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The angioarchitecture of the canine thyroid gland

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The angioarchitecture of the
canine thyroid gland

by

Kenneth Kurt Booth

A Thesis Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE

Department: Veterinary Anatomy, Pharmacology and Physiology
Major: Veterinary Anatomy

Signatures have been redacted for privacy

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TABLE OF CONTENTS

	Page
DEDICATION	iv
INTRODUCTION	1
LITERATURE REVIEW	6
Gross Anatomy of the Canine Thyroid Gland	6
Gross Anatomy of the Canine Parathyroid Glands	10
Embryology of the Canine Thyroid Gland	12
Embryology of the Canine Parathyroid Glands	17
Histology of the Canine Thyroid Gland	18
Histology of the Canine Parathyroid Glands	28
Angioarchitecture of the Canine Thyroid Gland	30
Angioarchitecture of the Canine Parathyroid Gland	64
MATERIALS AND METHODS	66
RESULTS	75
Gross Anatomy of the Canine Thyroid Gland	75
Gross Anatomy of the Canine Parathyroid Glands	80
Histology of the Canine Thyroid Gland	82
Histology of the Canine Parathyroid Glands	84
Angioarchitecture of the Canine Thyroid Gland	85
Angioarchitecture of the Canine Parathyroid Gland	95
DISCUSSION	97
Gross Anatomy of the Canine Thyroid Gland	97
Gross Anatomy of the Canine Parathyroid Glands	100
Histology of the Canine Thyroid Gland	102
Histology of the Canine Parathyroid Glands	108

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	Page
Angioarchitecture of the Canine Thyroid Gland	109
Angioarchitecture of the Canine Parathyroid Gland	144
SUMMARY AND CONCLUSIONS	147
Gross Anatomy	147
Histology	148
Angioarchitecture	150
BIBLIOGRAPHY	158
ACKNOWLEDGEMENTS	173
APPENDIX	175

DEDICATION

Dedicated in memory of
my grandfather,
Kurt H. Booth

INTRODUCTION

The thyroid gland is an important endocrine gland in the mammalian body. Thyroxin (tetraiodothyronine), the principal circulating hormone of the thyroid gland, regulates the basal metabolic rate, water and ion transport, and it is necessary for the differentiation, growth, and maturation of the nervous system (Turner and Bagnara, 1971). Thyro-calcitonin (calcitonin), elaborated by the parafollicular or C-cells, decreases blood calcium levels and is antagonistic to the parathyroid hormone which increases blood calcium levels (Turner and Bagnara, 1971).

Since the thyroid is an endocrine gland, its function is very intimately dependent on its vasculature for transport of its hormonal secretions. Stewart (1932) believes the thyroid gland has the richest blood supply of any organ in the body. Tschuewsky (1903) states the human thyroid gland is 5.6 times as vascular as the kidney and estimates the amount of blood flowing through the gland to be 560 cc/min/100 g of tissue. Early physiologists speculate that the main function of the thyroid gland consists in acting as a vascular shunt to protect the circulation to the brain (Major, 1909). Johnson (1953) reports early physiologists also hypothesize that because the gland is superficially placed, perhaps it acts as a cooling organ for the blood.

Although these early hypotheses are no longer held to be correct, they demonstrate that early physiologists recognize the vascular pattern of the thyroid to be an important architectural component of the gland and is very closely related to its function. They also realize that an understanding of the normal vascular system would aid in explaining some important physiological and pathological manifestations of the thyroid gland.

The inaccessibility of live human specimens for thyroid gland research led investigators to use suitable animal substitutes and, especially, the dog is being intensely studied as a preferable animal model. This was preceded by reports (Major, 1909; Modell, 1933) that the canine thyroid gland angioarchitecture is identical to that of the human. Even more recent investigators (Johnson, 1953-1955; Ichev, 1965, 1967-1970), albeit they disagree as to the intrinsic vascular pattern of the thyroid gland, believe the canine and human thyroid gland angioarchitectures are basically the same.

These reports of similar angioarchitectures are questioned in this investigation primarily because of the following morphologic differences existing between the human and canine thyroid glands:

1. The human thyroid gland resembles a shield covering the ventral surface of the trachea (Smithcors, 1964). [The Greek word "thyreos = oblong shield."]. Most frequently, the

canine thyroid gland consists of two separate lobes situated on the ventrolateral aspects of the trachea (Smithcors, 1964).

