar to that of cervical oesophagus and crop. The longitudinal mucosal folds were wider and shorter and more than that of cervical oesophagus. Both primary and secondary folds were observed.

The stratified squamous non-keratinised epithelium showed a decrease in the thickness towards the posterior part and an increase with advancing age. In day-old ducklings the surface epithelium was smooth and became irregular by eight days. From 15th day onwards many microscopic papillae were observed on the epithelial surface (Fig. 35). Towards the posterior part, the dermal papillae and microscopic papillae were more deeper and more in number.

The lamina propria was more extensive and composed of collagen fibres. The simple tubular mucous glands of day-old ducklings became branched tubular by eight days and were few in the anterior part. The glands were more towards the posterior part of the thoracic oesophagus. Lymphoid tissue occurred both in diffuse and nodular forms. Lymphoid nodules were more towards the posterior part especially around the glands.

A well developed oesophageal tonsil was observed at the junction of thoracic oesophagus and proventriculus. At this junction, the stratified squamous epithelium of the oesophagus changed abruptly to simple columnar epithelium of the proventriculus. The oesophageal tonsil had a follicular nature. The stratified squamous epithelium showed many invaginations. Numerous simple tubular glands lined by low columnar to cuboidal cells with spherical vesicular nuclei and basophilic basal and acidophilic apical cytoplasm were

present in the lamina propria immediately below the surface epithelium (Fig. 36). Underlying the epithelium and surrounding the invaginations, diffusely arranged lymphoid tissue was observed upto 60 days of age. The lymphoid tissue was present around the mucosal crypts and in many places the epithelium was flattened and within this layer of epithelium many lymphocytes were present as intraepithelial lymphocytes (Fig. 37). The lumen showed lymphocytes and cell debris (Fig. 38). The oesophageal tonsil was well supplied with many blood vessels. From 75 days onwards, in addition to dense lymphoid tissue, lymph nodules were observed in the tonsil; germinal centres were evident in certain nodules (Fig. 36). In 150 and 180 day-old ducks, diffuse lymphatic tissue surrounded the lymphatic nodules which frequently possessed germinal centres. Connective tissue condensation separated the lymphoid tissue from surrounding structures and attempted encapsulation was evident at some areas. Connective tissue septa was seen extending between the nodules (Fig. 39).

Muscularis mucosa and submucosa were absent. The tunica muscularis consisted of inner longitudinal and outer circular layer of smooth muscle fibres. The longitudinal muscle showed thickenings at the base of the folds and the thickness was nearly half of that of circular muscles. The circular muscle was arranged in layers separated by thin layers of connective tissue. The thickness of the tunica muscularis increased with age.

The outermost layer of serosa consisted of loose connective tissue with many blood vessels, lymph vessels and nerves.

Proventriculus (glandular stomach)

Gross observations.

The proventriculus was an elongated organ with a narrow cranial and wider caudal ends. The long axis was directed craniocaudally somewhat ventral and to the left of the median plane. The left ventral surface was close to the liver especially to the left lobe on which it produced an impression. The right side was caudodorsally related to the spleen. Cranial part of the dorsal surface was separated from the ventral surface by cranial thoracic air sacs. Caudal part of the dorsal surface was related to ileum and caeca. It extended in the male from fourth thoracic to sixth lumbosacral vertebra. In female it reached upto the third lumbosacral vertebra. The proventriculus was connected to the craniodorsal sac of the gizzard by a narrow transitional zone, the isthmus, which showed a constriction at the dorsal aspect.

The wall of the proventriculus was thick. The mucous membrane showed numerous small papillae containing the openings of the proventricular gland. Proventricular glands were unilobular and each gland opened separately on the surface. Papillae were absent at the isthmus. Mucosal folds

of the oesophagus were found to terminate at the oesophageo-proventricular junction.

The lengths and weights of the proventriculus at different ages are shown in table 12. The weight of the proventriculus increased 17.6 times from 0.28 ± 0.01 g in day-old to 4.927 ± 0.144 g at 45 days of age and the maximum rate of growth was observed between 30 and 45 days. The contribution of proventriculus to body weight was maximum at eighth day (1.1%) while it was only 0.35% at 180 days. The length of the proventriculus increased 3.8 times in 75 days from 1.5 ± 0.66 cm to 5.72 ± 0.569 cm. The length had a significant positive correlation with weight (r = 0.9731). The middle portion had the greatest diameter and the posterior part was wider than its anterior part at all age groups (Table 13).

Histology.

The oesophago-proventricular junction.

The oesophageo-proventricular junction was a short zone which showed structures of both oesophagus and proventriculus. The longitudinal mucosal folds of the oesophagus terminated at this junction. The mucosa of the proventriculus was thrown into folds of varying height. The lining epithelium changed abruptly from stratified squamous of the oesophagus to simple columnar epithelium of the proventriculus, showing an intense PAS positive reaction.

The lamina propria was heavily infiltrated with lymphoid tissue and contained many blood and lymph vessels. Few oesophageal mucous glands were also present in the lamina propria.

From the inner longitudinal muscle of the oesophagus, strands of smooth muscle passed inwards towards the mucosa over the glandular lobules and seen mixed with the collagen fibres of the lamina propria.

The tunica muscularis became thicker and showed three layers. The thin inner longitudinal layer showed thickenings at the base of the gland, a very thick circular muscle forming the bulk of the musculature; a very thin compact layer of isolated longitudinal strands of muscle which appeared to begin from the oesophago-proventricular junction. Thin connective tissue layers were present between the muscle layers.

outermost layer had mainly loose connective tissue and contained many blood and lymph vessels and nerves and it was covered by a layer of serosa.

The proventriculus.

The mucosal lining of the proventricular lumen was thrown into folds of varying height which ranged from 80 um to 266 um. The folds were the plicae and the intervening depressions were the sulci. The surface epithelium of the mucosa consisted of columnar cells and the height of the

epithelium diminished towards the base of the sulci (Fig.40). Towards the basal region, the cells were cuboidal in shape. The nuclei were oval to spherical and vesicular. The cytoplasm was foamy and at the anterior and posterior parts of the proventriculus, it showed a supranuclear PAS positive reaction which became weak posteriorly.

From the base of the sulci many simple tubular glands extended into the lamina propria (Fig. 41). They were lined by low columnar cells with large, spherical, basal, vesicular nuclei. They showed a basophilic basal and acidophilic apical cytoplasm. The lumen of the gland was very narrow. Fat vacuoles were observed in the epithelial cells and in the superficial proprial glands. The lamina propria was composed only of collagen fibres. Few strands of smooth muscles were also observed beneath the epithelium mixed up with the connective tissue. The lymphoid tissue occurred in both diffuse and aggregated forms. The connective tissue of the lamina propria formed a thin capsule around the proventricular glands and contained many blood vessels and nerves.

The proventricular glands consisted of unilobular compound tubular glands. Only a single row of lobules were observed in day-old ducklings. The glandular zone was thickest at the middle portion of the proventriculus. In the day-old ducklings, the lobules were elongated in the anterior and middle part of the proventriculus whereas in

the posterior portion they were small in size and polygonal in shape. From 15 days onwards, most of the gland lobules were round or polygonal in shape. The size of the lobule was largest at the middle portion of the proventriculus than at its anterior and posterior part.

Each lobule consisted of numerous straight tubules radiating from a central cavity (Fig. 42). Between the tubules there were blood capillaries. The tubule was lined by a simple epithelium consisting of cells which made contact with adjacent cells towards their base and had a dentate appearance. The cells were low columnar to cuboidal in shape. Most of the cells bulged into the lumen and showed intense acidophilia of the cytoplasm and condensed oval nuclei towards their bases. Some cells were tall columnar with a spherical vesicular nucleus in the centre and less acidophilic cytoplasm. Between the basement membrane and glandular epithelium, few small cells with dark nuclei were also observed.

The tubules opened into the central cavity from which it was drained by a duct to the lumen of the proventriculus. The central cavity and the duct were lined by tall columnar cells with spherical nucleus and foamy cytoplasm (Fig. 43). They were positive for PAS reaction.

The muscularis mucosa as a separate distinct layer was not seen and the submucosa was not observed.

The tunica muscularis consisted of an inner and an outer longitudinal and a middle thick layer of circular smooth muscle fibres (Fig. 44). The thickness of the tunica muscularis showed an increase with advancing age. The tunica muscularis was thicker at the posterior end. A thin layer of connective tissue between the muscle layers contained many blood vessels and nerve plexuses.

The outermost layer of serosa consisted of loose connective tissue with many blood vessels, lymph vessels and nerves, in addition to mesothelial investment.

Isthmus.

The height of the mucosal folds gradually decreased and the plicae gradually replaced by gizzard glands. The surface was covered with a mixture of secretion from the proventricular and gizzard glands. The proventricular secretion showed PAS positive mucoid material and the gizzard secretion presented a thin layer of koilin material. At this portion, the proventricular glands terminated abruptly. The lamina propria contained straight tubular glands lined by tall columnar cells with spherical, basal, vesicular nuclei. These glands resembled that of gizzard glands. As the isthmus merged with the gizzard, the inner longitudinal smooth muscle layer merged with the circular layer to form the muscles of the craniodorsal sac of the gizzard. The outermost layer of longitudinal muscle was not observed at the isthmus.

The gizzard/muscular stomach

Gross observations.

The gizzard was shaped like a biconvex lens and almost filled the left lower quadrant of the body cavity. It presented two convex lateral surfaces connected by two ridges, one dorsal and one ventral. It also showed two blind sacs, craniodorsal and caudoventral sacs. The proventriculus opened at the left side of the craniodorsal blind sac and the duodenum took off from its right surface.

The gizzard was related to the dorsal surface of the left lobe of the liver and partly in contact with the right lobe (Fig. 30). Cranially and to the right, it was related to the spleen, and caudally and to the right to the jejunum and the caeca. Its ventral contour reached the ventral abdominal wall. The ventral part was close to the descending and ascending parts of the duodenum.

The dark coloured smooth muscle of the muscular stomach was well developed and separated into two lateral muscles (dorsal and ventral) of the body and two intermediate muscles (craniodorsal and caudoventral) of the blind sacs. All these muscles were attached to the extensive aponeurosis in the right and left walls. The mucosa was strongly adherent to the musculature.

The weight and length of the gizzard are shown in table 14. The weight of the gizzard increased at a

progressive rate from 1.146 ± 0.062 g in day-old to 54.525 ± 4.013 g at 60 days of age. A maximum weight of 58.317 ± 4.575 g was recorded at 75 days of age (Fig. 45). The gizzard contributed a maximum of 6.5% of the body weight at 22 days of age and in later stages the contribution was less and at 180 days it was only 3% of the body weight (Fig. 46). The weight of the gizzard remained static from 120 days and above (average of 50 g) which is about 3.1% of the body weight.

The gizzard had a greater dorso-ventral diameter except in day-old ducklings in which the reverse was true. The craniccaudal and dorso-ventral diameter and thickness was highest at 75 days of age (Table 15).

The weight had a correlation coefficient r = 0.9795 with cranio-caudal diameter and r = 0.9694 with dorso-ventral diameter.

Histology.

The gizzard was covered externally by a serous coat containing many blood vessels, nerves and rich in adipose tissue. Below the serosa was a tendinous layer. It consisted of closely packed parallel collagen bundles with elongated, flattened fibroblasts lying amongst them. The tendinous layer was thickest at the tendinous aponeurosis. The centre of the aponeurosis was devoid of muscle fibres. It appeared from the observations that wherever the tendon

was thick, the underlying muscle layers were thin and conversely at the dorsal and ventral ridges of the gizzard, the tendon was thin but the muscle layers were thick. The thickness of the tendinous layer was 293 um in day-old ducklings and it went upto 933 um in 180 day-old ducks. The tendinous layer was absent in the craniodorsal and caudoventral blind sacs.

Below the tendinous layer was the gizzard smooth muscle. The lateral muscle consisted of a single layer of circularly arranged smooth muscle. The muscle fibres were grouped together into extensive interlocking small bundles with frequent anastomosis between the adjacent bundles (Fig. 47). The muscle bundles were separated by thin layer of connective tissue formed of collagen fibres arranged perpendicular to the direction of the muscle fibres. Blood vessels and nerve plexuses were seen in the connective tissue. In the young ducklings, the muscle bundles were loosely arranged whereas in the adult birds they were very compact. The muscle layer was directly attached to the tendon at right angles (Fig. 48).

In the craniodorsal and caudoventral sacs, the muscle was arranged in two layers, the inner longitudinal and outer circular muscle layers separated by connective tissue fibres containing blood vessels and nerve plexuses (Fig. 49). In certain regions of the caudoventral sac the inner layer of the tunica muscularis detached a thin layer of muscle that

extended through the lower part of the submucosa for a short distance and then disappeared (Fig. 50).

The submucosa consisted of a dense layer of connective tissue formed of collagen fibres, many blood vessels and submucosal plexus near the glands.

The lamina propria contained the gizzard glands which penetrated down through its thickness to the level of submucosa. The proprial tissue composed of collagen fibres was sparse and was seen between the glands. Towards the fundic portion of the gland the interstitial tissue presented small blood vessels.

Gizzard gland (Figs. 51, 52 and 53).

The gizzard glands were simple tubular glands. Some glands showed branching at its basal portion. Each gland consisted of a distended fundus, long body and a neck which opened into the crypt of the epithelium. Three types of cells were observed in the glandular epithelium.

The chief cell

In the lower part of the gland the chief cells were low columnar to cuboidal with relatively large, spherical, basal, vesicular nuclei. Some cells showed indented nuclei. The cells became flatter towards the neck portion of the gland. The cytoplasm was dense granular with indistinct cell borders. The cells rest on an intact basement membrane. The

free surface of the cell showed PAS positive striated border.

The cytoplasmic granules were demonstrated with phospho-tungstic acid-haematoxylin stain but they were PAS negative (Figs. 54, 55). In the fundic portion of the gland these granules were distributed uniformly throughout the cytoplasm. Slightly higher up the gland, the granules were numerous in the luminal part. At the fundus, the lumen was free of secretory material. The secretory material was seen in the lumen of the body and neck regions and was stained with PTAH. At this part the cytoplasmic granules were confined to the basal portion of the cell.

In trichrome staining, the cytoplasmic granules of the chief cell took pink colour. In the fundic portion of the gland the granules were concentrated at the luminal part of the cytoplasm and the lumen was free of secretory material. In the body and neck region of the gland, the lumen contained secretory material as thick rods where the cytoplasm was free of secretory granules (Fig. 56).

The basal cell.

The basal cells were few in number and observed at the fundic portion of the gland (Fig. 53). These cells were more at the craniodorsal and caudoventral blind sacs. They were large cuboidal cells with central, spherical, vesicular nucleus with a single nucleolus and pale cytoplasm.

The intermediate cell.

In the basal portion of the gland there were few cells which had the structural features of both basal and chief cells. They were large cells with vesicular nuclei and with single nucleolus and moderately granular cytoplasm (Fig. 53).

The surface epithelium.

The surface epithelium showed small papillary projections forming pits or crypts and composed of tall columnar cells. The apex of the cell bulged into the lumen and showed striated border. The nucleus was basal, spherical or oval and vesicular. In Haematoxylin and Eosin staining, the cytoplasm showed two zones, a basophilic basal zone containing the nucleus and an acidophilic apical zone. In PTAH staining the basal cytoplasm showed granules similar to that of the chief cells. The apical cytoplasm showed a PAS positive reaction (Fig. 55).

The core of the papillary projections of the surface epithelium consisted of connective tissue cells and capillaries. The cells at the summit of the papillary projections showed pyknosis and cytoplasmic degeneration. These degenerated cellular debris were found between the arrays of vertical columns.

The thickness of the glandular layer was more at the lateral wall of the gizzard than at the craniodorsal and caudoventral blind sacs (Table 16).

The gizzard lining.

The secretions of the gizzard glands formed a thick layer lining the lumen of the organ. The thickness was more at the lateral wall of the gizzard (Table 16). This layer had a laminated appearance in direction both parallel and perpendicular to the surface of the gizzard mucosa (Fig. 57). It consisted of arrays of vertical columns secreted by the tubular glands which showed strong PAS positive reaction and a matrix produced by the surface cells which deposited periodically to form a pattern of horizontal laminae and showed weak to negative PAS reaction (Fig. 55). In the caudoventral sac between the horizontal laminae, there were large cavities containing groups of cell debris (Fig. 58) and in the craniodorsal sac, the cavities were smaller in size. In the lateral wall of the gizzard the secreted material was uniformly spread out between the vertical rods. This layer was acidophilic in nature in H & E staining and it took yellow colour in Van Gieson's staining (Fig. 59).

The lumen of the fundic part of the gland was generally free of secretions but occasionally filamentous material was noticed. In the body and neck regions of the gland, the secretions were seen as thick rods and projected from the glandular lumen through the crypts and then vertically as columns reaching the entire thickness of the covering layer to its free surface to form a dentate surface (Gizzard teeth).

Response of secretory products of gizzard epithelium to various stains is shown in Table 17 (Fig.60, 61 and 62).

The gizzard-duodenal junction.

The gizzard-duodenal junction was a narrow zone characterized by the villus character of the mucosa and by the coiling of the tubular glands in the lamina propria. At the point where the duodenum leaves the gizzard, the main mass of the gizzard musculature narrows down rapidly and the muscularis mucosa originated from the inner longitudinal muscle layer of the craniodorsal sac. The gizzard lining became thin and fragmented and rapidly lost. The point of separation of these two organs was delineated by a constriction of the muscularis mucosa forming a fold of the muscularis and the tunica propria (Fig. 63). The fold on the ventral wall was thick than at its dorsal wall. Anterior to the fold, the depth of the crypt increased until the overall depth of the gland and the crypts were the same as that of the duodenal villi. Immediately posterior to the fold, the duodenal villi and the crypts of Lieberkuhn in the lamina propria were observed. Dense and nodular form of lymphoid tissue was observed anterior and posterior to the fold (Fig. 64).

The duodenal villi had the shape of a spatula. Both large and small villi were observed. The villus was lined by tall columnar cells with striated border. The nucleus was spherical, basal and vesicular. The cytoplasm was

granular and also showed vacuoles. The core of the villus consisted of smooth muscle cells, fibroblasts, leucocytes and red blood corpuscles.

The lamina propria was heavily infiltrated with lymphoid tissue. It contained many blood vessels and coiled tubular glands of the crypts (Crypts of Lieberkuhn). The glands were lined by tall columnar cells with basal, spherical nuclei. The cytoplasm was basophilic at the basal part and acidophilic at the apical portion. The luminal border had a striated appearance. Some cells of the gland showed an apical PAS positive reaction.

Few goblet cells were observed between the columnar cells of the villi and the gland. Between the columnar cells of the gland and the villi large round cells with pale cytoplasm were also observed. Small round cells with irregular dark nuclei with globular inclusions were seen in the interstitium of the intestinal villi (Fig. 65).

The muscularis mucosa consisted of longitudinally arranged smooth muscle fibres.

The submucosa was very thin and in some regions it was absent. Submucosal plexus was observed at this junction. Brunners glands were not observed in the submucosa.

The tunica muscularis consisted of inner thick circular and outer thin longitudinal smooth muscle fibres. Between these two layers, a thin layer of connective tissue

containing many blood vessels and nerve plexus were observed.

The outermost layer consisted of loose connective tissue with many blood vessels and nerves and invested with a layer of serosa.

Blood supply

Mouth cavity and pharynx.

The roof of the pharynx and the mouth cavity were supplied by the branches of the maxillary artery and the floor of the pharynx by descending oesophageal, laryngeal, lingual and sublingual branches of the mandibular artery.

The blood from the pharynx and the oral cavity were drained into the rostral cephalic vein and the interjugular anastomosis.

Oesophagus.

The oesophagus was supplied by the oesophageal branches of the vagal and mandibular arteries, descending oesophageal artery (branch of oesophagotracheal artery), ascending oesophageal artery, oesophagotracheobronchial (branch of carotid artery) artery and oesophageal branch of the aorta.

The left ascending oesophageal artery arose from the vagal artery and crossed towards the right, extended cranially between the trachea and oesophagus and supplied the cervical oesophagus and crop. The right ascending oesophageal artery originated from the common carotid artery

opposite to the cranial border of the thyroid, extended cranially and supplied the lateral wall of the crop and the oesophagus.

The oesophageal artery originated from the aorta near the beginning of the coeliac artery, entered the wall of the thoracic oesophagus close to the hilus of the lung and supplied the thoracic oesophagus.

The common carotid artery was given the oesophagotracheobronchial artery near the caudal border of the thyroid and supplied the caudal part of the trachea, syrinx, bronchi, thoracic oesophagus, cranial part of the proventriculus and thyroid gland (Fig. 66).

Branches of the mandibular artery supplied the cranial part of the oesophagus and pharynx while the descending oesophagotracheal branch supplied to the oesophagus and trachea.

The cervical oesophagus and crop were drained by small oesophageal veins extending cranially and caudally joining the jugular veins. The thoracic oesophagus was drained directly by the cranial venacavae and also by the veins of the glandular stomach.

Proventriculus and gizzard.

The proventriculus and gizzard received blood supply from the coeliac artery (Fig. 67). The coeliac artery

coursed caudoventrad between the proventriculus and the right lobe of liver. The dorsal proventricular artery arose from the coeliac artery and continued on the dorsal surface of the proventriculus on to the dorsal surface of the gizzard as the dorsal gastric artery.

The coeliac artery was divided into large right and small left rami at the cranial pole of the spleen. The left ramus of the coeliac artery progressed on the right side of the proventriculus to its junction with the gizzard, gave the left hepatic artery, ventral proventricular artery, a series of ventral gastric arteries to the ventriculus and the pyloric artery to the pylorus. The left ramus continued on to the left side of the gizzard as the left gastric artery.

Right ramus of the coeliac artery continued as the right gastric artery.

The venous drainage of proventriculus by the cranial and caudal proventricular veins. Dorsal proventricular vein was absent.

The blood from the muscular stomach was drained by the right gastric vein which opened into right hepatic portal vein. The cranioventral and left aspect of the gizzard were drained by the ventral and left gastric veins which joined the left hepatic portal vein.

Nerve supply

The oral cavity and pharynx were innervated by branches of the glossopharyngeal and hypoglossal nerves.

The oesophageal plexus was formed on the cervical oesophagus by the oesophageal branches of the glossopharyngeal nerve and the descending branches of the hypoglossal nerve. The oesophageal branches of the glossopharyngeal nerve along with the recurrent branches of the vagi near the crop supplied the oesophagus and crop. The thoracic oesophagus was innervated by the branches of the recurrent nerves and the pulmonoesophageal branches of the vagi, oesophageal plexus and nerves from the coeliac plexus.

The proventriculus was innervated by the direct branches of the vagus and from the recurrent nerves of the vagus. Those from the main trunk of the vagus reached the ventral surface of the proventriculus. Dorsal to the proventriculus, the right and left vagi exchangedtheir fibres and supplied the dorsal part of the proventriculus.