2. Some investigators (Berry, 1901; Williamson, 1926) affirm that the inferior thyroid artery is a more important vessel to the human thyroid gland than the superior thyroid artery. Available literature on the canine thyroid gland, on the other hand, states that the cranial thyroid artery is the principal vessel as compared to the caudal thyroid artery.

3. The major vessels supplying the human thyroid gland divide on the surface of the thyroid gland (Mastin, 1923). The major vessels supplying the canine thyroid gland, on the contrary, divide within the thyroid gland (Major, 1909).

The above differences form the basis for this investigation assuming that if differences exist on the gross morphologic level between the human and canine thyroid glands, differences may exist internally at the microscopic level as well. Further, it is thought that if the vascular pattern of a structure conforms to its morphology and two structures are morphologically different, there is a possibility that the vascular pattern is likely to be different. Halsted and Evans (1907) find many distinct differences in the anatomy and histology between humans and animals, and conclude that it is no longer justifiable to assume that the findings in animals must be identical with those in man.

Also, a survey of the literature to date reveals conflicting reports relating to the angioarchitecture of the canine thyroid gland. For studying the angioarchitecture of both the human and canine thyroid glands, almost all investigators in the past have employed the microscopic examination of stained serial sections of the thyroid glands, whose vascular system had been injected with a colored gelatin mass. Though this is a good method of investigation, occasionally serial sections can be misleading without giving a clear picture of the actual vascular pattern, e.g. sections not cut at the proper angles, too thick sections, and even some missing sections can attribute to an inaccurate picture and interpretation of the angioarchitecture. This can, in turn, lead the investigator to deduce wrong conclusions. The discrepancies in the literature attest to this fact and therefore need to be reconciled.

It has amply been made clear that conclusions should not be drawn from one method of study (Johnson, 1953). In addition to, 1) the conventional microscopic examination of stained serial sections of canine thyroid glands, 2) the examination of plastic casts of the entire vascular system depicting a three dimensional picture of its vasculature, which is not readily obtainable from serial sections, and 3) a clearing technique allowing observation of the capillary pattern around the follicles in the transparent, intact gland, were employed in

this investigation.

In view of the importance of the canine thyroid gland in research and of modern and unattempted techniques (2 and 3 above) providing a fairly accurate picture of the vascular pattern within the thyroid gland, the present investigation was initiated to accomplish the following:

1. to give a complete and fairly accurate description of the blood vascular system of the canine thyroid gland;
2. to resolve discrepancies existing in the literature on the vascular pattern of the canine thyroid gland;
3. to conclude the feasibility of using the canine thyroid gland as an animal model for human thyroid gland research; and
4. to provide additional information that may prove useful to future thyroid gland research.

Within the framework of this study, the gross morphology and histology, as well as the lymph drainage of the canine thyroid and parathyroid glands are investigated.

With respect to the nomenclature, the English equivalent of the latin terms in the *Nomina Anatomica Veterinaria*, 2nd edition (1973), published by the World Association of Veterinary Anatomists, is used.

LITERATURE REVIEW

Gross Anatomy of the Canine
Thyroid GlandLocation

The canine thyroid gland consists of two loosely attached lobes, lying ventrolateral to the cranial aspect of the trachea (Adam et al., 1970). They extend along the length of the trachea between the first five and eight tracheal rings (Smithcors, 1964). Bradley and Grahame (1959) and Hoskins et al. (1962) state that the lobes are symmetrical in size and shape, and are elongated with narrow extremities. The extremities are frequently referred to as the cranial and the caudal poles of the gland.

Although the lobes are symmetrical in size and shape, they are not always symmetrical in position. The cranial pole of the right lobe lies opposite either the caudal border of the cricoid cartilage of the larynx or the first tracheal ring. The cranial pole of the left lobe usually lies one to three tracheal rings caudal to that of the right lobe (Smithcors, 1964). Therefore, it can be inferred that the right lobe is more cranial in position than the left.

The thick dorsal border of each lobe is in close proximity to the carotid sheath (Smithcors, 1964). The lateral surface of each lobe is covered by the sternocephalicus muscle and its

relatively thin ventral border is in contact with the sternothyroideus muscle (Bradley and Grahame, 1959).

Thyroid isthmus

The presence or absence of a glandular isthmus seemingly depends upon the age and breed of the dog. Gilmore et al. (1940) and Hoskins et al. (1962) state that a glandular isthmus is present in the larger breed of dogs, but is absent in the smaller breed of dogs. Bradley and Grahame (1959) state that the two lobes are connected ventral to the trachea by an isthmus of variable dimensions, while Adam et al. (1970) describe the dog lacks a well-developed isthmus. Smithcors (1964) concludes that there is a small fibrous band in some dogs, representing a fetal vestige of the isthmus. According to him, a glandular isthmus is most frequently found in brachycephalic breeds along the ventral surface of the trachea, connecting the caudal poles of both lobes.

Size and weight

The relationship between size and weight of the thyroid gland to body weight has thoroughly been studied by many investigators. A variety of factors may influence thyroid gland size and weight; to mention a few are age, sex, estrous cycle, pregnancy and number of pregnancies, geographic origin, breed, and season of the year.

Gilmore et al. (1940) state that there are wide variations in the thyroid gland weight, but not exceeding 0.300 g/kg body weight. Reinhold (1949) studied 34 normal canine thyroid glands and reports the absolute weight of the glands range from 0.08 g - 6.09 g, with an average weight of 2.48 g. He observed that in pathological cases the relative weight is decreased or reduced, with a relative weight of 0.5 g.

Vicari (1932) and Latimer (1967) affirm the effect of age and body weight on the size and weight of the thyroid gland. Both investigators find that younger dogs and smaller breeds, especially the brachycephalic breeds, have proportionally larger thyroids. In younger animals, the ratio of size of the thyroid (in length) to pounds body weight is higher than in the adult.

Larger breed dogs have comparatively smaller thyroids, but practically the same absolute amount of thyroid tissue functions in a smaller breed dog as that present in a larger breed (Vicari, 1932). According to him, there is a tendency for a large thyroid being associated with small external parathyroid glands and vice versa. Haensly et al. (1964) find in beagles that the absolute thyroid weight varies less significantly from the age of one day to eight weeks than from the age of nine weeks to 15 years. From one day through the third week of age, the thyroid weights are related to body weight, and in the age period from fourth to eighth weeks, the

gland weight is independent of body weight.

Latimer (1967) indicates that females have a relatively larger thyroid gland than males. There is a normal enlargement of thyroids during estrus and pregnancy, with heavier thyroids occurring in repeatedly pregnant females than in males or non-pregnant females. It is also heavier in castrates than in non-castrates. However, Haensly et al. (1964) mention there is no sex difference in the weight of thyroid glands of the beagles in their studies.

Smithcors (1964) states both thyroid lobes (within the same dog) are more or less symmetrical in size and shape, with no constant difference between the mass of the two. He further describes that the size of the two lobes is variable. Occasionally the mass of one can be as much as 50 per cent or more greater than that of the other.

Accessory thyroid tissue

Hoskins et al. (1962) state that accessory thyroid tissue occurs in 50-75 per cent of all dogs. It may be found in a number of locations. It is distributed in the cervical connective tissue from the region of the larynx to the thoracic cavity. Hoskins et al. (1962) and Smithcors (1964) describe that accessory thyroid tissue can be found in the vicinity of the thyroid gland, in the region of the hyoid bone, within the thymus, along the entire cervical portion of the trachea, between the mediastinal pleurae, within the pericardium in the

aortic arch region, embedded in the periaortic fat, and subendocardially in the conus arteriosus. Accessory thyroid tissue has also been found in the vaginal wall of humans (Kurman and Prabha, 1973).

Gross Anatomy of the Canine Parathyroid Glands

The parathyroid glands are first described by Sandström (1880) (cited by Stromsten, 1947). Early investigators believe they are remnants of embryonic thyroid tissue and call them thyroid glandules (Smithcors, 1964). They are gray to golden brown in color and thus can easily be distinguished from the darker colored thyroid gland (Adam et al., 1970).

Location

Although Fowler and Hanson (1929) report the finding of only one parathyroid gland in close contact with the medial surface of the middle third of each thyroid lobe in the human, it is generally accepted that there are usually one pair of parathyroid glands in association with each thyroid lobe in the canine. Each one of the pair is designated as the "external" and "internal" parathyroid gland (Smithcors, 1964).

The external parathyroid gland is always lateral to the thyroid capsule of the respective lobe (Smithcors, 1964). Usually it lies in the cervical fascia at the cranial pole of the lobe (Hoskins et al., 1962), but it may be found between

the cranial and caudal poles, and occasionally it is seen lateral to the thyroid lobe (Smithcors, 1964).