Both vagi were distributed to the muscular stomach. Right vagus innervated mainly the ventral part and left vagus the dorsal part of the gizzard.

Tables

Table 1. Body weight of ducklings at different ages. Mean ± S.D.

Age in days	Body weight (g)
1	34.33 ± 0.80
8	44.66 ± 3.48
15	86.00 ± 9.57
22	162.33 ± 18.77
30	326.33 ± 25.45
45	784.17 ± 25.45
60	1246.66 ± 62.91
75	1661.66 ± 67.00
90	1708.30 ± 80.88
120	1600.00 ± 51.05
150	2023.30 ± 53.64
180	1611.66 ± 36.55

Table 2. Average length and width of the upper bill and hard keratin at different ages

Age in days	Upper bill		Hard keratin	
	Length (mm)	Width (mm)	Length (mm)	Width (mm)
1	15.8	8.0	5.7	5.0
8	24.2	12.3	7.0	6.5
15	27.0	13.4	7.3	6.9
22	33.2	14.6	8.3	7.4
30	40.7	17.9	8.3	7.6
45	51.0	23.6	9.5	7.7
60	58.0	24.8	10.6	8.8
75	64.0	25.6	11.2	9.7
90	70.5	26.3	11.7	10.4
120	71.0	27.7	11.9	11.5
150	74.6	27.2	12.5	11.6
180	75.0	27.6	14.0	11.6

Table 3. Average length of the choanal slit at different ages

Age in days	Anterior narrow part (mm)	Posterior wider part (mm)	Total (mm)
1	1.6	6.0	7.6
8	3.2	7.0	10.2
15	4.0	8.3	12.3
22	4.5	9.6	14.1
30	5.7	11.5	17.2
45	6.9	14.5	21.4
60	7.6	15.0	22.6
75	8.3	15.2	23.5
90	9.0	15.5	24.5
120	9.8	16.0	25.8
150	10.6	16.5	27.1
180	11.0	16.8	27.8

Table 4. Length and weight of the tongue at different ages (Mean ± S.E.)

Age in days	Length (cm)	Weight (g)
1	1.50 ± 0.03	0.142 ± 0.003
8	1.85 ± 0.07	0.319 ± 0.03
15	2.25 ± 0.08	0.556 ± 0.04
22	2.60 ± 0.08	0.994 ± 0.06
30	3.38 ± 0.06	1.937 ± 0.06
45	4.35 ± 0.11	3.253 ± 0.04
60	5.23 ± 0.09	4.820 ± 0.19
75	5.43 ± 0.17	5.503 ± 0.32
90	5.45 ± 0.14	5.320 ± 0.40
120	5.48 ± 0.13	5.498 ± 0.25
150	5.92 ± 0.15	6.070 ± 0.20
180	6.00 ± 0.18	5.932 ± 0.33

Table 5. Thickness of the tongue epithelium (um)

Mean ± S.D.

Age in days	Anterior		Middle		Posterior	
	Dorsal	Ventral	Dorsal	Ventral	Dorsal	Ventral
1	196.6 ± 6.6	106.6 ± 3.6	194.6 ± 9.9	127.9 ± 7.6	137.3 ± 7.6	79.9 ± 11.2
8	245.3 ± 2.6	146.6 ± 2.4	206.6 ± 4.4	130.6 ± 13.3	136.6 ± 11.1	129.9 ± 11.9
15	253.3 ± 4.3	199.9 ± 5.9	223.3 ± 6.6	166.6 ± 7.3	167.9 ± 13.3	133.3 ± 6.6
22	333.2 ± 3.6	239.9 ± 6.2	259.9 ± 13.3	226.6 ± 7.9	181.3 ± 14.6	166.6 ± 9.3
30	339.9 ± 9.3	253.3 ± 5.3	323.9 ± 7.5	243.9 ± 10.6	247.9 ± 9.9	230.6 ± 6.3
45	353.2 ± 13.6	279.9 ± 8.6	326.6 ± 4.3	323.3 ± 6.6	813.3 ± 7.9	233.3 ± 9.3
60	373.2 ± 11.7	313.3 ± 6.6	353.2 ± 6.6	333.3 ± 13.3	337.3 ± 4.6	293.3 ± 4.6
75	399.9 ± 6.6	350.6 ± 6.7	373.2 ± 13.3	337.3 ± 11.3	373.2 ± 5.6	306.6 ± 8.6
90	373.2 ± 7.5	269.9 ± 10.6	366.6 ± 4.3	319.9 ± 4.6	363.9 ± 8.3	279.9 ± 9.9
120	379.9 ± 5.3	270.6 ± 7.6	413.2 ± 8.6	333.6 ± 8.6	399.9 ± 6.6	319.9 ± 6.8
150	386.6 ± 8.6	293.3 ± 3.4	474.6 ± 5.3	399.9 ± 6.6	461.2 ± 7.9	339.9 ± 9.3
180	367.9 ± 13.3	270.6 ± 16.6	346.6 ± 14.6	336.6 ± 14.6	386.6 ± 5.9	323.9 ± 10.6

Table 6. Length and weight of the pharynx at different ages (Mean ± S.E.)

Age in days	Length (cm)	Weight (g)
1	0.93 ± 0.049	0.237 ± 0.03
8	1.00 ± 0.045	0.428 ± 0.039
15	1.28 ± 0.048	0.676 ± 0.076
22	1.53 ± 0.033	1.010 ± 0.064
30	2.00 ± 2.049	2.049 ± 0.115
45	2.40 ± 0.082	3.682 ± 0.084
60	2.85 ± 0.081	4.761 ± 0.337
75	3.13 ± 0.154	5.445 ± 0.436
90	2.92 ± 0.055	5.206 ± 0.445
120	2.83 ± 0.128	5.770 ± 0.437
150	2.97 ± 0.033	5.887 ± 0.216
180	2.67 ± 0.105	4.964 ± 0.343

Table 7. Pharyngeal roof - thickness of the epithelium at different ages (Mean ± S.E.)

Age in days	Anterior (um)	Posterior (um)
1	66.65 ± 0.0	66.65 ± 0.00
8	102.64 ± 27.7	79.98 ± 13.3
15	127.97 ± 11.86	103.30 ± 6.67
22	162.60 ± 11.2	122.60 ± 17.3
30	186.62 ± 0.0	159.96 ± 0.0
45	219.95 ± 7.7	176.62 ± 6.6
60	226.61 ± 9.3	186.62 ± 9.3
75	266.60 ± 2.0	230.60 ± 15.3
90	288.86 ± 19.99	248.87 ± 15.3
120	296.59 ± 22.6	253.27 ± 31.59
150	266.60 ± 6.4	226.60 ± 8.2
180	226.60 ± 7.7	213.28 ± 6.7

Table 8. Length of the oesophagus at different ages (Mean ± S.E.)

Age in days	Cervival oesophagus (cm)	Crop (cm)	Thoracic oesophagus (cm)	Total (cm)
1	3.25±0.056	1.03±0.076	1.42±0.07	5.70±0.089
8	4.18±0.285	1.63±0.12	1.97±0.182	7.78±0.464
15	4.68±0.265	2.38±0.199	2.65±0.205	9.72±0.564
22	5.70±0.69	3.75±0.28	3.85±0.34	13.22±1.05
30	7.20 ±0.31	6.17±0.167	4.62±0.33	17.98±0.589
45	9.42±0.56	7.25±0.281	6.45±0.457	23.12±0.653
60	9.83±0.573	11.08±0.83	6.50±0.46	27.42±1.07
75	10.20±0.622	12.50±0.922	7.20±0.436	29.90±1.22
90	10.22±0.425	12.42±0.757	7.50±0.258	30.13±1.002
120	9.52±0.607	12.67±0.494	7.23±0.46	29.42±0.514
150	11.00±0.465	13.00±0.885	7.08±0.396	30.08±1.234
180	9.75±0.54	14.67±0.357	7.92±0.436	32.33±0.945

Table 9. Weight of the oesophagus and crop at different ages (Mean ± S.E.)

Age in days	Oesophagus and crop (g)
1	0.225 ± 0.011
8	0.542 ± 0.066
15	0.856 ± 0.084
22	1.744 ± 0.165
30	3.414 ± 0.304
45	7.192 ± 0.16
60	12.405 ± 0.534
75	14.802 ± 0.858
90	12.616 ± 0.736
120	11.544 ± 0.575
150	13.351 ± 0.717
180	14.047 ± 0.133

Table 10. Diameter of the oesophagus at different ages (Mean ± S.E.)

Age in days	Cervical oesophagus (mm)			Crop (mm)			Thoracic oesophagus (mm)		
	Anterior	Middle	Posterior	Junction of cervical oesophagus	Middle	Junction of thoracic oesophagus	Anterior	Middle	Posterior
1	3.87 ±0.22	2.43 ±0.08	2.38 ±0.101	2.35 ±0.118	2.68 ±0.17	2.45 ±0.16	2.2 ±0.103	2.33 ±0.092	2.47 ±0.061
8	4.25 ±0.145	3.2 ±0.24	3.22 ±0.235	3.3 ±0.208	3.98 ±0.319	2.98 ±0.219	2.65 ±0.226	2.45 ±0.143	2.43 ±0.149
15	3.8 ±0.246	3.52 ±0.151	4.216 ±0.199	4.7 ±0.229	4.95 ±0.235	3.87 ±0.229	3.03 ±0.147	2.68 ±0.105	3.17 ±0.247
22	5.2 ±0.35	4.57 ±0.198	5.08 ±0.318	5.63 ±0.428	6.55 ±0.442	5.17 ±0.322	4.9 ±0.338	3.53 ±0.368	3.63 ±0.283
30	6.78 ±0.503	5.08 ±0.17	6.15 ±0.201	6.7 ±0.389	8.6 ±0.855	7.22 ±0.517	5.983 ±0.409	4.68 ±0.285	4.1 ±0.342
45	8.817 ±0.127	7.283 ±0.483	8.23 ±0.528	9.38 ±0.859	12.32 ±0.902	9.42 ±0.687	7.95 ±0.741	6.27 ±0.36	5.483 ±0.257
60	8.9 ±0.298	7.5 ±0.469	8.48 ±0.363	9.37 ±0.482	13.47 ±0.62	9.05 ±0.352	7.5 ±0.262	5.783 ±0.312	5.65 ±0.274
75	8.13 ±0.413	6.37 ±0.364	7.42 ±0.501	8.95 ±0.78	12.68 ±0.658	8.48 ±0.35	6.5 ±0.416	5.88 ±0.239	5.62 ±0.308
90	8.18 ±0.266	6.683 ±0.346	7.6 ±0.611	8.32 ±0.604	13.25 ±0.716	8.63 ±0.564	6.72 ±0.229	5.567 ±0.248	4.95 ±0.256
120	9.08 ±0.573	7.32 ±0.302	7.783 ±0.462	8.57 ±0.454	12.67 ±0.635	8.33 ±0.352	7.12 ±0.219	6.42 ±0.154	6.45 ±0.377
150	8.88 ±0.602	7.15 ±0.429	7.63 ±0.539	8.42 ±0.36	14.1 ±1.34	7.7 ±0.276	6.6 ±0.289	6.12 ±0.264	6.27 ±0.298
180	9.5 ±0.543	7.63 ±0.398	8.35 ±0.535	9.9 ±0.359	14.55 ±1.39	8.37 ±0.259	6.98 ±0.443	5.9 ±0.267	6.6 ±0.339

Table 11. Average diameter of the cervical and thoracic oesophagus at different ages (Mean ± S.E.)

Age in days	Cervical oesophagus (mm)	Thoracic oesophagus (mm)
1	2.89 ± 0.13	2.30 ± 0.09
8	3.56 ± 0.21	2.51 ± 0.46
15	3.85 ± 0.60	2.96 ± 0.17
22	4.95 ± 0.29	4.02 ± 0.33
30	6.00 ± 0.29	4.92 ± 0.35
45	8.11 ± 0.38	6.57 ± 0.45
60	8.29 ± 0.38	6.31 ± 0.28
75	7.30 ± 0.43	6.00 ± 0.32
90	7.49 ± 0.41	5.75 ± 0.24
120	8.06 ± 0.45	6.66 ± 0.25
150	7.89 ± 0.52	6.33 ± 0.28
180	8.49 ± 0.49	6.49 ± 0.35

Table 12. Length and weight of the proventriculus at different ages (Mean ± S.E.)

Age in days	Length (cm)	Weight (g)
1	1.50 ± 0.68	0.28 ± 0.01
8	1.60 ± 0.146	0.493 ± 0.064
15	2.17 ± 0.112	0.927 ± 0.119
22	2.48 ± 0.180	1.589 ± 0.193
30	3.22 ± 0.142	2.570 ± 0.124
45	3.97 ± 0.033	4.927 ± 0.144
60	4.46 ± 0.133	5.393 ± 0.234
75	5.72 ± 0.569	5.638 ± 0.435
90	5.25 ± 0.250	5.274 ± 0.396
120	4.57 ± 0.152	5.212 ± 0.429
150	5.42 ± 0.20	5.810 ± 0.195
180	5.25 ± 0.112	5.587 ± 0.195

Table 13. Diameter of the proventriculus at different ages (Mean ± S.E.)

Age in days	Anterior (mm)	Middle (mm)	Posterior (mm)
1	3.00 ± 0.1	5.50 ± 0.14	5.23 ± 0.19
8	3.30 ± 0.22	7.67 ± 0.42	5.72 ± 0.43
15	4.33 ± 0.32	8.68 ± 0.32	7.21 ± 0.47
22	6.40 ± 0.49	10.23 ± 0.79	8.08 ± 0.52
30	7.60 ± 0.27	10.82 ± 0.37	9.17 ± 0.43
45	10.08 ± 0.50	13.47 ± 0.32	11.60 ± 0.29
60	9.83 ± 0.13	12.13 ± 0.50	10.83 ± 0.45
75	9.88 ± 0.28	11.27 ± 0.59	9.94 ± 0.24
90	9.05 ± 0.35	10.97 ± 0.46	9.85 ± 0.21
120	10.02 ± 0.36	11.95 ± 0.36	10.02 ± 0.60
150	9.23 ± 0.34	12.15 ± 0.24	9.27 ± 0.30
180	10.37 ± 0.27	12.03 ± 0.36	10.60 ± 0.44

Table 14. Weight and length of the gizzard at different ages (Mean ± S.D.)

Age in days	Weight (g)	Length (cm)
1	1.15 ± 0.062	1.75 ± 0.067
8	2.68 ± 0.275	2.00 ± 0.086
15	5.52 ± 0.724	2.60 ± 0.144
22	10.60 ± 0.964	3.18 ± 0.145
30	18.16 ± 0.815	3.90 ± 0.224
45	34.64 ± 1.118	4.68 ± 0.114
60	54.53 ± 4.013	5.65 ± 0.131
75	58.32 ± 4.575	5.85 ± 0.233
90	57.70 ± 2.95	5.30 ± 0.052
120	50.80 ± 1.856	5.43 ± 0.145
150	50.84 ± 0.745	5.37 ± 0.089
180	50.12 ± 0.365	5.32 ± 0.087

Table 15. Diameter of the gizzard at different ages (Mean ± S.E.)

Age in days	Cranio-caudal (mm)	Dorsoventral (mm)	Thickness (mm)
1	15.37 ± 0.11	14.40 ± 0.29	8.48 ± 0.21
8	18.68 ± 0.56	21.82 ± 1.001	13.12 ± 0.63
15	23.13 ± 0.78	28.38 ± 1.81	16.55 ± 0.90
22	25.75 ± 1.12	35.52 ± 1.61	20.50 ± 0.66
30	32.38 ± 1.15	45.10 ± 0.63	24.70 ± 0.52
45	41.03 ± 1.01	53.62 ± 0.59	30.75 ± 0.45
60	44.82 ± 0.99	62.42 ± 1.09	34.87 ± 1.27
75	48.30 ± 1.018	64.75 ± 1.48	37.20 ± 1.045
90	46.21 ± 0.56	62.60 ± 1.02	34.68 ± 0.579
120	45.21 ± 0.70	61.37 ± 0.93	33.63 ± 0.32
150	47.20 ± 1.05	62.58 ± 1.17	33.35 ± 0.44
180	44.60 ± 1.14	61.73 ± 1.81	32.73 ± 0.87

Table 16. Thickness of the gizzard lining and the glandular layer of the gizzard (Mean ± S.D.)

Age in days	Gizzard lining (um)			Glandular layer (um)		
	Lateral wall	Craniodorsal sac	Caudoventral sac	Lateral wall	Craniodorsal sac	Caudoventral sac
1	12.50 ± 1.87	9.80 ± 1.48	12.00 ± 2.44	30.50 ± 3.69	20.00 ± 1.66	21.35 ± 1.65
8	18.75 ± 0.96	10.25 ± 1.26	15.75 ± 1.70	31.75 ± 1.71	22.75 ± 2.99	30.25 ± 1.71
15	20.75 ± 2.21	15.25 ± 1.26	17.75 ± 2.22	32.75 ± 2.5	30.75 ± 1.89	24.50 ± 2.08
22	20.80 ± 1.92	18.20 ± 3.11	19.80 ± 2.39	54.20 ± 3.19	36.00 ± 1.83	30.25 ± 1.71
30	28.80 ± 1.30	15.75 ± 1.70	17.80 ± 1.48	44.00 ± 1.82	34.12 ± 1.84	23.75 ± 2.55
45	28.40 ± 2.88	18.50 ± 2.08	21.25 ± 2.99	48.75 ± 2.98	37.40 ± 1.14	38.60 ± 5.45
60	43.40 ± 2.96	20.75 ± 2.22	22.75 ± 3.59	68.25 ± 3.3	34.40 ± 3.28	52.50 ± 6.45
75	40.20 ± 3.35	21.20 ± 3.03	25.00 ± 2.58	71.50 ± 6.35	34.50 ± 2.65	38.75 ± 2.98
90	40.60 ± 3.58	20.20 ± 1.92	29.25 ± 2.22	70.40 ± 2.70	45.00 ± 3.01	60.50 ± 2.08
120	51.25 ± 2.98	19.50 ± 1.29	23.80 ± 1.92	70.75 ± 2.5	39.00 ± 5.59	52.00 ± 3.16
150	33.50 ± 2.38	22.75 ± 2.75	32.00 ± 6.48	66.40 ± 3.05	34.50 ± 3.87	45.20 ± 2.17
180	45.25 ± 2.5	15.60 ± 1.5	51.20 ± 2.23	51.75 ± 1.70	25.75 ± 1.70	31.20 ± 1.30

Table 17. Response of secretory products of gizzard epithelium to various stains

Method	Intracellular granules		Luminal contents			Covering membrane	
	Tubules	Surface	Fundus	Body	Neck	Column	Matrix
PAS	-	+++	-	++	+++	+++	+
AF	-	+++	-	++	++	-	+
Trichrome	++	-	-	+++	+++	+++	++++
PTAH	+++	++	-	++	+++	+++	+

The intensity of the reaction was graded as follows:

'-' Absent
'+' Slight/trace
'++' Moderate
'+++' Strong
'++++' Very strong

Table 18. Correlation matrix of weights

	Age	Body weight	Tongue weight	Pharynx weight	Oeso-phagus weight	Proven-tricular weight	Gizzard weight
Age	1.0000	0.8831	0.8892	0.8409	0.8441	0.8101	0.7898
Body weight		1.0000	0.9863	0.9790	0.9744	0.9409	0.9588
Tongue weight			1.0000	0.9909	0.9889	0.9738	0.9811
Pharynx weight				1.0000	0.9760	0.9797	0.9840
Oesophagus weight					1.0000	0.9664	0.9891
Proventricular weight						1.0000	0.9795
Gizzard weight							1.0000

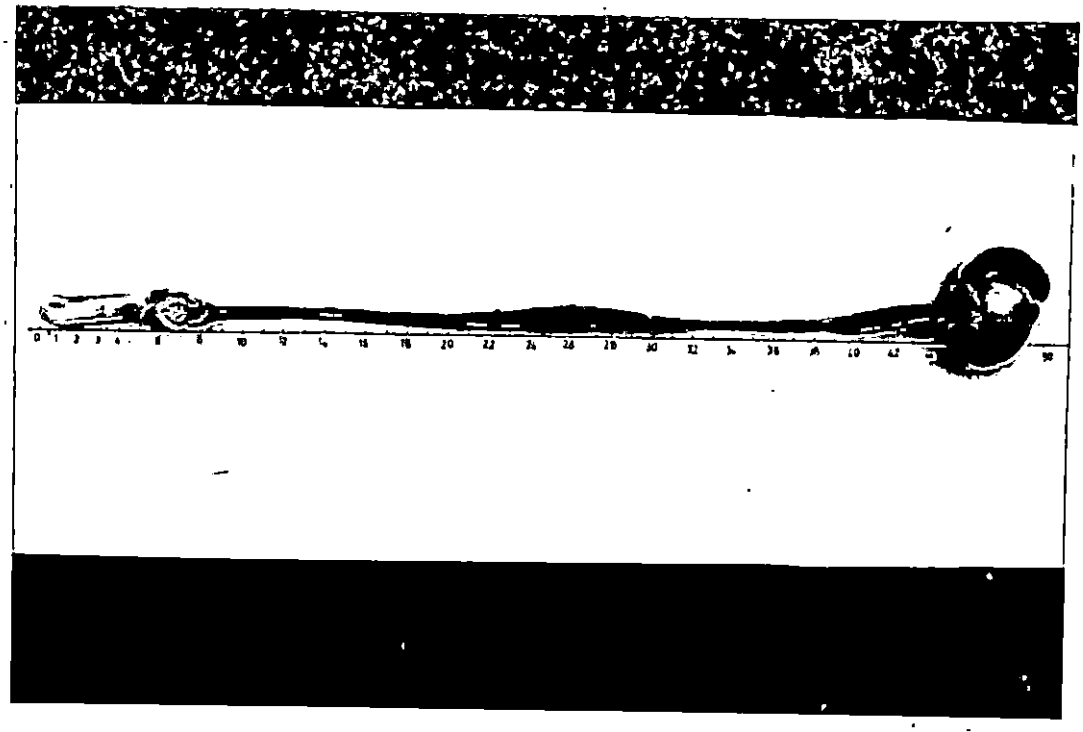
Table 19. Correlation matrix of lengths

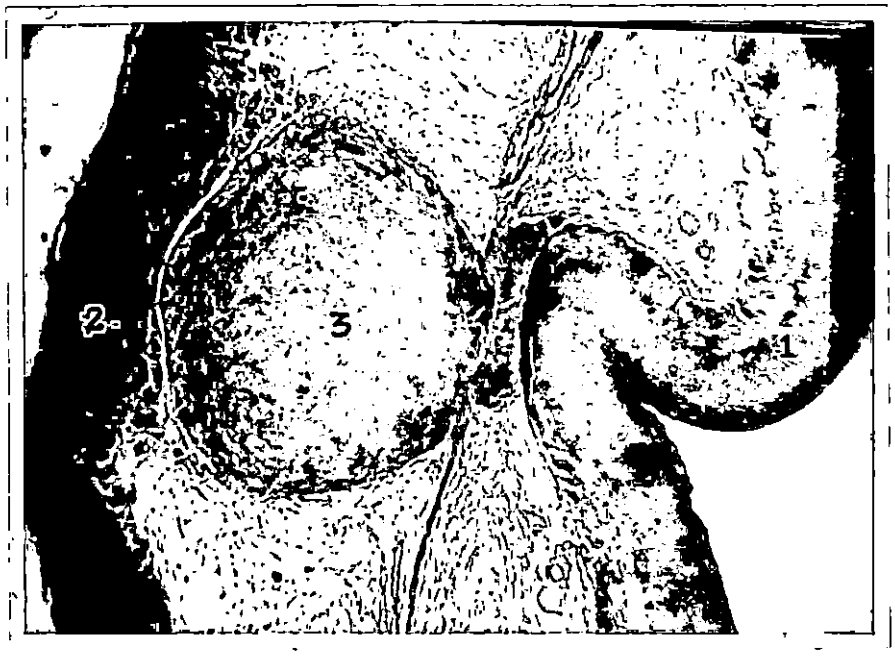
	Age	Tongue length	Pharynx length	Cervical oeso-phagus length	Crop length	Thoracic oeso-phagus length	Length of oeso-phagus	Proven-triculus length
Age	1.0000	0.8812	0.7674	0.7884	0.9019	0.8349	0.8603	0.8300
Tongue length		1.0000	0.9760	0.9777	0.9914	0.9831	0.9966	0.9838
Pharynx length			1.0000	0.9862	0.9592	0.9714	0.9809	0.9814
Cervical oesophagus length				1.0000	0.9475	0.9786	0.9787	0.9726
Crop length					1.0000	0.9689	0.9903	0.9708
Thoracic oesophagus length						1.0000	0.9921	0.9703
Oesophagus length							1.0000	0.9833
Proventriculus length								1.0000

Table 20. Correlation coefficients of weight and length of the organs

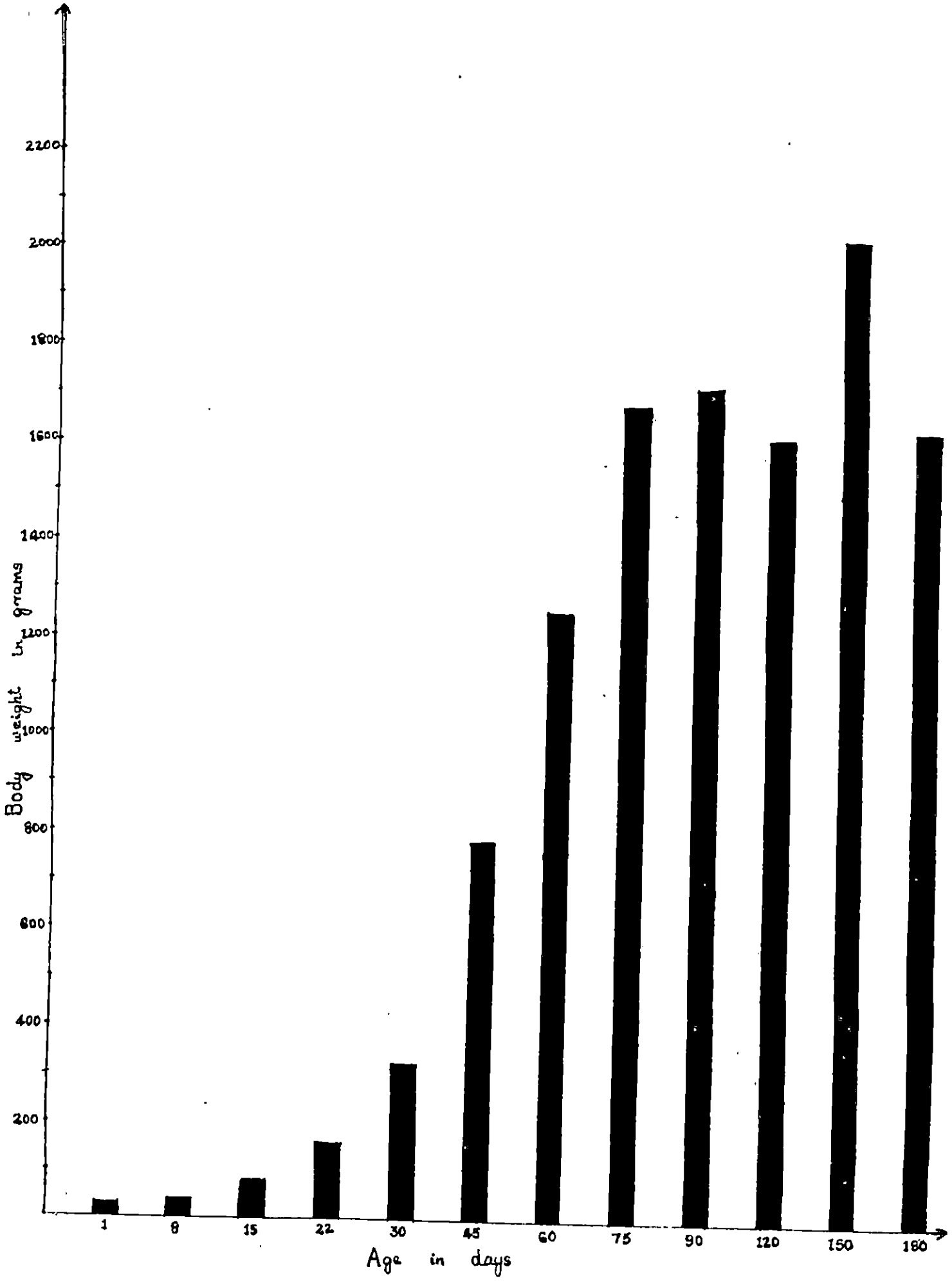
Organ	Correlation coefficient
Tongue	0.9934
Pharynx	0.9799
Oesophagus	0.9748
Proventriculus	0.9731
Gizzard (Cranio-caudal diameter)	0.9795
Gizzard (Dorso-ventral diameter)	0.9694

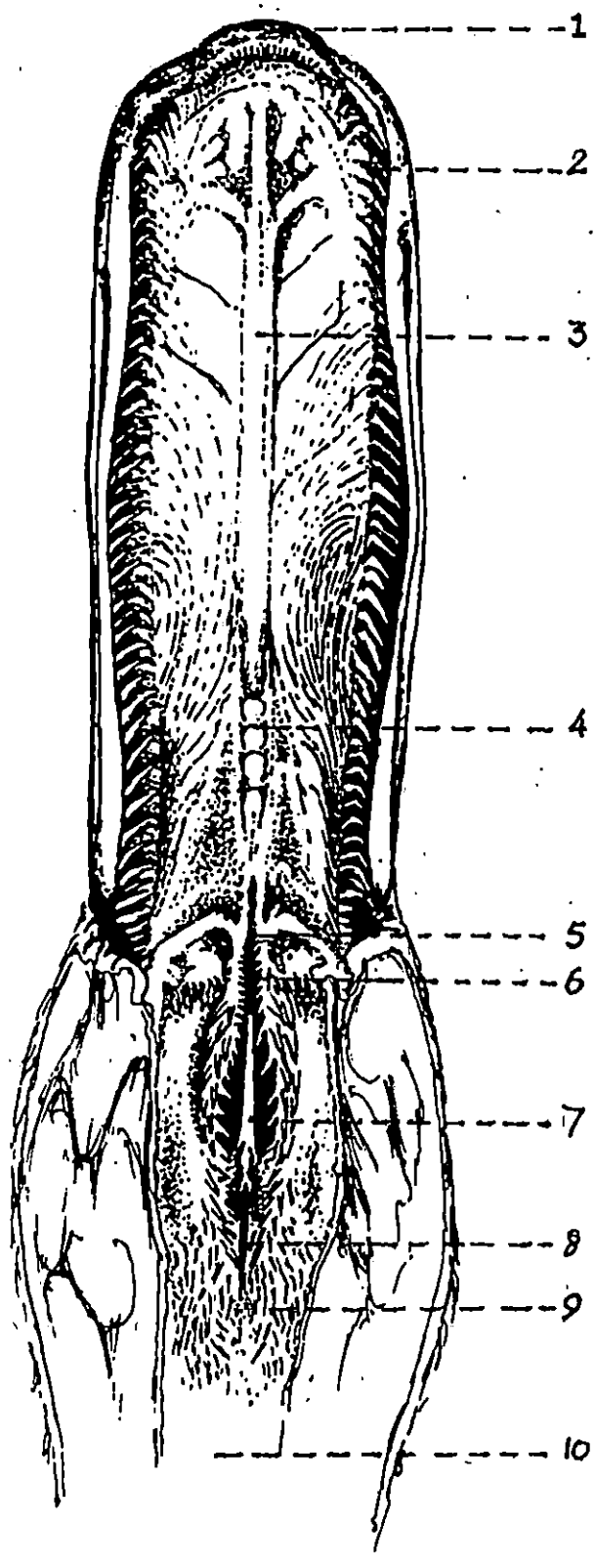
Figures

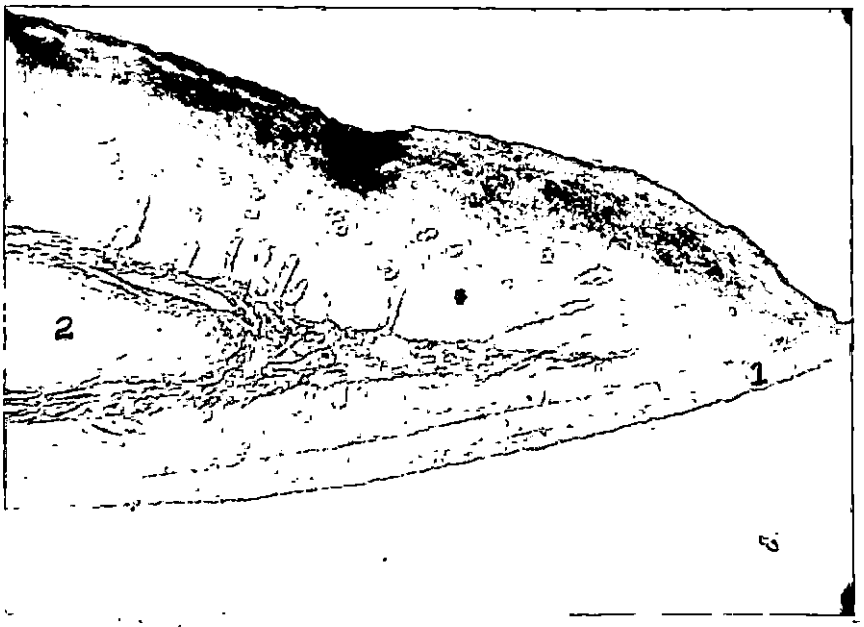


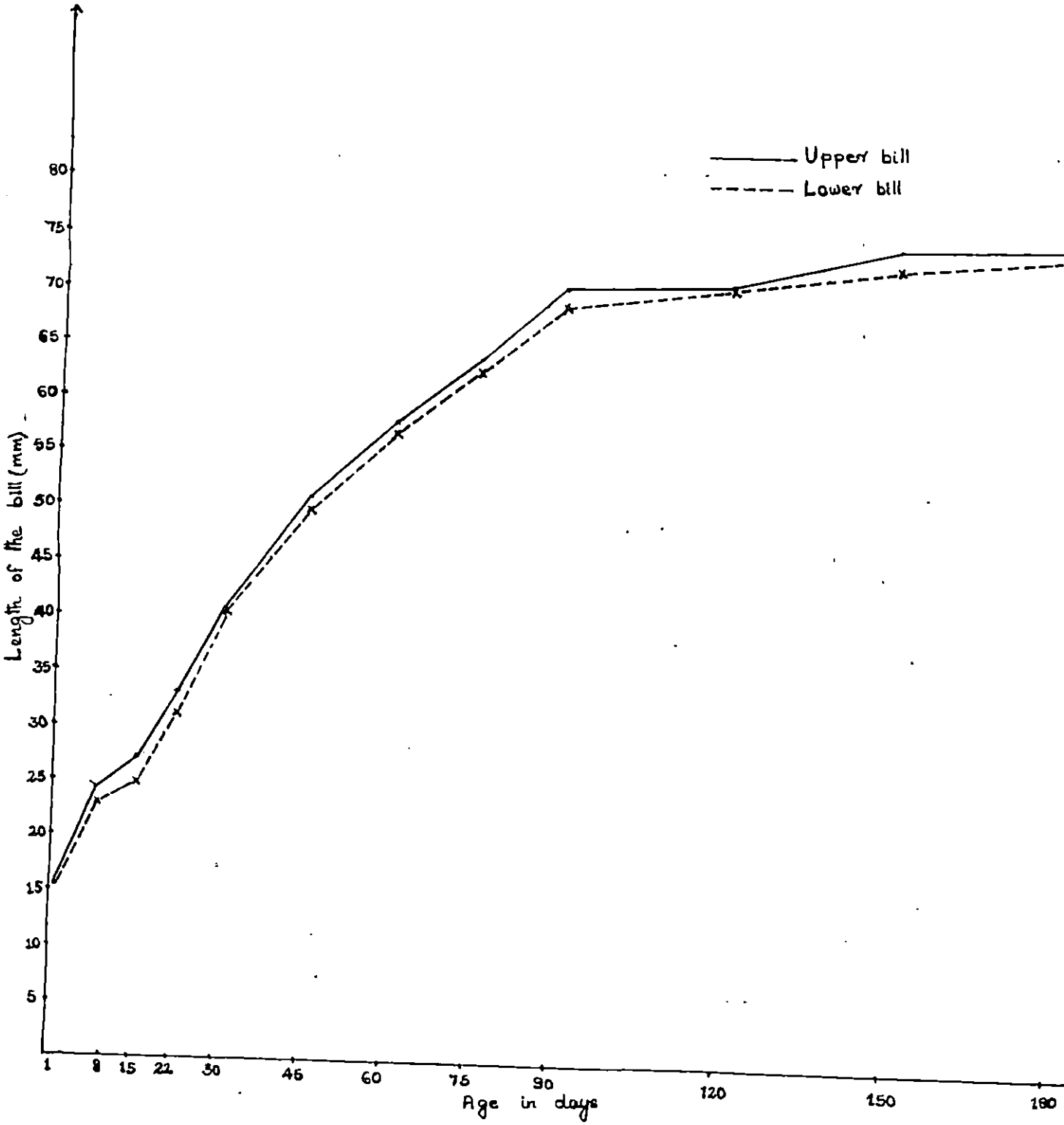


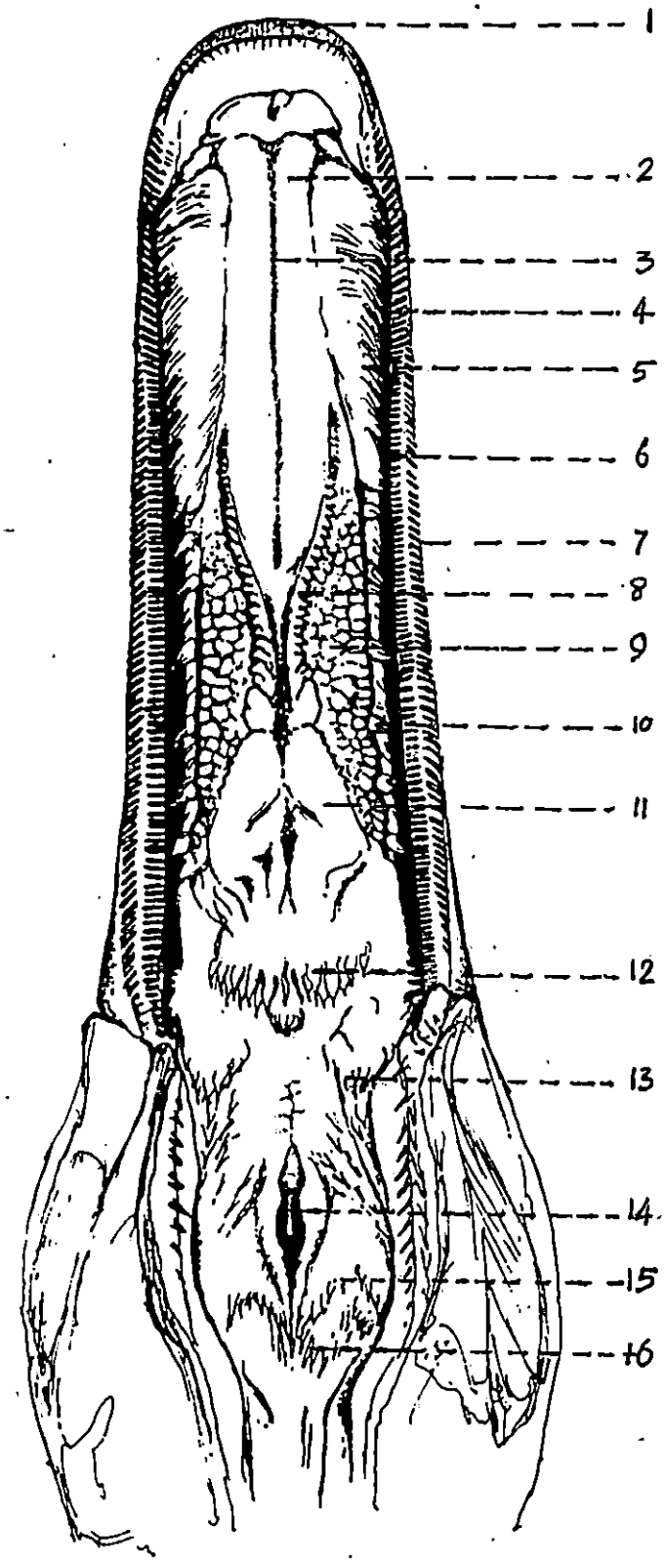
Age in days

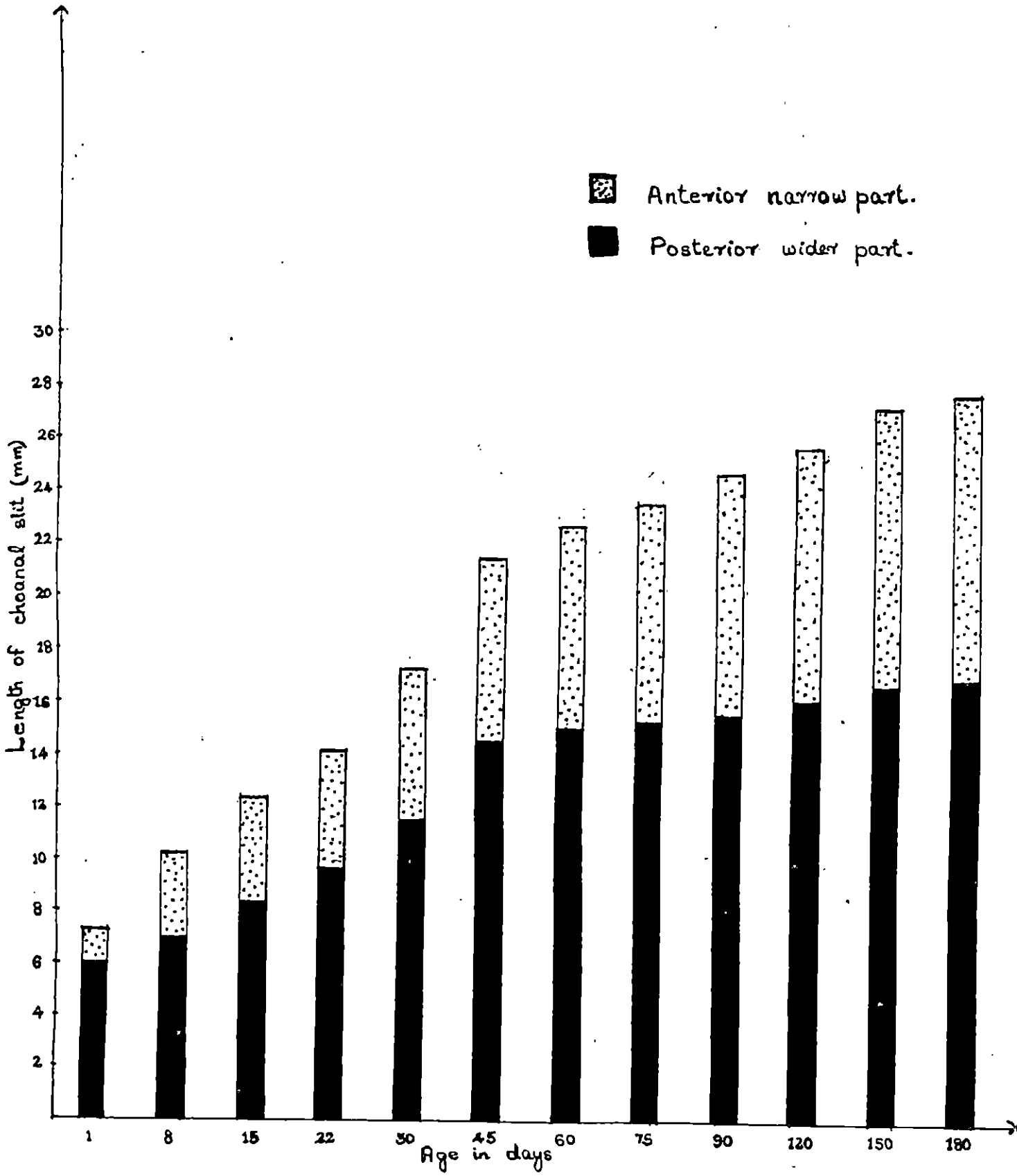

Body weight in grams
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1
8
15
22
30
45
60
75
90
120
150
180
Age in days