The internal parathyroid gland lies beneath the thyroid capsule on the medial surface of the thyroid lobe. Occasionally it is embedded in the thyroid parenchyma and sometimes it is found on the lateral surface of the lobe (Smithcors, 1964).

Size and weight

Bradley and Grahame (1959) describe the parathyroid glands as small rounded bodies which vary in size from a large pin-head to a millet seed. The external parathyroid gland is usually larger than the internal gland, but this can vary contingent upon number, location, and structure in different breeds (Vicari, 1938). Smithcors (1964) describes the external parathyroid gland as a flattened oval body about 2-5 mm long, but it can range from 1 mm - 1 cm in length. Further, he states that the internal parathyroid gland is a small mass of inconstant size and shape. Mulligan and Francis (1951) find that the average weight of the external parathyroid gland is about 5 mg in the larger breeds of dogs.

Accessory parathyroid tissue

Hoskins et al. (1962) report that accessory parathyroid tissue occurs in about six per cent of all dogs. It may be dispersed within or in the region of the thyroid gland, in the entire neck region embedded in the cervical fat, along the

common carotid artery both cranial and caudal to the thyroid gland, along the cranial laryngeal nerve, in the cervical and thoracic parts of the thymus, and in the cranial mediastinum. Kurman and Prabha (1973) report the finding of accessory parathyroid tissue in the vaginal wall of humans.

Embryology of the Canine Thyroid Gland

Thyroid primordium

The primordium of the thyroid gland first appears as a solid cellular mass on the floor of the pharyngeal gut, in the lingual primordia, between the tuberculum impar ventrally, the copula dorsally, and the lateral lingual primordia arising from the first pharyngeal arch laterally, in man and other primates (Tuchmann-Duplessis and Haegel, 1972). The cellular mass forms a groove at the site of the embryonic foramen cecum. The groove deepens and a bud (composed of hypoblast and mesoblast) appears growing down into the underlying mesoblast (Williamson and Pearse, 1930).

As the bud moves caudally, it keeps a communication with the pharynx in the form of a hollow canal called the thyroglossal duct (Smithcors, 1964). This duct normally regresses, but may persist and not involute completely forming a thyroglossal cyst (Tuchmann-Duplessis and Haegel, 1972). Smithcors (1964) describes that groups of cells may become detached from this developing bud and descend with the aortic sac. He cites

this as reason for the presence of accessory thyroid tissue found at various locations as a result of further modifications of the aortic sac and aortic arches growing out of it.

Follicular development

Norris (1916, 1918) gives a very descriptive account of the development of the thyroid follicles in the human and states the same development has been observed in the dog and other animals. After a time, there appears in the thyroid mass a number of completely closed cavities. These cavities increase in size and finally open to the outside, whereupon they are invaded by vascular mesenchyme. These cavities are surrounded by epithelial plates, two cells in the thickness, and they appear before the follicular lumina develop (Norris, 1918). Williamson and Pearse (1930) believe these spaces are the precursors of the intrathyroidal lymph system. Thus, at this time, the thyroid gland is a mass of irregular, branching and fenestrated plates, arranged longitudinally, paralleling the long axis of the body. Because of this arrangement, the plates appear as cords of epithelial cells in cross section. It is within these plates that the follicles of the thyroid develop (Norris, 1916).

The first primary follicles appear as hillocks or mounds in the plates. The hillocks are produced as a result of four processes in the epithelium (Norris, 1916):

1. The first process is cell rearrangement where the cells of the plates rotate, so that their long axes are at right angles to their original position (long axes perpendicular to the surface of the plate).
2. The second process is cell proliferation where there is an increase in the number of cells.
3. The third process is increase cellular size where the cells increase in height.
4. The fourth process is lumen formation. Before the lumen forms, the cells of the follicle are circularly arranged with their central ends in contact with each other. These cells then seem to draw apart and leave a small, central lumen. Norris (1916) notes that there is no tubular stage formed. The lumina are independent spaces which contain some substance that do not stain with ordinary methods. Some larger lumina contain a hazy, granular substance (Norris, 1916). Colloid does not appear in the dog's thyroid until the fetus is 25 days old (Gilmore et al., 1940).

The follicles then increase in number and may form a number of solid or hollow buds. This process of budding forms new follicles and it continues until the gland is made up entirely of spherical follicles (Wilson, 1927). During this period of development, groups of cells may become isolated and form accessory thyroid tissue (Smithcors, 1964).