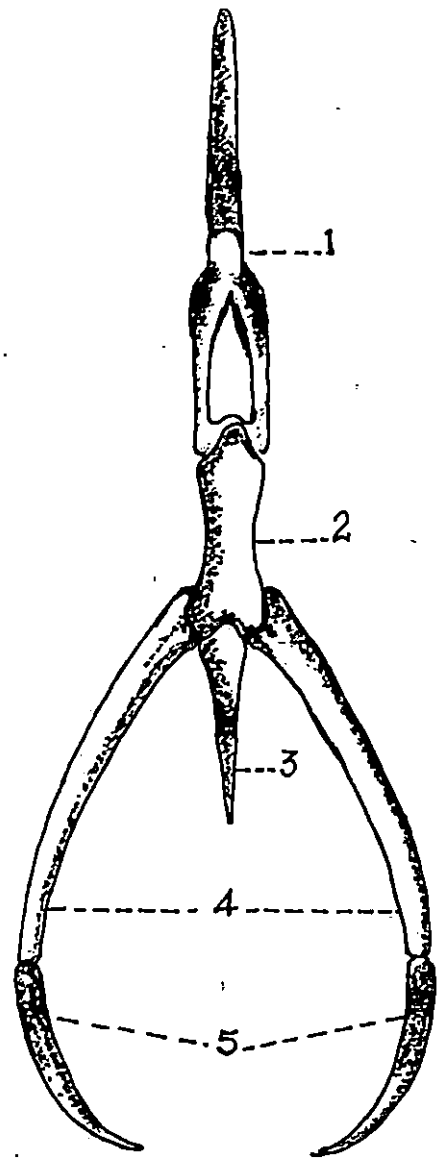

1
2
3
4
5
6
7
8
9
10

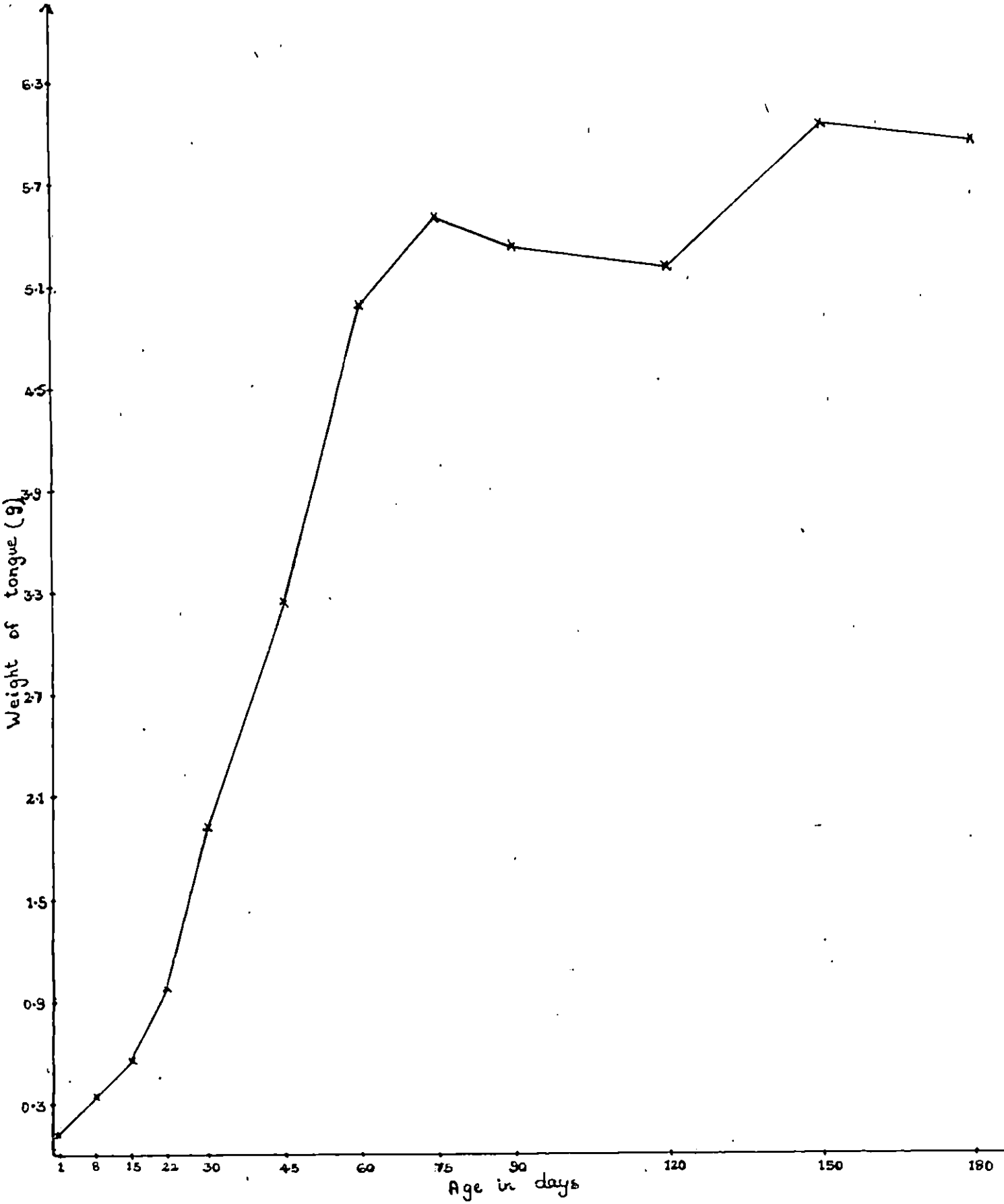

2
1

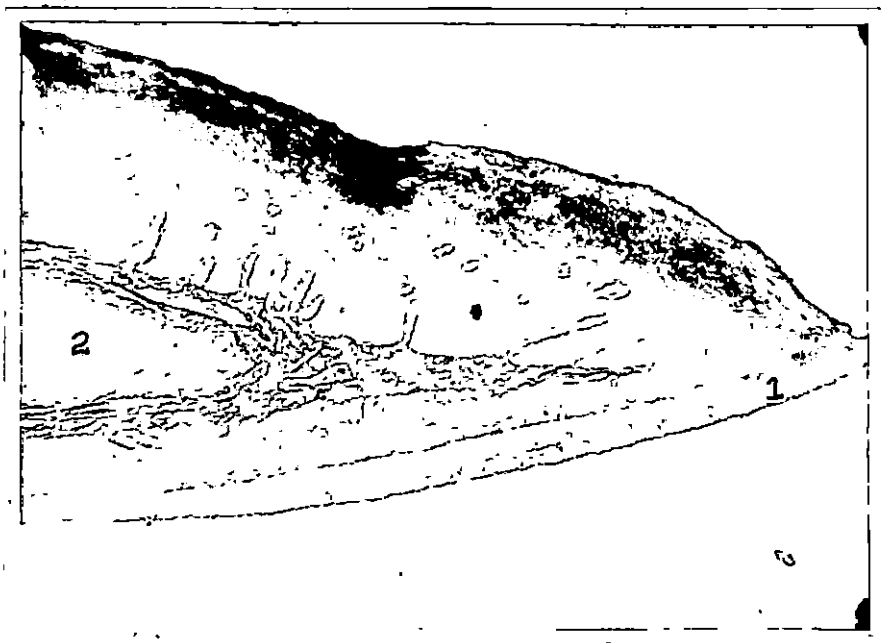

Upper bill
Lower bill
Length of the bill (mm)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1
8
15
22
30
45
60
75
90
120
150
180
Age in days


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

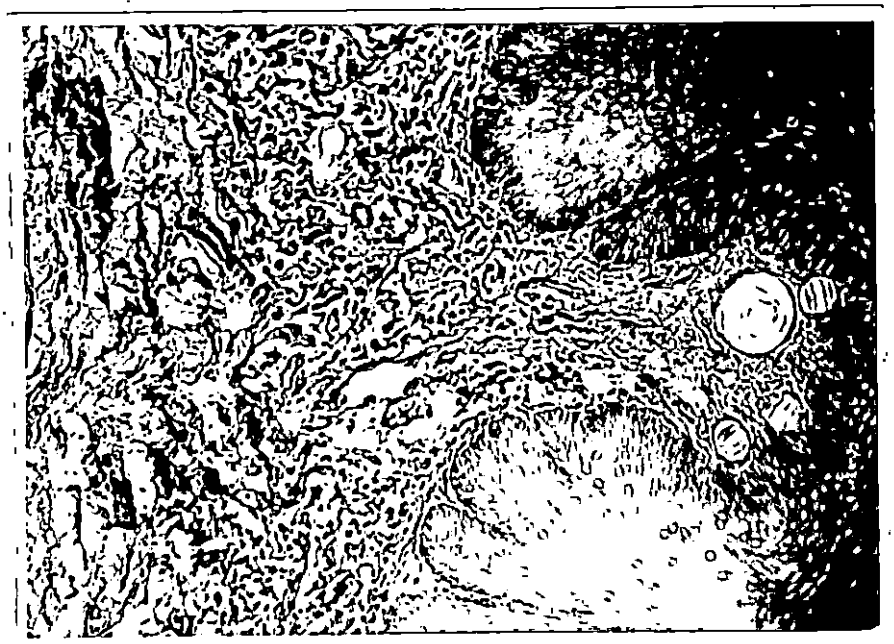

Anterior narrow part.
Posterior wider part.
Length of choanal slit (mm)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
1
8
15
22
30
45
60
75
90
120
150
180
Age in days

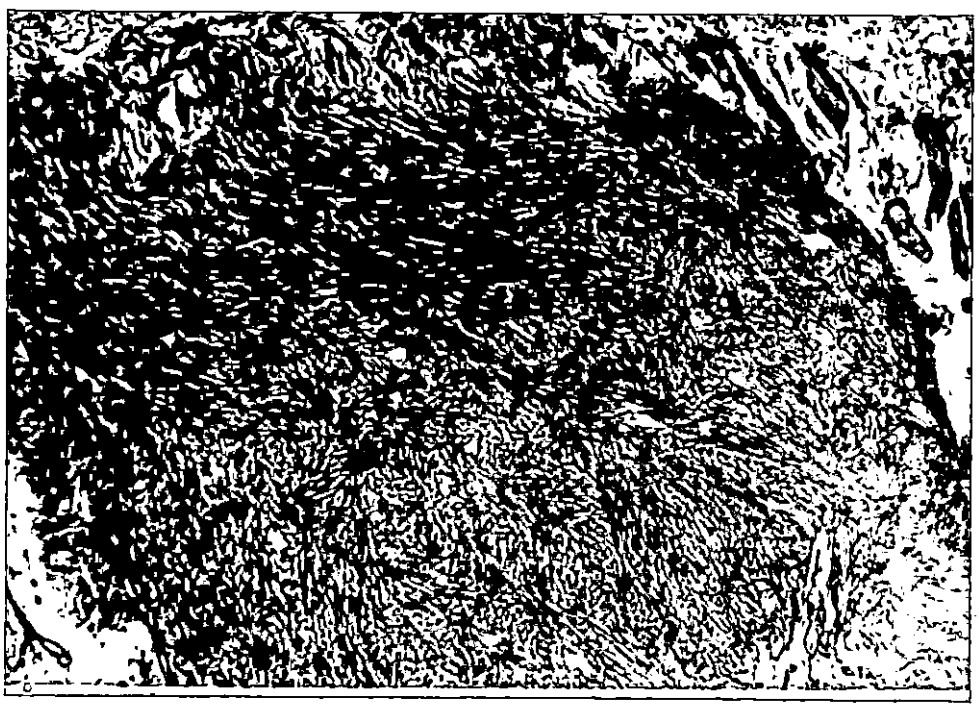

1
2
3
4
5

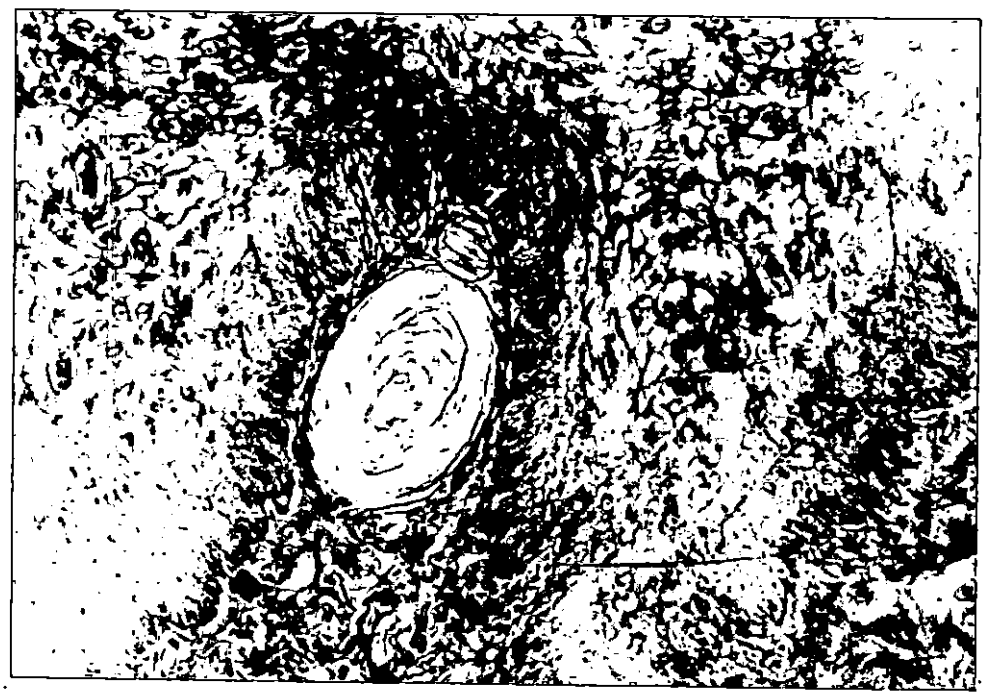

6·3
5·7
5·1
4·5
3·9
3·3
2·7
2·1
1·5
0·9
0·3
Weight of tongue (g)
1
8
15
22
30
45
60
75
90
120
150
180
Age in days