Thyroid isthmus

The isthmus is formed from the medial portion of the thyroid plate (Smithcors, 1964).

Ultimobranchial body

Before the follicles are formed, the thyroid gland fuses with the ultimobranchial body along the caudal two thirds of the gland. Usually, the fusion is by interdigitation of the ultimobranchial body with the thyroid cells, but sometimes the ultimobranchial body extends free, caudal to the thyroid lobes (Godwin, 1937a).

The ultimobranchial body arises as an endodermal diverticulum from the caudal wall of the fourth branchial pouch. Because it is quite large in the dog, it is sometimes considered as a fifth pouch with certain differences (Godwin, 1937a).

There is varied opinions about the ultimobranchial body forming thyroid tissue in the early literature. Godwin (1937a) cites Rogers (1927) stating that the ultimobranchial body forms one-third to one-half of the thyroid gland, whereas Mason (1931) believes it does not form any thyroid tissue in the cat. Godwin (1937a) compromises by stating that the ultimobranchial body in the dog is not endowed with thyroid forming potencies, but it does form thyroid tissue, apparently by homeogenetic induction.

Parafollicular or C-cells (Calcitonin cells)

It is now believed that the ultimobranchial body gives rise to the parafollicular or C-cells of the thyroid gland. These cells were once thought to be associated with the formation of new thyroid follicles (Smithcors, 1964), but it is now considered that the parafollicular cells secrete thyrocalcitonin, whose function is to lower the blood calcium levels. Its effect is antagonistic to the parathyroid hormone, Parathormone, which increases calcium levels in the blood (Turner and Bagnara, 1971).

Nonidez (1932a and b), Raymond (1932), Zechel (1933), and Vicari (1937) all consider the parafollicular cells to arise from the follicular epithelium in the dog, however Jordan et al. (1973) state that Le Douarin and Le Lieure (1972) have provided experimental support for the hypothesis advanced by Pearse (1966, 1969) that the parafollicular cells originally arise from neural crest cells which form an immigrant population within the endodermal ultimobranchial body. Jordan et al. (1973), by electron microscopic study on sheep, have traced the origin of the parafollicular cells to "Dark Cells" contained within the ultimobranchial body. Kameda (1972) found no parafollicular cells in accessory thyroid tissue and states that this "not only indicates that the parafollicular cells and follicular cells are of two distinct cell lines but also suggests that accessory thyroid glands are separated before the

ultimobranchial body becomes involved in the main thyroid."

Embryology of the Canine Parathyroid Glands

Parathyroid primordium

The parathyroids of the dog originate from the third and fourth pharyngeal pouches. There has been no evidence that parathyroid tissue arises from any other source (Godwin, 1937b).

External parathyroid glands

The external parathyroid glands are known as Parathyroid III because they develop from the third pharyngeal pouch. Part of the thymus, i.e. Thymus III, also develops from this same pouch. The external parathyroid gland develops as a thickening on the dorso-cranial face of pharyngeal pouch III (Smithcors, 1964). A duct is formed connecting the parathyroids with the pharynx, which later regresses (Smithcors, 1964).

In further growth, cells dissociate from the external parathyroid mass and give rise to accessory parathyroid tissue (Godwin, 1937b). Since Thymus III develops from the same third pharyngeal pouch, some parathyroid cells become associated with it. In its descent, Thymus III, developing from the third pouch, carries parathyroid tissue with it and some endodermal epithelial cells become detached and may be left stranded at various levels (Godwin, 1937b). This explains the distribution of accessory parathyroid tissue in the neck region (Smithcors,

1964), and those cells that are not stranded, remain in the thymus. This explains the presence of parathyroid tissue in the thymus (Godwin, 1937b).

Internal parathyroid glands

The internal parathyroid glands arise from the fourth pharyngeal pouch. Thus, they are known as Parathyroids IV, arising together with Thymus IV. These parathyroids are first connected to the pharynx by an open duct becoming a solid cell cord which later regresses. The internal parathyroid mass then undergoes a period of fusion and inclusion with the thyroid (Smithcors, 1964).

Early fragmentation of Parathyroid IV, with subsequent growth shiftings, is quite sufficient to account for the number and position of the accessory Parathyroids IV found within or associated with the thyroid gland or Thymus IV of the dog (Godwin, 1937b).

Histology of the Canine Thyroid Gland

Thyroid gland capsule

Varied opinions exist in the literature about the fascial and spacial arrangements surrounding the human and canine thyroid glands (de Quervain, 1916; Fowler and Hanson, 1929; and Thorek, 1949). However, the description of the capsule of the canine thyroid gland will be restricted to its significance so

far the angioarchitecture is concerned.

Most histology textbooks (Bloom and Fawcett, 1968; Leeson and Leeson, 1970) describe the human thyroid gland as being enveloped by a double capsule, viz. 1) an external capsule which is continuous with the deep cervical fascia and is easily removed and, 2) an internal (true capsule) which is closely adherent to the gland. On the other hand, in domestic animals, Trautmann and Fiebiger (1957) state that the thyroid gland is surrounded only by a connective tissue capsule. Smithcors (1964) adds that the capsule of the canine thyroid gland is composed of the middle cervical fascia and the pre-vertebral fascia, and this capsule is intimately related to the parenchyma of the gland.

Similar to that in human (Wilson, 1927; Ichev, 1965), the capsule of the canine thyroid gland sends trabeculae (septa) into the gland thus lobulating its internal structure (Trautmann and Fiebiger, 1957; Smithcors, 1964; Dellmann, 1971). Reinhoff (1929) does not affirm the lobular structure of the human gland. However, Johnson (1955) points out that Reinhoff's conclusions might have been arrived at from his wax reconstruction models. According to Johnson, the trabeculae are relatively thin and the boundries of the lobular structure are not well delineated. He believes that since these boundries are only barely visible in stained microscopic sections, they probably are not observable from wax models. Dellmann (1971)

states that the trabeculae are thin in all domestic animals, except in large ruminants and swine.

Major (1909) and Ichev (1965) have classified this lobulation as follows:

1. Lobes of First Order (Structural Lobes)¹ - the anatomical lobes of the gland. They consist of:
2. Lobes of Second Order (Functional Lobes) - first subdivision. They consist of a variable number of:
3. Lobes of Third Order (Lobules) - second subdivision. They consist of a variable number of:
4. Follicles (Follicles) - basic units of the thyroid gland.

Thyroid follicles

The follicles are the basic unit of the thyroid gland and are responsible for the elaboration, storage, and secretion of thyroxin (Turner and Bagnara, 1971). Their shape is usually described as being round (Gilmore et al., 1940; Reinhold, 1949), ovoid, or tubular or saccular (Trautmann and Fiebiger, 1957).

Smithcors (1964) states that the follicles are composed of two types of cells, viz., chief and colloid cells. The

¹Synonymes in parentheses are comparable names used for correlating the intrinsic vasculature which closely follows the internal structure of the gland as observed in this investigation.

chief cells are cuboidal and are supposed to be the actively secreting cells (Webster, 1933; Taylor and Weber, 1951) containing a rounded, lightly staining nucleus (Baillif, 1937). The colloid cells are supposed to be postsecretory cells (Webster, 1933; Taylor and Weber, 1951), which are also cuboidal but contain darkly staining cytoplasm with pycnotic nuclei (Baillif, 1937). Hoskins et al. (1962) describe the cells lining the follicles as flattened, cuboidal, or columnar, depending on their physiological state of activity. Wilson (1927) believes the cuboidal form is found in pathological glands, whereas the normal gland contains the columnar type. However, Baillif (1937) and Taylor and Weber (1951) contend these two cell types represent different stages of the secretory activity of the same cell. Sugiyama (1954) and Dellmann (1971) state that in the inactive or resting phase, the cells are squamous and in the active or stimulated phase, the cells become columnar.

Bloom and Fawcett (1968) report that the size of the follicles in man vary greatly, whereas in animals "the follicles are of more uniform size." Reinhold (1949), however, observes follicles of different sizes in the dog, and Dellmann (1971) contends the follicles in domestic animals vary in size. The follicles range from 30 to 160 microns in diameter in the dog (Smithcors, 1964).

This variation in size is correlated to the physiological state of activity of the follicles which, in turn, is depended upon diet, nutrition, climate, sex, age, season, geographic location, pregnancy, and sexual cycle (Hoskins et al., 1962). Hoskins et al. (1962) also state that it seems to be related to the shape of the muzzle and head in different breeds, where the thyroids of the dolicocephalic breeds contain large, well-developed follicles and those of the brachycephalic breeds contain small abnormally arranged follicles. Zechel (1933) believes this variation in size is due to a "follicular cycle"- a continuous process of destruction and formation of new follicles. Wilson (1927), on the other hand, contends that the number of follicles is determined at an early stage of development and this variation is due to growth in size and not in number of follicles.