2
1

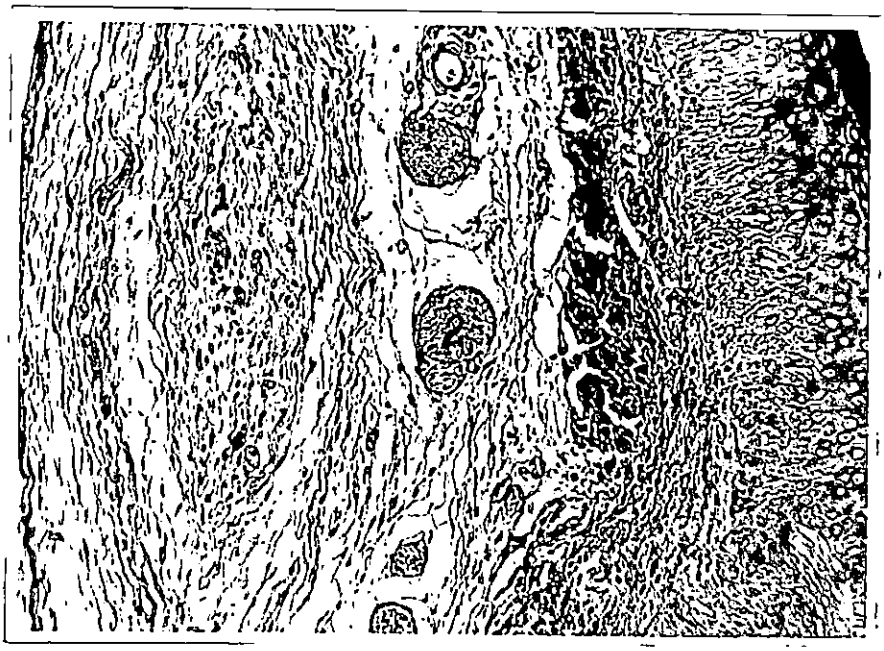

2
4

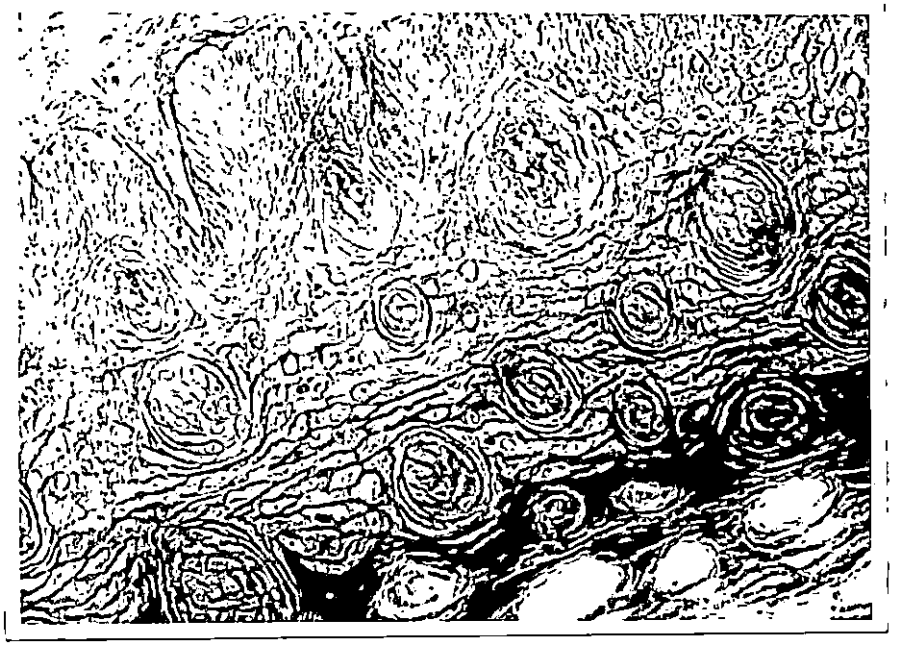


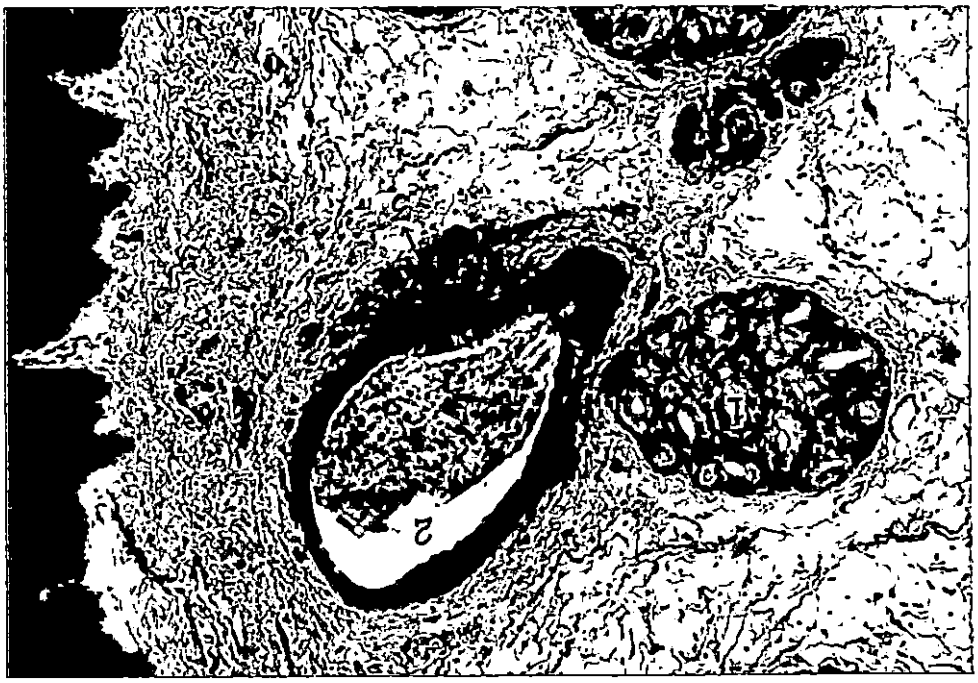





1
2


1
2

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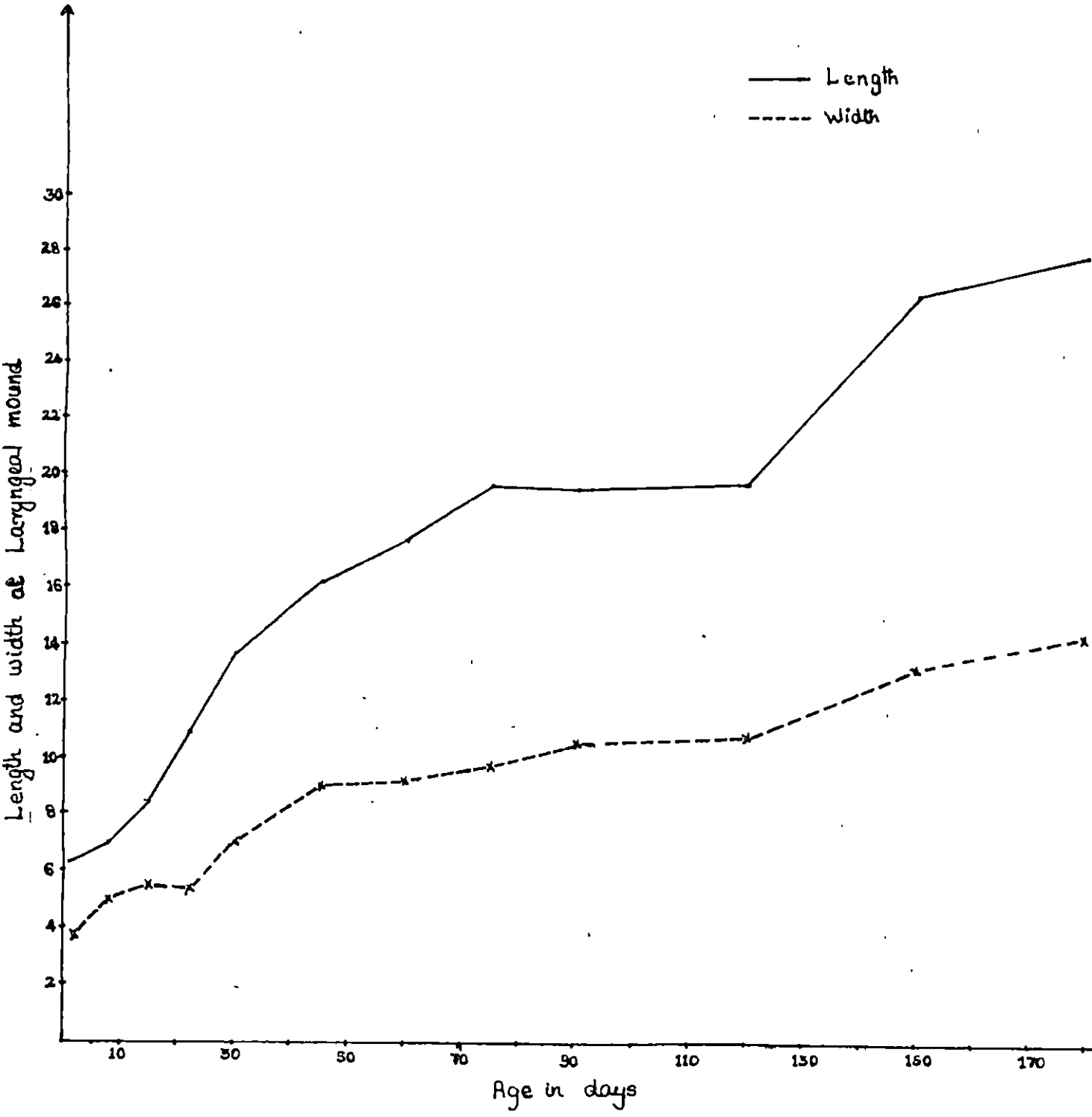
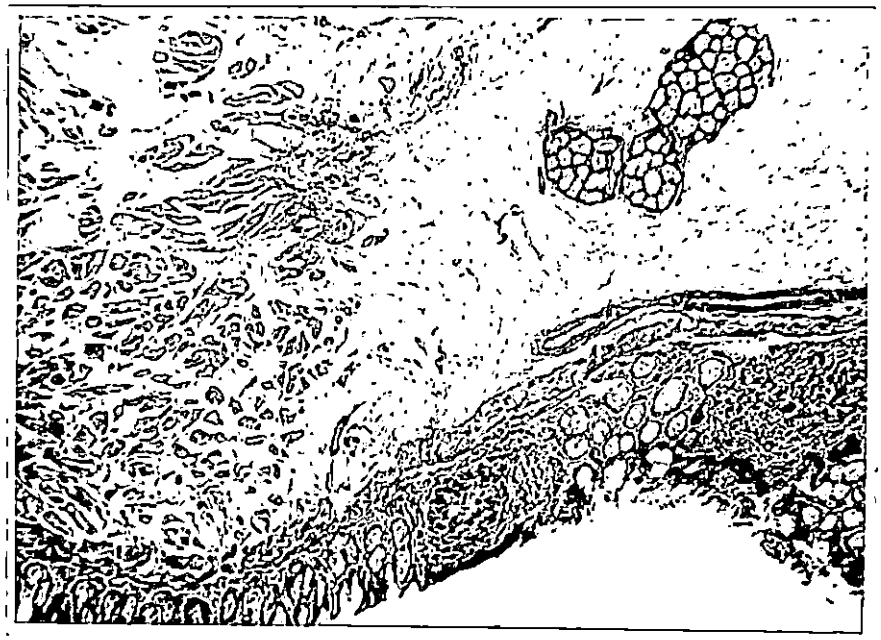
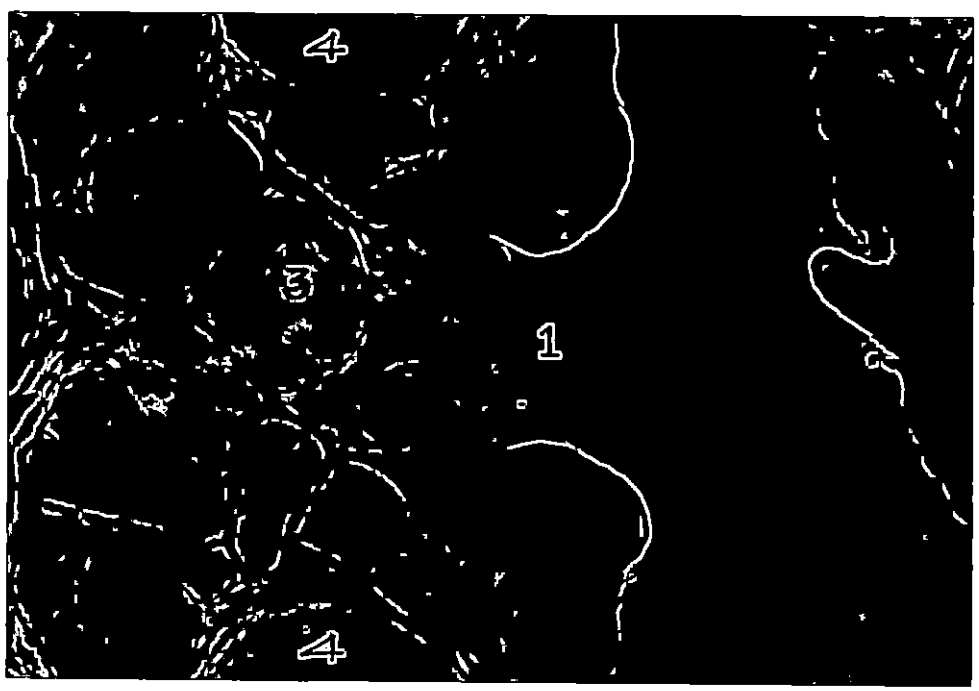
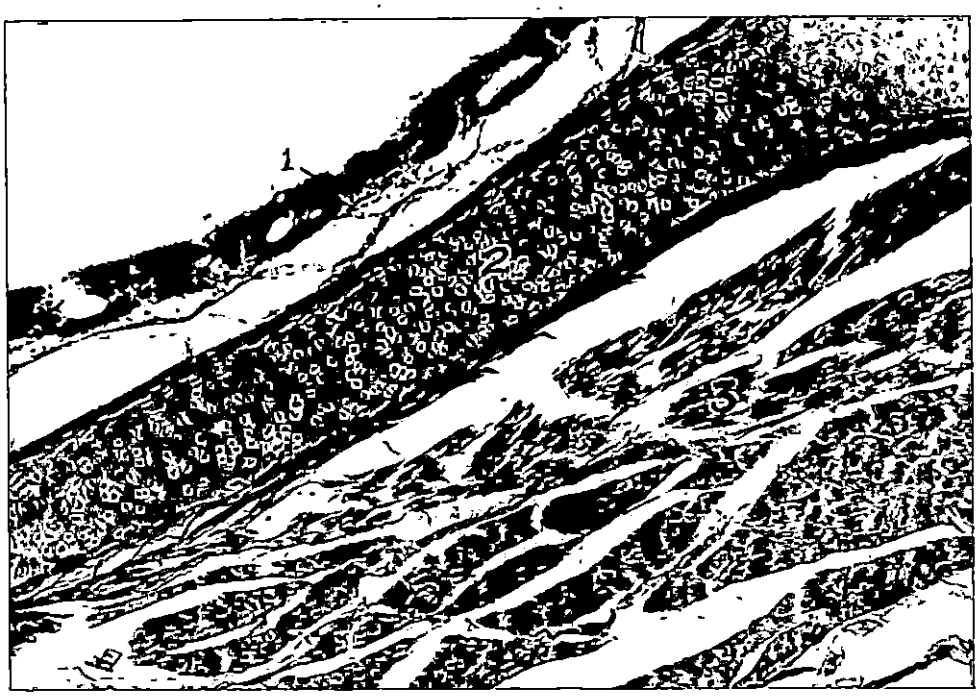

Length
Width
Length and width at Laryngeal mound
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
10
30
50
70
90
110
130
150
170
Age in days


3
4
2
3


1
2




4
3
1
4


1
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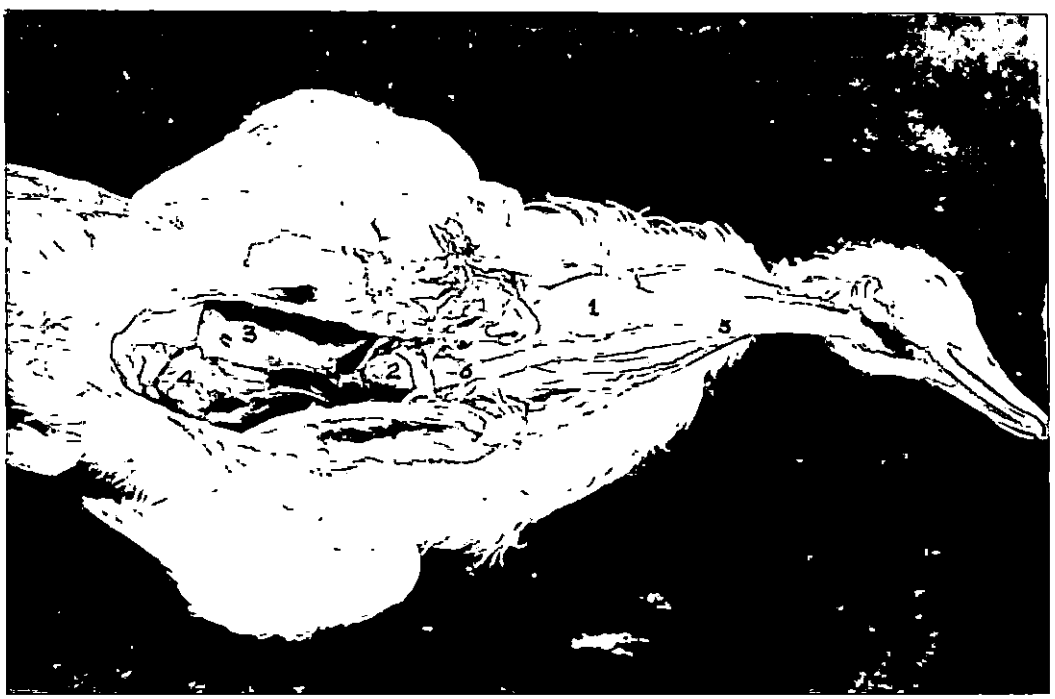
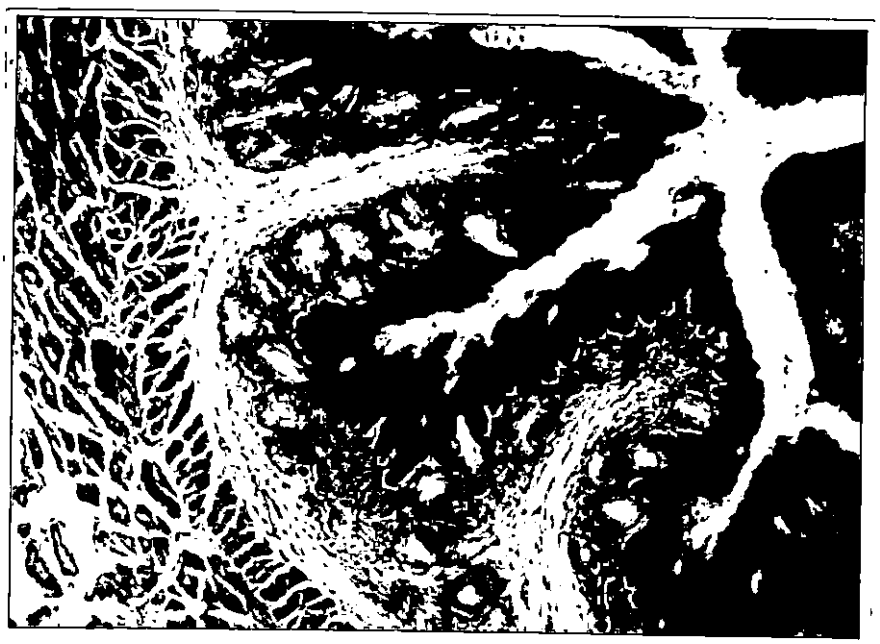
3


1
2
3
4
5
6


3
2
1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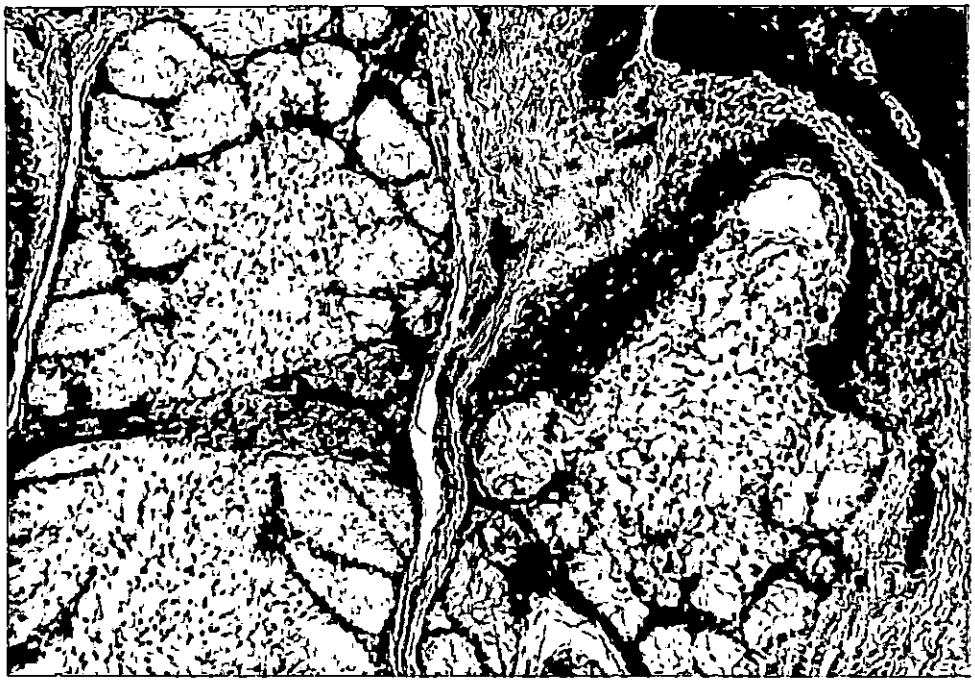
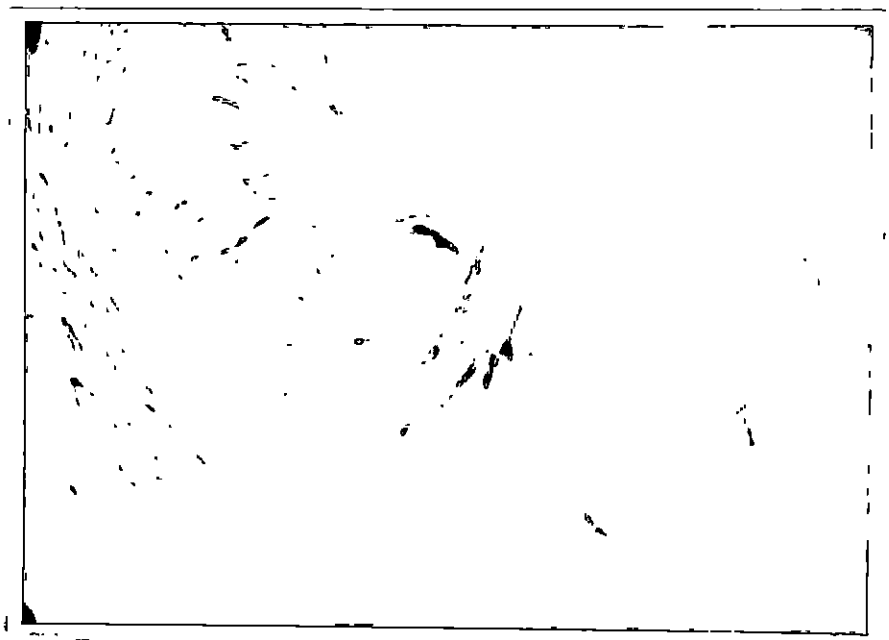
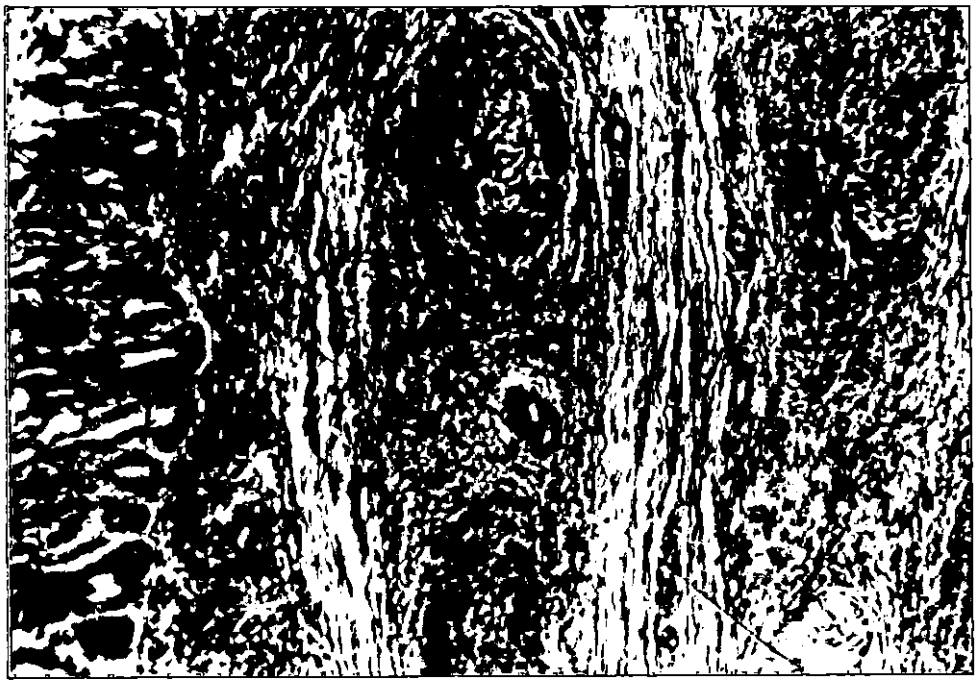
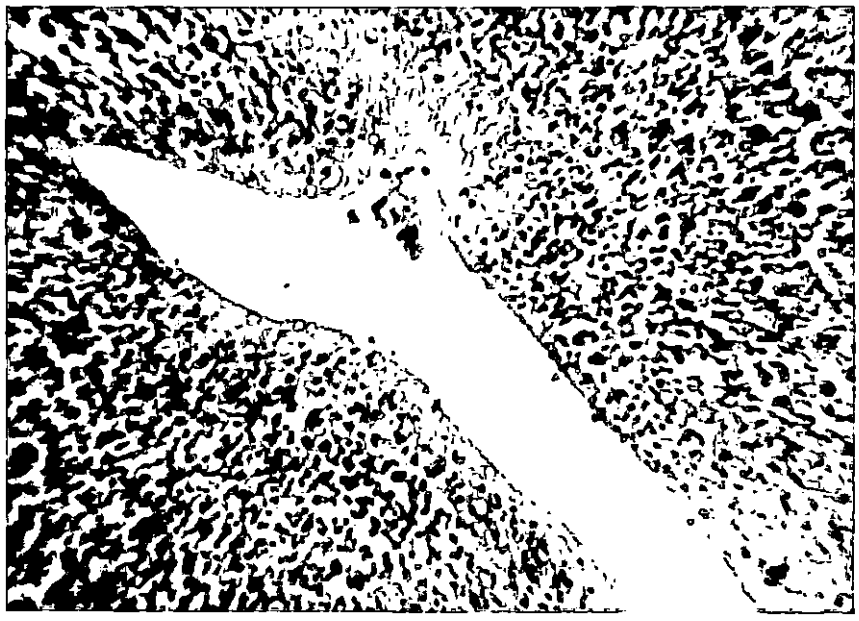
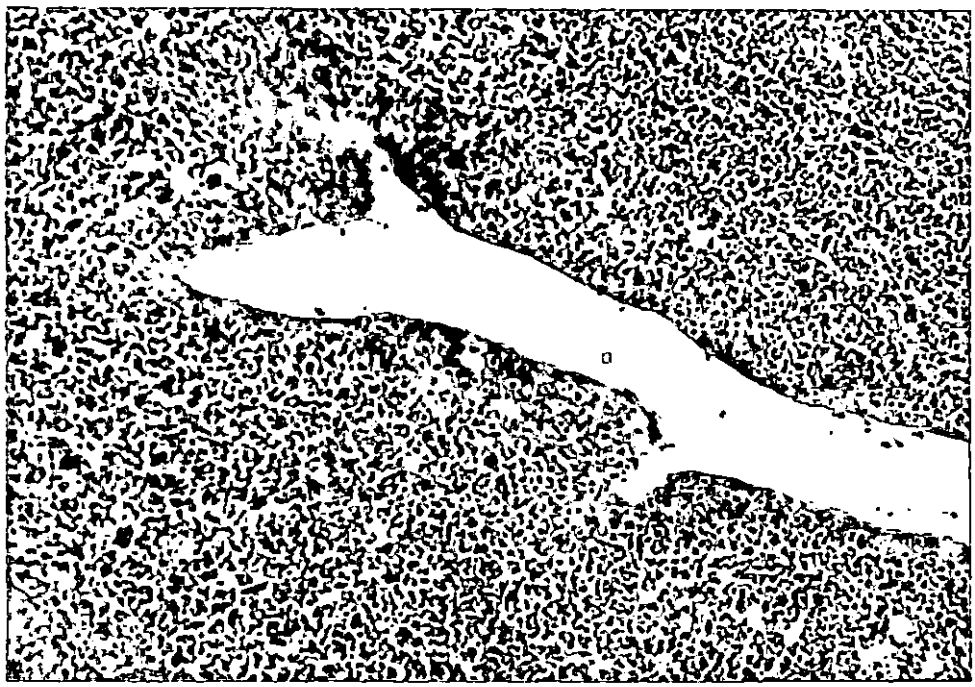