Dellmann (1971) believes reticular fibers, continuations of the trabeculae, form the basement membrane of the thyroid follicles, while Gilmore et al. (1940) state that the reticular fiber boundary is not always present. Therefore, the follicles may or may not be completely surrounded by these fibers and there is no true basement membrane. Isler et al. (1969) find follicles in direct contact with each other. They are not separated by connective tissue, reticular fibers, or basement membrane, and this area of contact involves about twelve follicular cells in each follicle.

Follicular colloid

The follicular lumina are filled with a homogeneous, iodine-rich material called colloid (Hoskins et al., 1962; Trautmann and Fiebiger, 1957). Colloid is the stored secretion of the follicular cells and it contains thyroglobulin, an iodized glycoprotein (Turner and Bagnara, 1971). Berthezene and Greer (1974) describe "Psammona Bodies" - small PAS - positive, concentrically laminated structures, which they find in human papillary cancer and in the colloid of iodine-deficient rats. They postulate these structures might contain or consist of thyroglobulin.

There are two striking histologic features of the follicular colloid:

1. Its differential staining capacity (Hoskins et al., 1962): Reinhold (1949) finds the colloid in different follicles to be either eosinophilic or basophilic with some follicles containing partly eosinophilic and partly basophilic stained colloid. He also finds some follicles with a clear, water-like, unstained colloid. Stein (1940) attributes this to the activity of the follicle, for he observes hyperactive follicles stain basophilic and inactive follicles stain eosinophilic. He also believes this staining reaction is influenced by the iodine content of the colloid. In contrast, Hewer (1927) does not believe it is due to the iodine content, while De Robertis (1941) assumes it is due to differential penetration of fixing

agent and its chemical effect on the iodine content.

2. The occasional appearance of vacuoles in the colloid. De Robertis (1941) regards them as artifacts, while Williams (1941) believes they are an abnormal secretory response. He finds them to contain a thin watery material and states they are produced by "colloid liquefaction of the cytoplasm."

Hormonal secretion

Although the mechanism of thyroxin secretion from the follicles is not completely understood, Turner and Bagnara (1971) state the epithelial cells secrete a protease into the colloid which breaks up the thyroglobulin into a series of iodinated derivatives of tyrosine, viz. thyroxine and triiodothyronine, which pass into the circulation by a concentration gradient between the colloid and the tissue fluids. However, Nunez et al. (1972) observe, in the canine thyroid gland, colloid droplets in the cytoplasm of the follicular cells formed by "phagocytosis through the formation of apical cytoplasmic pseudopods which enclose portions of the peripheral colloid." They believe that the colloid within these droplets are then digested by cellular enzymes to amino acids, thyroxin and triiodothyronine; the last two of which are released into the circulation.

Parafollicular or C-cells (Calcitonin cells)

Parafollicular or C-cells, a second epithelial component of the thyroid gland (Nonidez, 1932a), are associated with a

variety of names. Baber (1876, 1881), who is the first to describe these cells, calls them parenchymatous cells. They are also known as "protoplasmareichen zellen" (Huerthle, 1894), interfollicular cells (Takagi, 1922), and macrothyrocyte (Zechel, 1933). Nonidez (1933) gives them their present name, parafollicular cells. The literature also describes them as C-cells, since they are now known to secrete calcitonin (thyrocalcitonin).

In histologic sections, parafollicular cells can be distinguished from follicular cells by the following characteristics:

1. The cells are larger than the follicular cells (Bensley, 1914; Nonidez, 1932a, b) and are spherical in shape with a homogeneous cytoplasm (Zechel, 1933).
2. Their nuclei do not differ in size or shape from that of the follicular cells (Raymond, 1932), but do differ in being clear and vesicular (Nonidez, 1932a; Teitelbaum et al., 1971) with a distinct net of chromatin (Zechel, 1933).
3. Their cytoplasm contains numerous argyrophilic (Nonidez, 1933) or darkly staining secretory (Kameda, 1973) granules.

The cells are usually found in three locations, viz.

- 1) between the follicular cells, 2) between the follicular cells and the basement membrane of the follicle, and 3) as cell

clusters, with their own basement membrane, outside the follicular membrane (Bensley, 1914; Nonidez, 1933; Zechel, 1933; Vicari, 1937; Roediger, 1973). Roediger (1973) observes that in young dogs the parafollicular cells are concentrated in the area of the parathyroid gland and cranial thyroid artery, whereas in older dogs they are dispersed throughout the thyroid gland. He attributes this dispersal to growth of the gland.