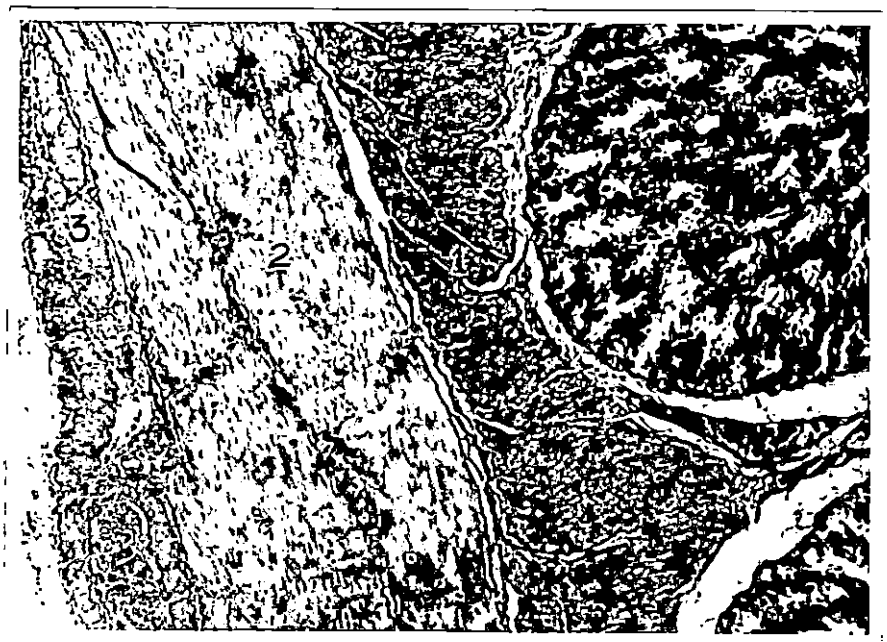

C2
C1
C3

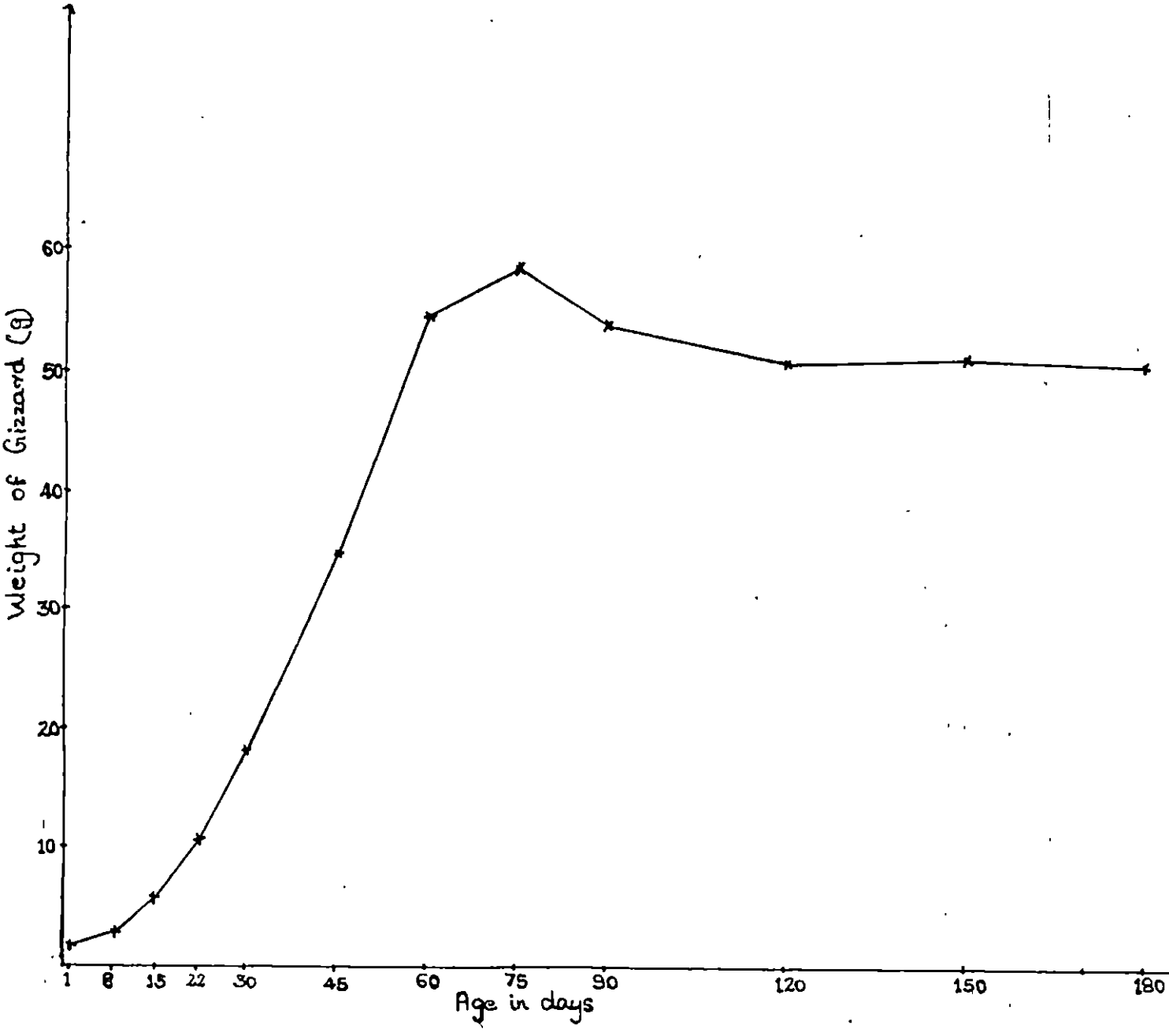


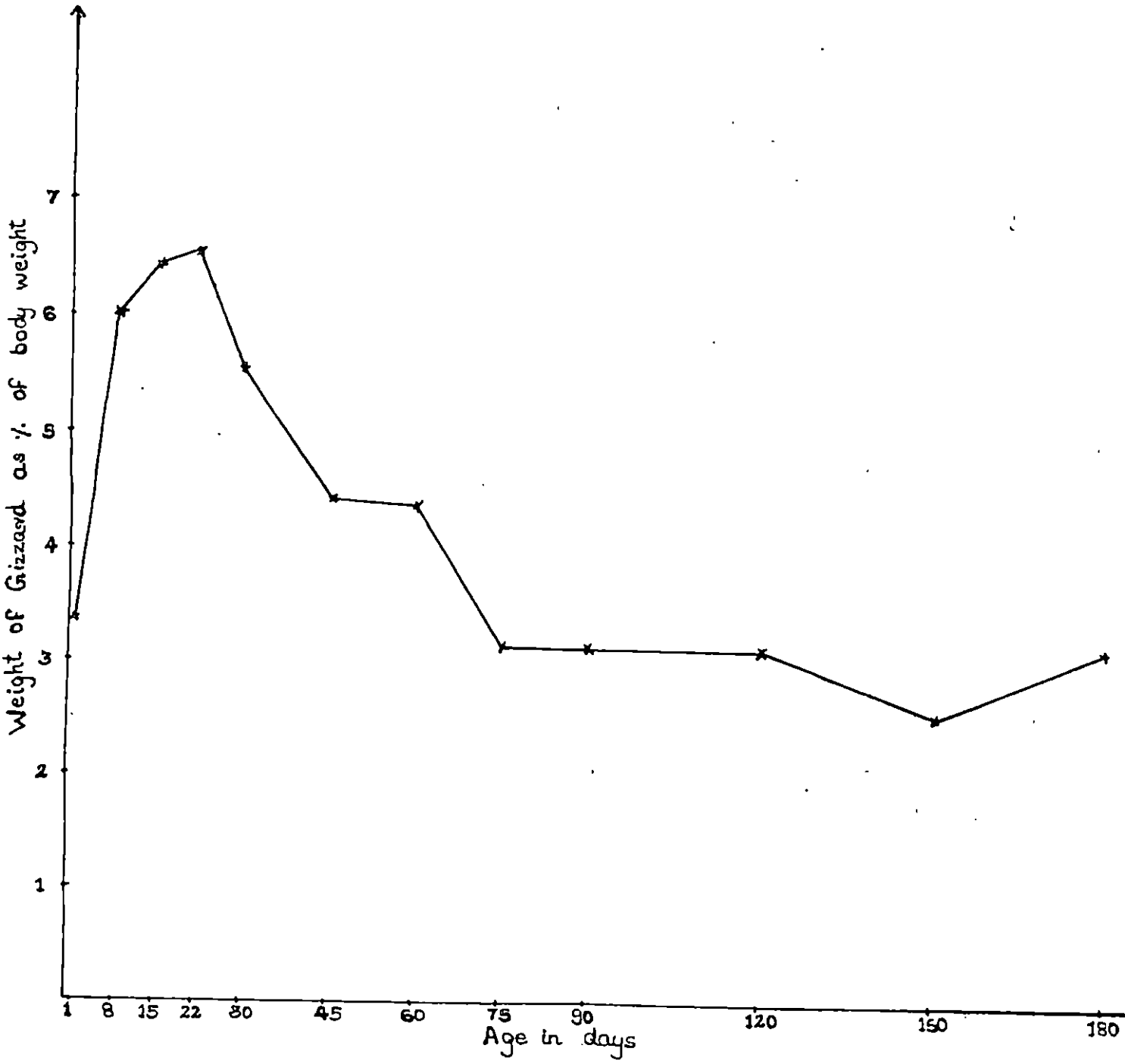


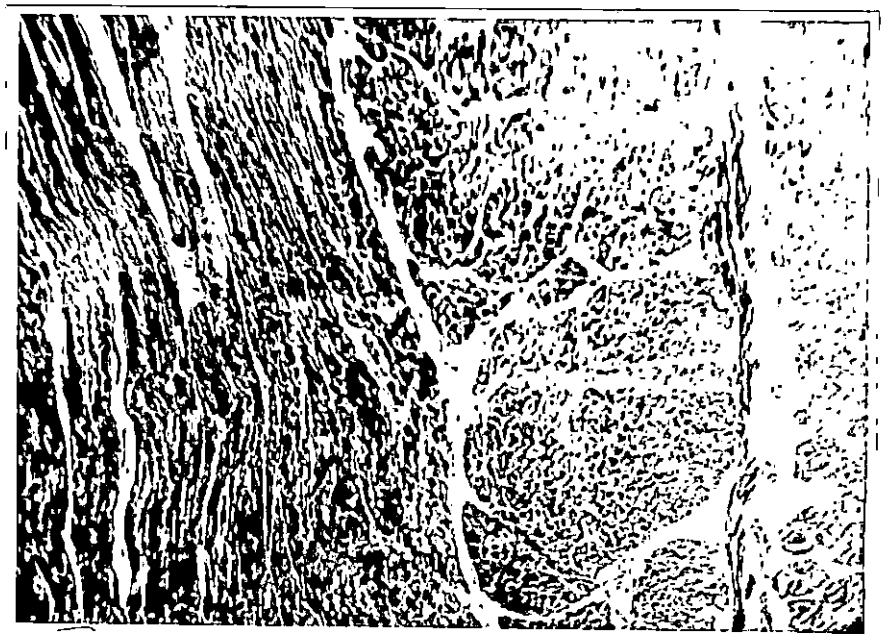

1
2
3

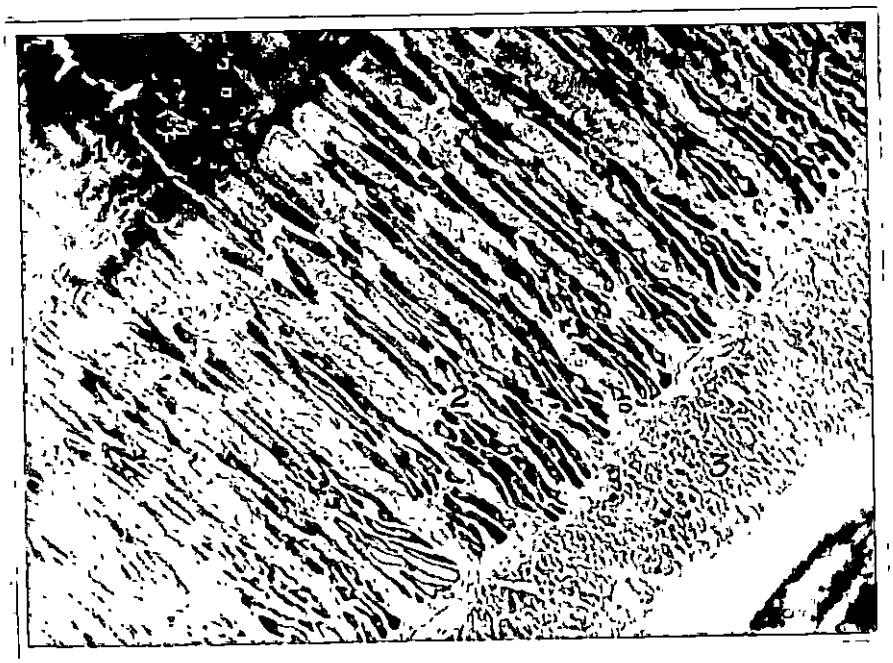

2
1


3
2


Weight of Gizzard (g)
60
50
40
30
20
10
1
8
15
22
30
45
60
75
90
120
150
180
Age in days


Weight of Gizzard as % of body weight
7
6
5
4
3
2
1
1
8
15
22
30
45
60
75
90
120
150
180
Age in days

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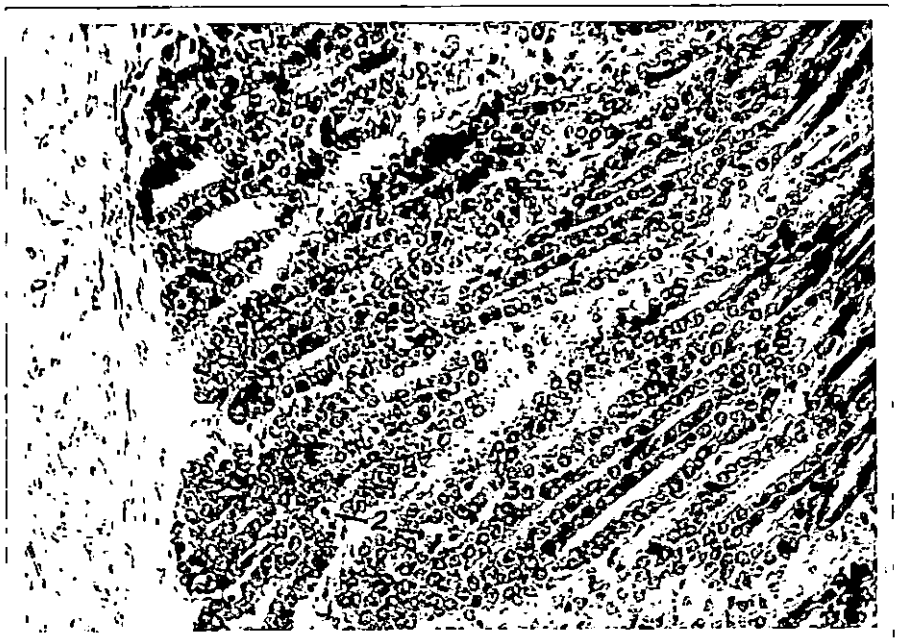

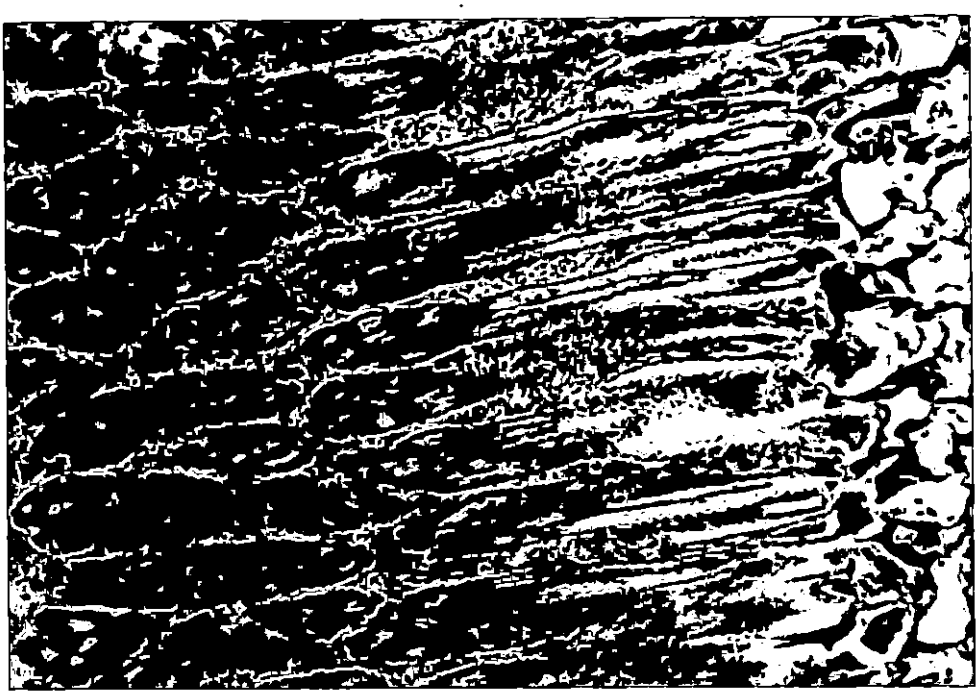

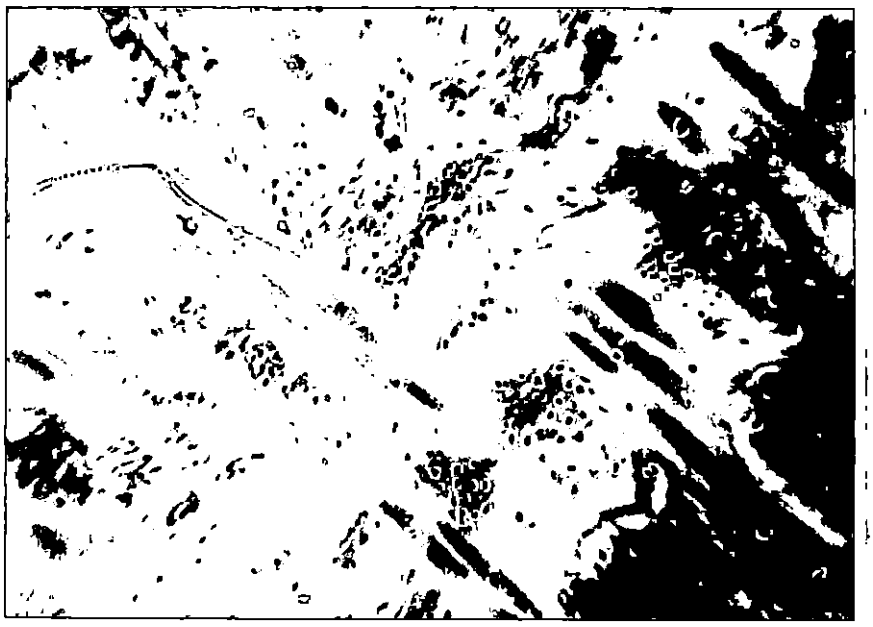

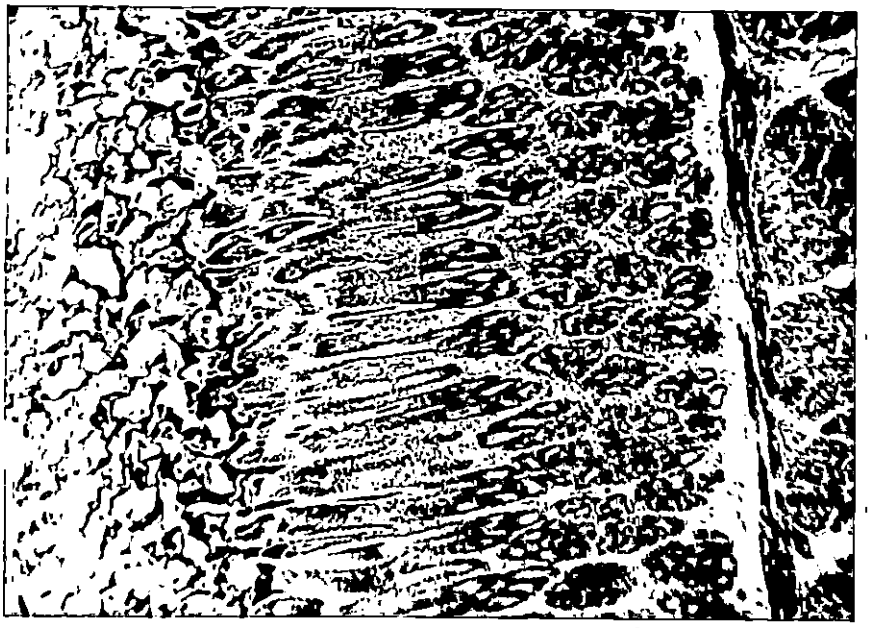

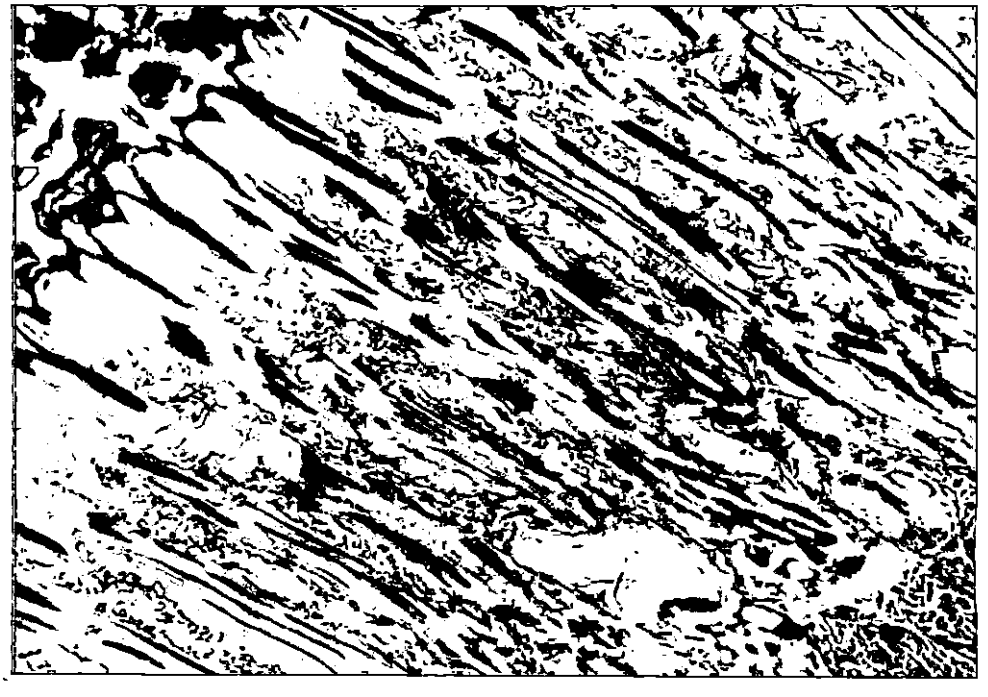

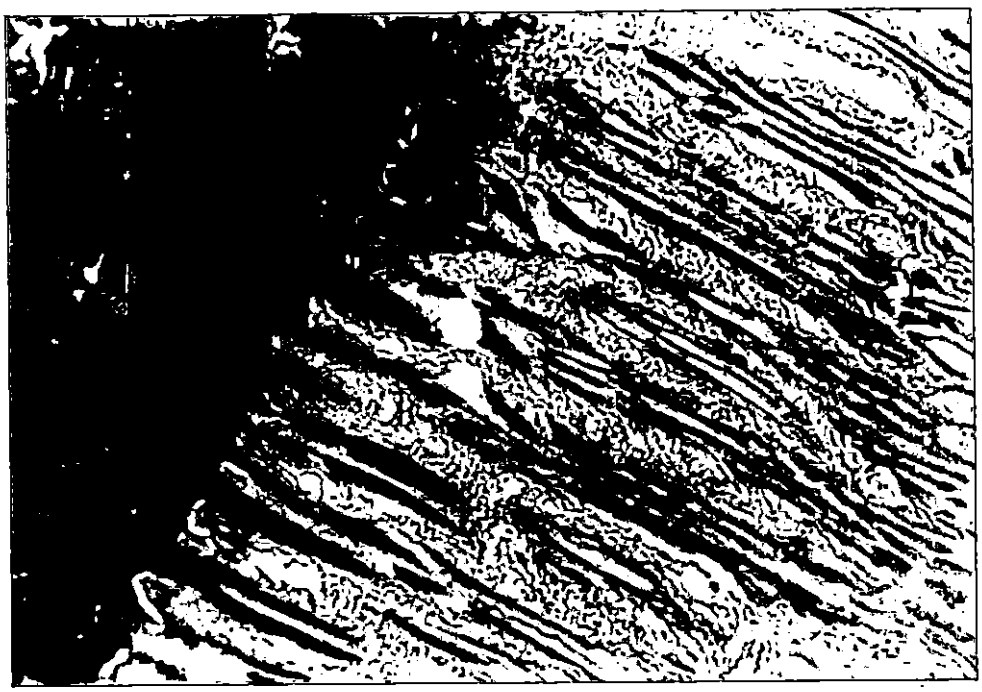

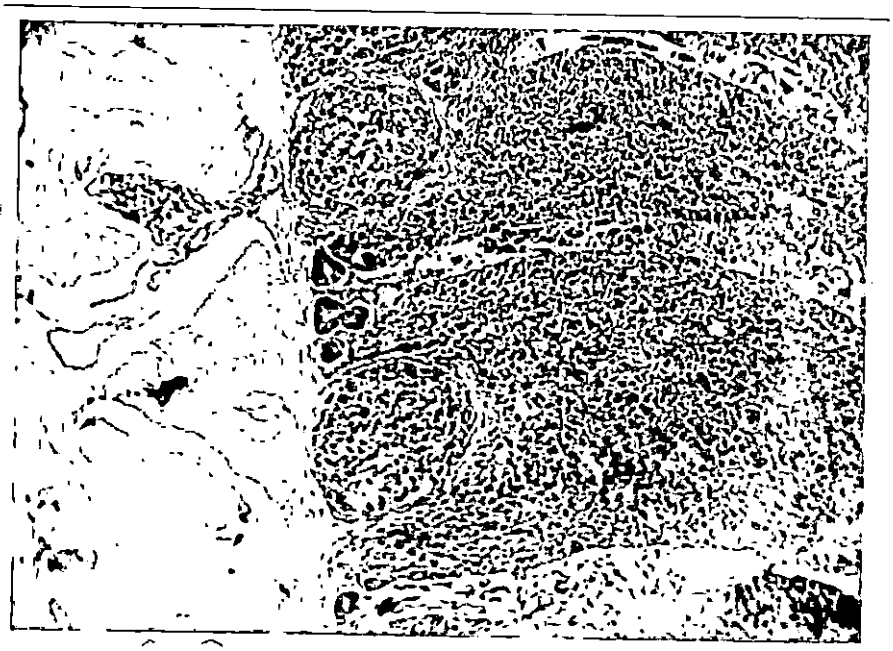

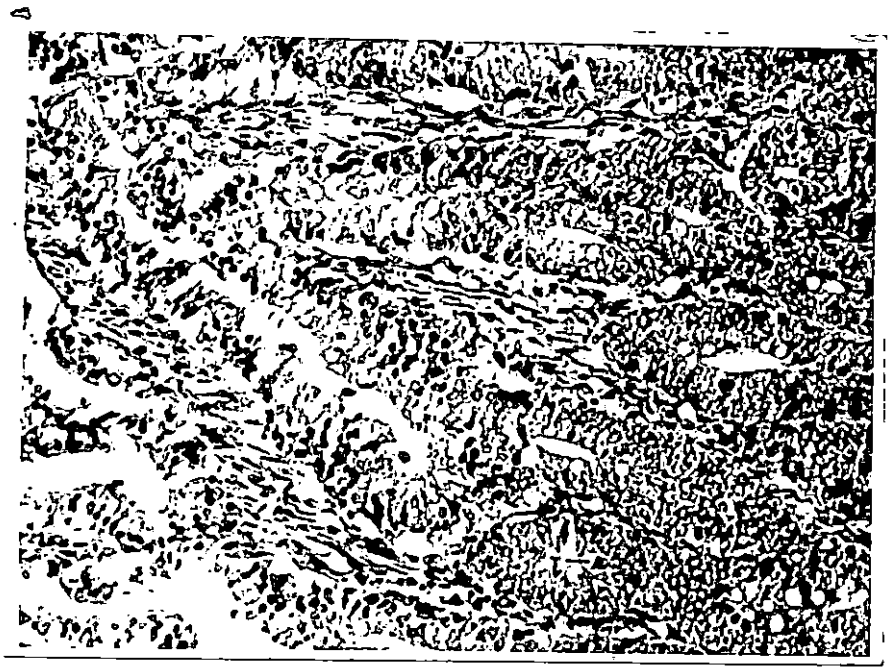

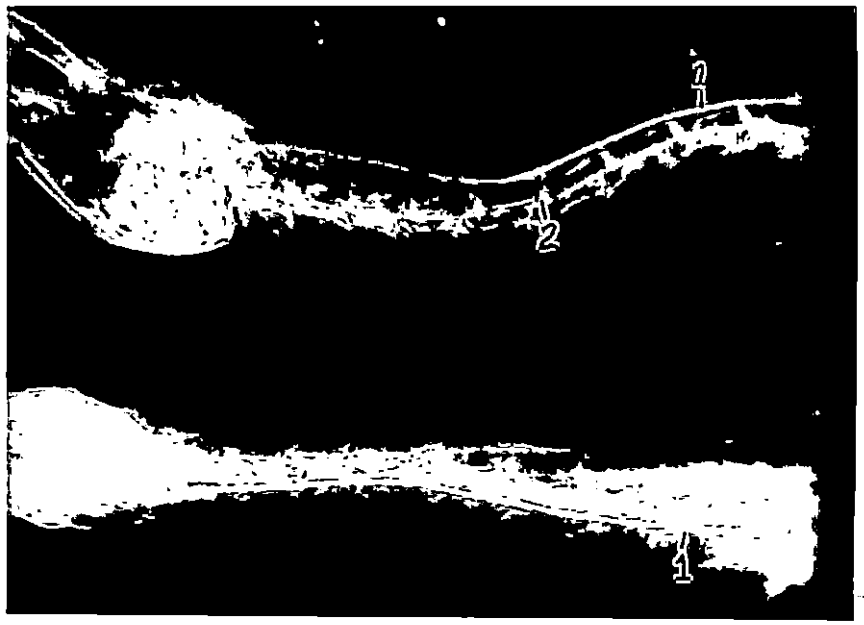
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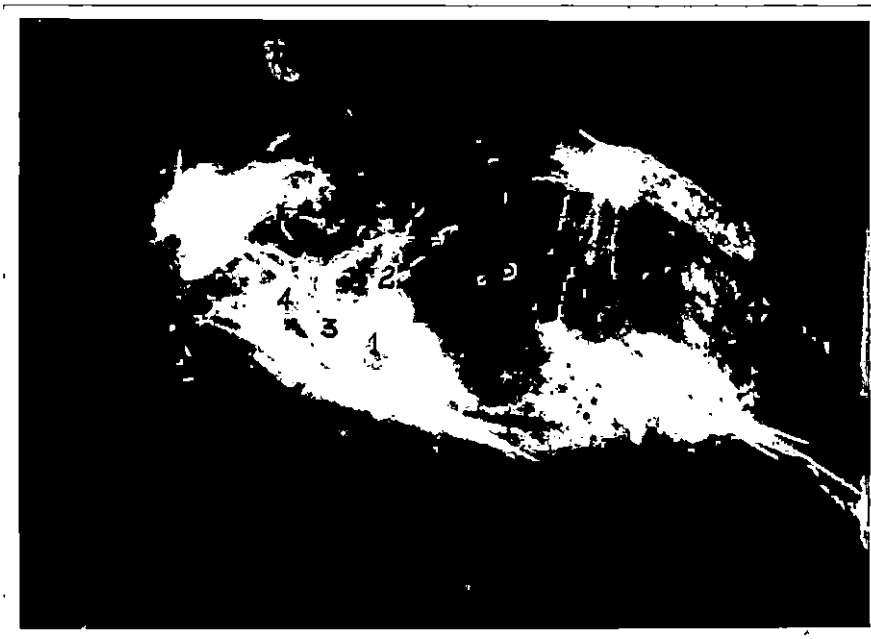
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Discussion

DISCUSSION

Growth

The tongue, pharynx, oesophagus and crop, proventriculus and the gizzard showed a progressive growth pattern upto 75 days of age. The oesophagus and crop and the gizzard attained the maximum weight at 75 days whereas the tongue, pharynx and proventriculus only at a later age of 150 days. The weight of all these organs were more correlated positively to body weight than with age (Table 18). The contributions of tongue, pharynx, oesophagus and crop and proventriculus to body weight were maximum at eighth day of age and that of gizzard at 22 days of age. The order of decreasing contribution to body weight was gizzard followed by the oesophagus and crop and proventriculus. The contributions of tongue and pharynx were negligible.

Mouth cavity

The hard keratin at the tip of the upper bill was spatula shaped and presented a whitish median line which was absent in ducks aged 45 days and above. The lamellae o on the upper and lower bill acted as a sieve and helped during foraging. The four wide based papillae caudal to the median longitudinal mucosal ridge of the palate were arranged in line in most birds and in pairs in some birds, one pair in line with the ridge and the caudal pair side by side. The length of the bill and the choanal slit increased

with advancing age (Tables 2 and 3). In addition to the detailed observations noted above, the present findings agreed with the general morphological descriptions given by Das et al. (1965) and McLelland (1975).

Tongue

The spatula shaped tongue with thin rostral end showed a median longitudinal groove on its dorsal surface which did not extend to the full length of the tongue. This groove stopped a little in front of the middle third of the tongue. The various papillae on the dorsal surface and lateral margins reported by Das et al. (1965) namely, filiform, conical and fungiform papillae have been observed in the present study also. However, the longitudinal rows of small papillae in the middle third of the tongue converged caudally where a nodular enlargement on either side was seen.

The papillae at the root of the tongue, forming the landmark of the oral cavity, were arranged in two rows. Among these, the largest ones were seen close to the midline except in day-old ducklings in which the papillae were of equal sizes.

The ventral surface of the tongue was marked by a median ridge and at its tip a triangular eminence corresponding to the depression recorded on the dorsal surface was seen.

The differences in thickness of the stratified squamous epithelium at different ages and regions reflected variations in the degree of mechanical stress to which the particular region is exposed. Similar observations have been reported by Biswal and Das (1967) and Rao and Hafeezuddin (1988). The superficial layers of the epithelium showed strong propensity to slough off. In the day-old ducklings, the stratum cylindricum was thick and composed of long columnar cells.

The dermal papillae surfaced with cells of the stratum cylindricum giving a fern like appearance and they showed a progressive development with age. There was also a proportionate increase in number of dermal papillae with thickness of the epithelium. In the adult duck, the dermal papillae at the middle and caudal part of the tongue were wide and few but it presented a follicular nature. The general increase in the thickness of the epithelium and the development of the dermal papillae as age advanced suggest that these changes are based on physiological need. The vascular connective tissue in the papillae provided nourishment to the epithelium.

The lamina propria was thin towards the anterior portion of the tongue whereas in the body and root it was thick.

The muscles of the tongue were scanty and observed mainly in the caudal part arranged longitudinally around the entoglossal bone and some fibres were arranged transversely

and obliquely. Similar observations have been made by Rao and Hafeezuddin (1988). The origin of these muscles was said to be from the hyoid bone (Ziswiler and Farner, 1972).and as such there is no intrinsic muscle in the tongue. The movement of the tongue is very largely due to the great mobility of the hyoid apparatus and not entirely by the action of the muscles.

Large number of Herbst's corpuscles were observed in the lamina propria close to the deeper layers of the epithelium. They were numerous at the base of the barbs and other papillae. They occurred singly in the anterior part and in groups towards the posterior region of the tongue. Biswal and Dasa (1967) and Rao and Hafeezuddin (1988) have recorded the presence of Herbst's corpuscles in the tongue of domestic duck.

Grandry's corpuscles in the tongue of duck reported by Rao and Hafeezuddin (1988) have been confirmed in the present study. A few tactile corpuscles with a fir cone appearance resembling Meissner's corpuscles were also seen in the lamina propria. According to Nickel et al. (1977) these corpuscles are specialised touch endings supplied by trigeminal nerve.

In addition to these there were numerous encapsulated spherical bodies consisting of two to four horizontally oriented columnar like cells with a granular cytoplasm and central, spherical, vesicular nucleus with a distinct nucleolus. Its significance has not been understood.

According to Tucker (1966) the skeleton of the tongue of chicken was formed by paraglossal and rostral basibranchial bones between which they formed a synovial hinge. On the other hand the skeleton of the tongue of duck was formed entirely by paraglossal bone which was continued rostrally by an oval dorsoventrally flattened hyaline cartilage which remained cartilagenous even at the age of 180 days. At the middle portion of the tongue, the bone was more or less circular in outline and at the posterior part it was thin and wide with a ventral concavity. Ossification started from eight days of age from the posterior part of the bone.

Present study revealed the presence of filiform, fungiform and conical papillae on the tongue of the domestic duck as reported by Biswal and Das (1967). But Rao and Hafeezuddin (1988) could not observe true fungiform papillae on the tongue of duck. No taste buds could be detected in the fungiform papillae of the duck in the present study, as seen in mammals. According to Zietzschmann (1911) the tongue papillae of birds are distinct from the fungiform papillae of mammals.

Large number of oval shaped taste buds were observed in the middle and posterior part of the tongue. They consisted of an aggregation of elongated nucleated cells stained pale with eosin. Rao and Hafeezuddin (1988) observed only ten taste buds in the root of the tongue of duck. Gentle (1971b) observed similar type of taste buds in chicken.

Biswal and Das (1967) did not observe any taste buds in the tongue of domestic duck. While Hafeez (1968) and Dorst (1971) reported about 200 taste buds in the duck, Lindenmaier and Kare (1959) reported glandular buds in chicken associated with the ducts of salivary glands.

The anterior and posterior lingual glands of duck were observed on the dorsolateral aspect of the body and ventrolateral aspect of the root of the tongue respectively, as reported by Calhoun (1954) in chicken. They were compound tubuloalveolar glands entirely formed of mucous type columnar cells. Biswal and Das (1967) and Rao and Hafeezuddin (1988) observed only single row of mucous glands on the dorsolateral aspect of the tongue of domestic duck. The glands were holocrine in nature and the lumen contained cell debris and secreted material. Findings of the present study confirm the earlier reports of Biswal and Das (1967). But Chodnick (1948) described the apocrine nature of secretion of salivary glands of domestic fowl. The present study showed that the salivary glands of duck were well developed and composed entirely of mucous secretory end pieces. The adaptation of salivary glands to the type of food consumed has been studied extensively by Antony (1920). She has stated that ducks and geese whose food has little natural lubrication have a full compliment of salivary glands. The primary function of avian salivary gland is mucogenesis and that of saliva is lubrication.

Pharynx

The pharynx had many small caudally directed papillae. The infundibular slit was a narrow opening. Caudal to the base of the tongue two large pharyngeal papillae bearing numerous small papillae were present. These observations are similar to that of Das et al. (1965) and McLelland (1975). In the present study, a well defined transverse row of caudally directed papillae at the junction with the oesophagus was noticed as reported by McLelland (1975), but Das et al. (1965) could not locate them.

The laryngeal mound was relatively elongated and blended smoothly with the pharyngeal floor compared to chicken (White, 1968). The length of the laryngeal mound increased from 6.3 mm to 27.8 mm and width from 3.8 mm to 14.3 mm from day-old to 180 days of age. White (1968) had recorded the length of the mound as 24 mm to 28 mm and width as 12 mm in adult duck.

The pharynx was lined by stratified squamous epithelium and thickness decreased towards the junction with the oesophagus and more on the roof than its floor. The surface was rough due to sloughing of the superficial layers. The dermal papillae were scanty. Many caudally directed pointed papillae with a distinct lamina propria and covered by keratinised epithelium was observed on the mucosa. These findings agreed with the earlier reports of Rao and Hafeezuddin (1987b).

Though Ziswiler and Farner (1972) reported extensive cornification of the pharynx of birds, this could not be observed in the epithelium except on the papillae, as reported by Hodges (1974) in the fowl.

The lamina propria was continuous with the submucosa and the muscularis mucosa was absent as in fowl (Calhoun, 1954)and Hodges, 1974).

Dense lymphoid tissue in the form of pharyngeal tonsils has been located in the lamina propria near the choanal slit and infundibular slit. They were also seen in the submucosa adjacent to pharyngeal salivary glands. Similar lymphatic aggregations have been noticed in fowl by Calhoun (1954).

Trautmann and Fiebiger (1957) and McLelland (1975) have recorded Herbst's and Grandry's corpuscles and Lindenmaier and Kare (1959) have reported taste buds in the pharynx of fowl. In the duck these structures were not seen. These observations are in agreement with those of Rao and Hafeezuddin (1987b).

Densely arranged branched tubuloalveolar PAS positive glands were observed in the submucosa and below the glands, there were striated muscles as reported by Rao and Hafeezuddin (1987b).

The stratified squamous epithelium of the margin of the choanal slit changed to respiratory epithelium inside the slit. The slit contained simple mucous glands which showed

holocrine secretion and there was also a cavernous tissue in the lamina propria.

Lymphocytic nodules were observed at the transitional zone. The lamina propria was thin with collagen and few elastic fibres. Submucosa contained crico-arytenoid glands and superficial and deep intrinsic muscles of the larynx. The laryngeal cartilages were cricoid, procricoid and paired arytenoid cartilages. These cartilages showed signs of ossification from eight days of age. This confirms the findings of White (1968).

The oesophagus and crop

The course, diameter and relationship of the oesophagus of domestic duck have been worked out at length. The crop was observed as a spindle shaped enlargement just cranial to the thoracic inlet whereas Das et al. (1965) reported that the crop was absent in duck. The length of oesophagus and crop increased 3.15 times at a progressive rate upto 30 days of age and thereafter the increase was at a slower rate and at 180 days of age it had a length of 32.33 $\pm$ 0.945 cm. The anteriormost part of the oesophagus showed greater diameter compared to other regions except the crop.

The mucosa of the oesophagus and crop showed many longitudinal folds. The mucosal folds permit considerable distension without undue stretching of the mucosa.

The crop has been described by Blount (1947) as a

receptacle favouring the growth of acid-forming carbohydrate-splitting bacteria and has been considered by Bolton (1965) to function in a manner which bears certain resemblance to the rumen. The scanning electronmicroscopic study of the chicken crop showed folded surface with a very dense surface bacterial population indicating microbiological fermentation and digestion of feed in the crop of chicken (Bayer et al., 1975). Whether such a function exists in the crop of the duck has not been established.

Although Ziswiler and Farner (1972) reported extensive cornification of the oesophageal epithelium of the duck, in this study no distinct stratum corneum was observed. This is in agreement with the findings of Das and Biswal (1967) and Rao and Hafeezuddin (1987a).

The thickness of the stratified squamous epithelium of the oesophagus decreased towards the posterior part. The dermal papillae were more at the anterior part of the cervical oesophagus. The microscopic papillae appeared in the epithelium of the crop and thoracic oesophagus at 15th day of hatching. The dermal papillae and microscopic papillae were deep and more in number towards the posterior part of the thoracic oesophagus. The abundant mucosal folds with microscopic papillae of the crop increases the surface area of the crop mucosa for microbial action.

The simple tubular subepithelial mucous glands seen in the lamina propria of day-old ducklings became branched

tubular by eighth day. The mucous glands were more at the auditus oesophagi as well as at the posterior most part of the thoracic oesophagus. These glands were PAS positive and showed holocrine secretion. The holocrine nature of the glands confirms the findings of Das and Biswal (1967). In the duck, the mucosal glands were found throughout the crop as has been reported by McLelland (1975), whereas in the case of chicken, the glands were confined to the crop channel (Calhoun, 1954 and Nickel et al., 1977).

There were also lymphoid tissue both diffuse and nodular forms especially around the glands. But Calhoun (1954) could not find any lymphoid tissue in the crop of chicken.

The muscularis mucosa was not observed in any region of the oesophagus and crop. The submucosa was very thin. The tunica muscularis was composed of inner longitudinal and outer circular layers of smooth muscles whereas in the case of chicken the reverse was true (Calhoun, 1954 and Hodges, 1974). In the tunica muscularis the inner longitudinal layer showed thickenings at the base of the folds. In the day-old ducklings, this muscle entered a short distance into the mucosal folds at the anterior part. This observation agreed with those made earlier by Rao and Hafeezuddin (1987a). However Das and Biswal (1967) had reported the presence of muscularis mucosa in the oesophagus. Trautmann and Fiebiger (1957) stated that the inner longitudinal muscular layer

following mucosal folds alone must be considered as muscularis mucosa. Bone (1979) reported three layers of muscle fibres in avian oesophagus namely, an outer longitudinal, middle circular and an inner longitudinal muscles.

Presence of oesophageal tonsil at the oesophago-proventricular junction has been reported by Hodges (1974), McLelland (1975) and Nickel et al. (1977) and the findings have been confirmed in the present study also. The present study revealed that there was a progressive development of lymphoid tissue as age advanced. Dense and diffuse lymphoid tissue was present upto the age of 60 days. Flattening of mucosal crypt epithelium and intraepithelial lymphocytes were observed. Lymph nodules appeared by 75 days and germinal centres were evident at 150 and 180 days of age. Mucosal lymphoid tissue has been credited to contain cells which allow antigen uptake and processing with subsequent generation of an antibody response, primarily in the form of secreting IgA (Bienenstock and Befus, 1980). Gut associated lymphoid tissue (Befus et al., 1980;Bienenstock and Befus, 1984; Pappo and Owen, 1988) has been described in both birds and mammals. The close association of lymph nodule with a corresponding epithelium was typical in avian and mammalian descriptions of gut associated lymphoid tissue (Owen and Jones, 1974; Befus et al., 1980; Payne and Powell, 1984; Pappo and Owen, 1988). The specialised lymphoepithelium allows selective sampling of local antigen through

mucosal cells (Owen and Jones, 1974) and facilitate presentation of those antigen to near by cells of immune system. In the present study the development of nodules with germinal centres was seen at a later age and this may be due to exposure to antigens.

Proventriculus

The proventriculus of the domestic duck was found to be an elongated organ having narrow cranial and wider caudal ends with greatest diameter in its middle portion which is contrary to the observation of Das et al. (1965) who reported the proventriculus of duck as having a cylindrical shape with uniform diameter. Ziswiler (1967) has stated that the size of the glandular stomach is significantly correlated with the volume of food intake. The length of the proventriculus increased 3.8 times in 75 days from 1.5 $\pm$ 0.068 cm to 5.72 $\pm$ 0.569 cm. In the chicken the length of the proventriculus ranged from four to five cm (Nickel et al., 1977).

The mucous membrane of the proventriculus had numerous small papillae containing the openings of the proventricular glands supporting the observation made by Kolda and Komarek (1958). In the chicken these papillae were wider and macroscopically visible (McLelland, 1975).

The surface epithelium of the mucosa consisted of columnar cells with a basal nuclei and contained supranuclear mucin granules as in the fowl (Aitken, 1958 and Hodges, 1974).

The simple tubular glands extended from the base of the sulci lined by low columnar cells showed a basophilic basal and acidophilic apical cytoplasm. Clara (1934) was able to demonstrate the presence of oxyphilic granules in the epithelial cells of the tubular glands of thrushes. Bradley and Grahame (1960) have suggested that these cells produce hydrochloric acid (HCl).

Lipid vacuoles were observed in the surface epithelial cells and the superficial proprial glands, but not in the proventricular glands. A similar observation was made by Wight (1975) in both fasted and control domestic fowls. Toner (1963) did not observe lipids in the proventriculus of the domestic fowl by electronmicroscopy. As there was no morphological evidence that the lipid was secreted, possible explanation for its presence is that the lipids are mobilised to the area from adipose tissue during fasting as a readily available energy store for use by the cell on re-alimentation.

The lamina propria underlying the epithelium and occupying the centre of the mucosal folds consisted of collagen fibres and blood vessels. Elastic fibres were not observed in the lamina propria of domestic duck in contrast to the observation made by Calhoun (1954) in the domestic fowl. The lymphoid tissue occurred in both diffuse and aggregated forms as in the chicken (Calhoun, 1954 and Hodges, 1974) and as observed in the duck by Das and Biswal (1967).

There has not been a distinct muscularis mucosa in the duck proventriculus except the few strands of smooth muscle fibres mixed with the connective tissue fibres. Bradley and Grahame (1960) indicated diffuse muscularis mucosa in the chicken. Batt (1924) did not mention the muscular layer lying internal to the proventricular gland in fowl and he considered the inner longitudinal muscular layer of tunica muscularis as the muscularis mucosa. Calhoun (1954) found muscle bundles in chicken proventriculus below the surface glands, between the glandular lobules as well as in a longitudinal layer almost in contact with the tunica muscularis.

Farner (1960) stated that in many type of birds the glands penetrate into the muscularis mucosa during development, separating it into inner and outer layers. This explanation supports Calhoun's (1954) findings which suggested that the proventricular glands occurred within the muscularis mucosa. However, Menzies and Fisk (1963) and Toner (1963) considered the glands to be submucosal.

Czarnecki (1977) observed three layers of smooth muscles distal to the glandular elements of the proventriculus of developing chick. The inner longitudinal band of smooth muscle was found to be continuous with the muscularis mucosa of the oesophagus and it showed a bifurcation at the oesophageo-proventricular junction. The irregular smooth muscle masses seen immediately below the epithelium of the proventriculus represented the discontinuous inner layer of the

muscularis mucosae and the glands were situated in the tunica mucosa and hence referred to as mucosal glands.

Das and Biswal (1967) observed longitudinally oriented thick muscularis mucosae in duck proventriculus which was well developed at the base of the septa between the gland lobules and considered the proventricular glands within the lamina propria.

The proventricular glands of the domestic duck consisted of compound tubular glands arranged into many lobules. In the day-old ducklings, a single row of lobules with elongated ones at the anterior and middle part and small polygonal ones towards the posterior portion was observed in the present study. From 15 days onwards, the gland lobules were round or polygonal in shape in cross section. The largest lobules were observed at the middle part of the proventriculus. Ziswiler and Farner (1972) stated that the form of the proventricular gland is highly variable according to the group involved and they may be cylindrical, spherical or ellipsoidal.

Toner (1963) found that the gross clefts between cells were rare in osmium tetroxide fixed tissues by electron-microscopy, although the lateral cell membranes were not always closely apposed. He stated that the dentate appearance probably represented an artifact due to shrinkage during fixation and made possible by the basal location of the terminal bars plus absence of desmosomes.

The heterogenity of the glandular epithelium in morphology and staining reaction seen in this study would reflect the functional status of these cells (Chodnick, 1947 and Toner, 1963).

The cells of the glandular alveoli are oxyntico-peptic cells which secrete both HCl and the enzyme precursor pepsinogen hence combining the function of both chief cells and parietal cells of mammals and it resembled amphibian gastric glands where the glands has not been differentiated into acid and enzyme secreting types. The basal position of the terminal bars of the cell allows the use of most of the lateral surface as well as the apical surface for secretion and as such analogus to the intercellular canaliculi of the mammalian parietal cell and the surface area is increased by a factor of six (Toner, 1963).

The isthmus portion was characterised by the absence of proventricular glands and covered by a thin layer of koilin material. The lamina propria contained glands resembling gizzard glands.

The present study showed three layers of muscles in the tunica muscularis with thin inner longitudinal, thick middle circular and very thin outer longitudinal layers of smooth muscle as reported by Bradley and Grahame (1960), Nickel et al.,(1977) and Czarnecki (1977) in the fowl, whereas Batt (1924) and Calhoun (1954) observed only inner circular and outer longitudinal layers of smooth muscles in the tunica muscularis of the domestic fowl.

Gizzard

The gizzard attained a maximum weight of 58.317 ± 4.575 g at 75 days of age and the contribution to body weight was maximum at 22 days which is about 6.5% of the body weight and at 180 days, it was only 3% of the body weight.

The gizzard had a greater dorso-ventral diameter than its cranio-caudal diameter except in day-old ducklings in which the reverse was true. But in the case of chicken, the cranio-caudal diameter was more than its dorso-ventral diameter (McLelland, 1975). The weight of the gizzard was more correlated with its cranio-caudal diameter than dorso-ventral diameter.

The gizzard musculature was well developed in the duck and the mucosa was strongly adherent to the musculature which could not be peeled off easily.

The structure of the tendon layer of duck was similar to that of chicken as reported by Bradley and Grahame (1960) and Hodges (1974).

Fibrocartilage which was recorded at the junction of the smooth muscle and the tendon layer by Calhoun (1954) in the fowl was not observed in the duck.

The tendinous layer was absent in the craniodorsal and caudoventral blind sacs.

The lateral muscle of the gizzard of domestic duck

consisted of a single layer of circularly arranged smooth muscles eventhough Das and Biswal (1967) reported the presence of two layers of muscle. So also there was no striated muscle as described by Bradley and Grahame (1960) in the fowl.

The muscle fibres were grouped together into extensive interlocking small bundles with frequent anastomosis between the adjacent bundles. Bennett and Cobb (1969) suggested that this close connection between the muscle cells provide an anatomical bases for rapid propagation of impulses through the muscle mass and hence the massive rapid contractility of the whole organ.

The intermediate muscle of the blindsac consisted of inner longitudinal and outer circular layer of smooth muscles agreeing with the report of McLelland (1975) in chicken. This muscle bundles were smaller and loosely arranged as in chicken (Bennett and Cobb, 1969).

In certain regions of the caudoventral sac, the inner longitudinal layer of the tunica muscularis detached a thin layer of muscle that entered through the lower part of the submucosa for a short distance and then disappeared.

The absence of muscularis mucosa in the gizzard of domestic duck as reported by Calhoun (1954) and Das and Biswal (1967) in the chicken has been confirmed.

The submucosa consisted of a dense layer of connective tissue containing collagen fibres, blood vessels and nerve

plexuses similar to Calhoun's (1954) observation. Plenk (1932) and Das and Biswal (1967) designated this layer as the stratum compactum. Though Das and Biswal (1967) reported the presence of numerous branched tubular glands in the stratum compactum in the duck, none could be observed in the present study.

The gizzard glands were simple tubular glands and some glands showed branching at their basal portion and were present in the lamina propria.

The gizzard glands were lined mainly by the chief cells but few basal and intermediate cells were also observed in the basal portion of the gland as reported by Toner (1964) in the fowl.

The basal cell with large vesicular nucleus and pale cytoplasm had some of the characteristics of an undifferentiated cell. Chodnick (1947) observed these cells in the mitotic zone of the gland. The basal cell could therefore be a stem cell and the intermediate cell types represent phases in the differentiation of the chief cell from the basal cell.

Eglitis and Knouff (1962) mentioned certain large clear cells which they believed to be a second secretory type. These cells correspond in their distribution to the basal cells. Toner (1964) had opined that the basal cell might supply the carbohydrate component of the secretion in the

gizzard gland. But in this study the basal cells did not show any PAS positive reaction.

The surface cells showed two zones in the haematoxylin and eosin staining, a basal basophilic and apical acidophilic zone. The apical zone was PAS positive whereas the basal portion showed granules similar to that of chief cells in PTAH staining. According to Toner (1964) the surface cells might be an unusual form of mucosal cell or might perhaps be the final desquamating phase of the chief cell sequence.

The surface cells undergo a sequence of change involving the break down of cytoplasmic organisation and terminating in the sloughing off of these cells in the epithelial surface and they were seen within the gizzard lining.

The chief cell granules were specifically demonstrated by PTAH staining. The material in the gland lumen also shared the affinity for PTAH stain shown by the intracellular granules indicating that it was the secretion of the chief cells. A similar observation was made by Toner (1964) in fowl.

The substance in the glandular lumen gave positive carbohydrate reaction and this was absent from the chief cell granules as had been reported by Eglitis and Knouff (1962). Toner (1964) opined that the carbohydrate component was produced by the chief cell independently of the cytoplasmic granules, perhaps being added to the material in the lumen by the elaborate microvilli.

The gizzard lining consisted of arrays of vertical columns and a matrix which was arranged in a pattern of horizontal laminae. The vertical columns showed PAS positive reaction and also stained by PTAH. The intensity of the reaction varied from site to site. In the fundic portion of the gland there was a very slight response. But in the body and neck region where the secretion was in the form of thick rods, there was a strong response. A similar response was also observed by Eglitis and Knouff (1962) in the fowl. According to Aitken (1958) the response to Schiff's reaction was not due to glycogen since it occurred even after treatment with diastase and was negative with Best's carmine. He also observed that a corresponding reaction was not noted in the gland cells and much reduced in the secreted layer on the surface suggested the possibility of a progressive chemical change beginning immediately after secretion. The mucus secreted by the surface cells and cells lining the gland tubules near the free surface might serve as protective or adhesive purpose.

The histochemical analysis of the secretion of the tubular glands revealed the presence of carbohydrate and protein (Eglitis and Knouff, 1962). But the intensity of reactions varied at different levels of the secretory channels and identified the secretion as carbohydrate-protein complex of mucoprotein variety. The hardening of the secretion was due to the binding of -S-S- groups. But the amount of cystine in the membrane was relatively small in comparison with the

amount in the keratin. It was suggested that the lining was anchored to the mucosa by the hardened glandular secretion with the upper regions of the glands.

Luppa (1959) explained that the metachromasia of the surface cell granules was due to binding of the acid mucopolysaccharide group to basic amino acids of the protein.

The chemical nature of the gizzard lining has been described by many authors as being of a keratinoid nature. It has been termed Koilin by Hofmann and Pregl (1907) and keratohyalin by Calhoun (1954) and Bradley and Grahame (1960) and a hard keratin similar to hair by Aitken (1958).

Webb and Colvin (1964) have shown that the substance was a protein and not a keratin since it was insoluble in keratolytic solvents, resistant to pepsin but hydrolysed by trypsin. Its amino acid composition was similar to keratin except that the cystine content was much less and electronmicroscopically it had the appearance of precipitated protein. The mode of formation of the lining protein was described as initial secretion as liquid droplets into the lumen of the gland tubules, coalition and flow to the opening of the gland, where the liquid spreads out over the surface beneath the overlying hardened material. Hydrochloric acid, diffusing through from the lumen precipitates the liquid to form an additional lamellae under the hard lining. Continued repetition of this process resulted in laminated structure.

Eglitis and Knouff (1962) considered that the lining

consisted of arrays of vertical columns which represent secretion stream of chief cells which were strongly carbohydrate and protein positive and a matrix produced by the surface cells in horizontal laminations which showed negative to weak response to carbohydrate tests and a strongly positive test for protein indicating predominance of a protein. According to them, the chief cell secretion entered the gland lumen as fine filament and joined up with secretion from other cells to form compact masses in the glandular lumen. This suggested how the lining is anchored to the mucosa by hardened glandular secretion within the upper regions of the glands.

Toner (1964) demonstrated the filamentous structure of the intraglandular secretion. The mass became hardened in the middle and upper regions of the gland and entered the pit together with several other glandular masses. The secretion from the surface cells of the pits surrounds the glandular rodlets and leaving the mouths of the pits, spreads out to form the layers of matrix.

The gizzard-duodenal junction

The point of separation of these two organs was delineated by a constriction of the muscularis mucosa, forming a fold of the muscularis and the tunica propria, similar to the earlier observations of Hodges (1974) in the fowl. The fold on the ventral wall was thicker than at its dorsal wall.

Brunner's glands were not observed at this junction

eventhough Bradley and Grahame (1960) reported some simple branched acinar glands resembling Brunner's glands in the fowl. Absence of these glands is compensated by the abundance of mucus secreting cells in the surface epithelium and superficial parts of the glands.

Small round or oval cells with irregular dark nuclei and globular inclusions in the cytoplasm were observed in the duodenal villi which is similar to globular leucocytes reported by Toner (1965) in the fowl. Globular leucocytes were first described in the fowl by Clara (1926) and later by Greulich (1949). They were mildly eosinophilic, metachromatic with toluidine blue, PAS positive and they might have an immunosecretory function (Toner, 1965). Holman (1968) in an electromicroscopic study has localised the presence of acid phosphatase to the peripheral vacuolated areas of the leucocyte granules. Colvin et al. (1974) reported that the partial and complete degranulated mast cells migrated through the epithelium and was referred as globule leucocyte or Schollen leucocytes and the formation of these cells was not a pathological phenomenon. However, increased numbers of these cells were reported in some pathological states.

SUMMARY

Postnatal development of the upper digestive tract of of the White Pekin ducks were carried out using 72 ducklings aged from day-old to 180 days of age. The tongue, pharynx, oesophagus and crop, proventriculus and the gizzard showed a progressive growth pattern upto 75 days of age. The oesophagus and crop and the gizzard attained a maximum weight at 75 days whereas the tongue, pharynx and the proventriculus at a later stage of 150 days of age.

The spatula shaped hard keratin at the tip of the upper bill presented a whitish median line which was absent in ducklings aged 45 days and above. The four wide based papillae caudal to the median longitudinal mucosal ridge of the palate were arranged either in line with the ridge or in pairs, one pair in line with the ridge and the other side by side.

The long and spatula shaped tongue had a median longitudinal groove in the middle third of the tongue presented longitudinal rows of small papillae which converged to a nodular enlargement on either side and continued caudally by a wide ridge of mucous membrane. Lateral margins of the caudal half of the tongue presented about five conical papillae united by fine papillae. Among the transverse rows of papillae at the root of the tongue, the largest ones were seen close to the midline except in day-old ducklings in which they were of equal sizes.

The tongue was lined by stratified squamous epithelium which was keratinised at the lateral margins covering the horny papillae and the ventral surface at the tip of the tongue. The dermal papillae increased proportionately with thickness of the epithelium and had a follicular nature in the middle and caudal part of the tongue of the adult duck. The lamina propria was well developed in the body and root of the tongue and it showed encapsulated sensory nerve endings like Herbst's corpuscles, Grandry's corpuscles and Meissner's corpuscles. Numerous ganglion cells and encapsulated spherical bodies were also present in the lamina propria. The skeleton of the tongue was formed only by the entoglossal bone and its tip remained cartilagenous even at the age of 180 days. Ossification of the bone began by eighth day from the posterior part. Filiform, conical and fungiform papillae were observed in the tongue. Taste buds were many in the middle and posterior part of the tongue. Compound tubuloalveolar mucous glands were present in the body and root of the tongue which were holocrine in nature. Lymphocytic aggregations were frequently observed in the septa of the glands.

The pharynx was lined by stratified squamous epithelium. The choanal slit was lined internally by stratified squamous epithelium with numerous simple alveolar glands and the ducts opened separately to the surface epithelium. A cavernous tissue covered by pseudostratified ciliated columnar epithelium

was observed within the choanal slit. Diffuse and aggregated forms of lymphatic tissue were present below the epithelium. Submucosa presented densely arranged branched tubuloalveolar mucous glands. At the inlet of the laryngeal mound, the stratified squamous epithelium changed abruptly to pseudostratified ciliated columnar with numerous simple tubular or alveolar mucous glands. The crico-arytenoid glands and superficial and deep intrinsic muscles of the larynx were present in the submucosa. Cricoid, procricoid and paired arytenoid cartilages of the larynx showed signs of ossification from eighth day of age.

The oesophagus had a long cervical part, spindle shaped crop and a short thoracic part. The auditus oesophagi was very wide. The length of the oesophagus and crop increased progressively upto 180 days of age. The longitudinal mucosal folds were more at the crop and was lined by stratified squamous epithelium with an irregular surface. From 15th day onwards microscopic papillae were observed on the epithelial surface of the crop and thoracic oesophagus. The lamina propria presented mucous glands and lymphoid tissue throughout the oesophagus and crop. Muscularis mucosa was absent. Submucosa was very thin at the cervical oesophagus and absent in the crop and thoracic oesophagus. The tunica muscularis consisted of inner longitudinal and outer circular layer of smooth muscles and the thickness increased progressively with advancing age. The adventitial coat was replaced

by a layer of serosa in the thoracic part. A well developed oesophageal tonsil was observed at the junction of the thoracic oesophagus and proventriculus.

The elongated proventriculus of the domestic duck had a narrow cranial and wider caudal ends with numerous small papillae containing the opening of the proventricular gland on the mucous membrane. The mucosa was thrown into folds. The surface epithelium was lined by cuboidal to columnar cells which showed PAS positive reaction at the anterior and posterior part of the proventriculus. The simple tubular glands of the lamina propria were lined by low columnar cells with basophilic basal and acidophilic apical cytoplasm. The proventricular glands were unilobular compound tubular glands with straight tubules radiating from a central cavity and were lined by oxyntico-peptic cells which had a dentate appearance. From the central cavity, it was drained by the duct to the proventricular lumen. The muscularis mucosa as a separate distinct layer was not seen and the submucosa was absent. The tunica muscularis consisted of three layers with inner and outer longitudinal and middle circular layer of smooth muscle fibres. At the isthmus the mucosal folds gradually decreased in height and the plicae changed over to gizzard glands. The inner longitudinal muscle merged with the circular layer to form the muscles of the craniodorsal sac of the gizzard and the outer longitudinal layer was absent at the isthmus.

The gizzard had a greater dorso-ventral diameter than its cranio-caudal diameter except in day-old ducklings in which the reverse was true. The length and weight of the gizzard increased progressively upto 75 days of age. The gizzard was covered externally by the serosa below which was the tendon layer. In the blind sacs, the tendon layer was absent. The lateral muscle consisted of a single layer of circular smooth muscle while in the craniodorsal and caudoventral sacs, the muscle was arranged into inner longitudinal and outer circular layers of smooth muscles. The submucosa was dense and the muscularis mucosa was absent. The surface epithelium showed small papillary projections forming pits or crypts and composed of tall columnar cells which showed supranuclear PAS positive reaction. The gizzard glands in the lamina propria were simple or branched tubular glands lined mainly by the chief cells. Few basal and intermediate cells were also observed at its basal portion. The chief cell granules and the luminal contents showed similar reactions in PTAH and Trichrome staining. While the cell granules were PAS negative and the luminal contents showed a PAS positive reaction. The gizzard lining consisted of arrays of vertical columns secreted by the tubular glands which showed strong PAS positive reaction and a matrix produced by the surface cells which deposited periodically to form horizontal laminae and showed weak to negative PAS reaction. The fundic part of the gland was generally free

of secretion. The gizzard-duodenal junction was delineated by the constriction of the muscularis mucosa forming a fold of the muscularis and the tunica propria. Brunner's glands were absent. Globular leucocytes and lymphoid tissue were observed and crypts of Lieberkuhn were present in the lamina propria. The muscularis mucosa consisted of longitudinally arranged smooth muscle fibres. The tunica muscularis consisted of inner thick circular and outer thin longitudinal smooth muscles and covered by the serous layer.

The mouth cavity and the pharynx were supplied by branches of maxillary and mandibular arteries. The blood from these regions were drained into rostral cephalic vein and interjugular anastomosis. Oesophageal branches of the vagal and mandibular arteries and the aorta were distributed to different regions of the oesophagus and the blood drained from the cervical oesophagus and crop to jugular veins and thoracic oesophagus to cranial venacava. The proventriculus and gizzard received blood from coeliac artery and drained by proventricular veins and gastric veins.

Branches of the glossopharyngeal, hypoglossal and recurrent vagus nerve supplied the oral cavity, pharynx, oesophagus and crop. Branches of the recurrent nerves, vagus, oesophageal plexus and coeliac plexus innervated the thoracic oesophagus. The proventriculus was innervated by branches of the vagus and recurrent nerves and the gizzard by both vagi.

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* Originals not seen

POSTNATAL DEVELOPMENT OF UPPER DIGESTIVE TRACT IN THE DUCK

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ABSTRACT OF A THESIS

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ABSTRACT

The structure and postnatal development of the upper digestive tract of ducks at different stages of growth was studied using 72 White Pekin ducklings aged from day-old to 180 days for the proper understanding of their functional peculiarities. The growth, morphology and histology of the tongue, pharynx, oesophagus and crop, proventriculus and gizzard were studied using six birds at each age group. The oesophagus and the gizzard attained the maximum growth by 75 days whereas the tongue, pharynx, and the proventriculus at 150 days of age.

The tongue, pharynx and oesophagus were lined by stratified squamous epithelium. Herbst's, Grandry's and Meissner's corpuscles, ganglion cells and encapsulated spherical bodies were present in the tongue. Filiform, fungiform and conical papillae, many taste buds, anterior and posterior lingual holocrine mucous glands were observed in the tongue. The tip of the entoglossal bone remained cartilagenous and showed signs of ossification from eighth day of age.

Within the choanal slit, cavernous tissue covered by pseudostratified ciliated columnar epithelium was present. In pharynx, pharyngeal tonsils, palatine, sphenopterygoid and laryngeal salivary glands were noticed. At the inlet of the larynx, the epithelium changed to pseudostratified ciliated columnar. The laryngeal cartilages were cricoid, procricoid and paired arytenoid.

The oesophagus consisted of longer cervical part, spindle shaped crop and short thoracic part. The longitudinal mucosal folds were more at the crop and the microscopic papillae appeared on the crop and thoracic oesophagus from 15 days of age. The mucous glands were present throughout the oesophagus and crop. The muscularis mucosa and submucosa were absent. Tunica muscularis consisted of inner longitudinal and outer circular layer of smooth muscles. The adventitial cost was replaced by a layer of serosa in the thoracic part. A well developed oesophageal tonsil was present at the oesophago-proventricular junction.

The elongated proventriculus had narrow cranial and wider caudal ends with numerous small papillae containing the opening of the proventricular gland. The mucosal folds were lined by cuboidal to columnar cells. The superficial proprial glands showed zonation. The unilobular compound tubular glands were lined by oxyntico-peptic cells which had a dentate appearance. In the day-old ducklings, the lobules were elongated in the anterior and middle part and in the posterior portion they were small and polygonal in shape. From 15 days onwards, most of the gland lobules were round or polygonal in cross section. The central cavity of the gland and the duct were lined by tall columnar cells which were PAS positive. The muscularis mucosa as a distinct layer was not seen and the submucosa was absent. Tunica muscularis consisted of inner and outer longitudinal and

middle circular layer of smooth muscles and invested by the serous layer. At the isthmus, the proventricular glands and the outer longitudinal muscle layer were absent and the lamina propria contained glands similar to gizzard glands.

The gizzard had greater dorso-ventral diameter than cranio-caudal diameter except in day-old ducklings in which the reverse was true. The tendon layer was thickest at the tendinous aponeurosis and absent in the blind sacs. The lateral muscle consisted of single layer of circular smooth muscle whereas the blind sacs had inner longitudinal and outer circular layers of smooth muscle. Submucosa was dense and the muscularis mucosa was absent. The simple tubular gizzard gland was lined mainly by chief cells. The chief cell granules and the luminal contents showed similar reactions in PTAH and Trichrome staining. The surface epithelium showed papillary projections and were lined by tall columnar cells which showed supranuclear PAS positive reaction. The thickness of the glandular layer and the gizzard lining was more at the lateral wall. The gizzard lining consisted of arrays of vertical columns secreted by the tubular glands and the matrix produced by the surface cells. The lining was strongly adherent to the musculature and could not be peeled off. The blood and nerve supplies to these organs were studied using embalmed carcasses and angiograms.