Vicari (1936a, b, 1937) states that age does not influence the amount of parafollicular cells in the canine thyroid gland, however the amount does vary with breed, pregnancy status, and physiologic activity of the gland. He finds parafollicular cells in an external parathyroid gland of a female dog in estrus. Roediger (1973) states that Stux et al. (1961) find parafollicular cells to be 5 per cent of the total thyroid weight in rats, irrespective of age.

Other cellular masses

Occasionally, one can find other cellular masses within the thyroid gland which are designated as remnants of embryonic structures. Thyroid cysts, originating from the ultimobranchial body, are normally found in the thyroid gland of the cat (Mason, 1931). Jordan et al. (1973) find ultimobranchial cysts embedded within the thyroid gland of sheep. They describe these cysts as forming a large elongated structure, whose cells form cords, extending away from the cyst wall

and thus making contact with the thyroid tissue. Tashiro (1963) describes an ultimobranchial cyst in a dog as consisting of simple and stratified epithelia, both containing faintly eosinophilic granules. Superficial epithelial cells of these cysts are cuboidal to columnar in shape, with some being ciliated. Underlying cells are polygonal. Most of the centrally located nuclei are irregular and appeared multi-lobulated, others are oval.

Jubb and Kennedy (1963) describe ultimobranchial cysts as having a clear fluid content or pale eosinophilic colloid. The cysts are lined by a simple columnar, partially ciliated epithelium, which may form thyroid microfollicles. Calvert (1975) finds ultimobranchial bodies in rats and states they develop into an elongated tube or duct which give off numerous smaller ducts. These smaller ducts dilate into ultimobranchial follicles. According to him, the walls of the tube are composed of stratified epithelium and its lumen contains a PAS - positive material together with cellular debris. The smaller ducts contain a colloid-like material. The ultimobranchial follicles consist of a stratified squamous epithelium and range in diameter from 30 to 200 μm . Calvert also describes mixed follicles, whose walls are composed of follicular and ultimobranchial cells, and states that these mixed follicles could be mistaken for typical thyroid follicles because their lumina contain a colloid-like material. However,

he observes that these mixed follicles do not incorporate radio-iodine and thus do not function as thyroid follicles. He does not attribute any function to them.

Kameda (1971 and 1973) finds parafollicular cell complexes within canine thyroid glands and regards them as remains of the ultimobranchial body. His oval complexes, separated from the thyroid parenchyma by connective tissue, are found around the internal parathyroid glands and consist of parafollicular cells and a few columnar epithelial cell masses. The largest complex measure 2.5 mm in diameter.

Norris (1916) describes cysts which he believes to be remnants of embryological primary follicles. According to him, these cysts are located in the lower and dorsal part of the thyroid lobe; their walls are made up of fattened epithelial cells; the circular lumina contain a glandular substance; and they give off hollow buds by constriction.

Histology of the Canine Parathyroid Glands

Parathyroid gland capsule

The external parathyroid glands possess a thin connective tissue capsule (Trautmann and Fiebiger, 1957; Dellmann, 1971). However, a capsule is often absent around the internal parathyroid glands when they are embedded in the thyroid gland (Trautmann and Fiebiger, 1957). Fowler and Hanson (1929) do not observe a capsule between the parathyroid and thyroid.

glands.

Similar to the thyroid gland, the capsule of the parathyroid glands sends fine, delicate septa into the gland (Flint, 1904), which end as reticular fibers surrounding individual cells (Trautmann and Fiebiger, 1957).

Parathyroid gland epithelial cells

According to Dellmann (1971), there are four types of cells comprising the parathyroid glands, viz.:

1. Light Chief Cells - inactive cells possessing a large, light nucleus and light acidophilic cytoplasm.
2. Dark Chief Cells - active cells possessing a much darker cytoplasm and containing many large (100-200 μ m) secretory granules.
3. Oxyphilic cells - very large cells with a light eosinophilic cytoplasm. These cells are rare in all domestic animals, except horse and large ruminants.
4. Syncytial Cells - small, dark cells containing an acidophilic cytoplasm and dark nucleus.

By this classification, Dellmann appears to indicate all cell types, except oxyphil cells, are present in the dog. Adam et al. (1970), on the contrary, state that only the chief cell is present in young dogs, while oxyphil cells appear in older prosenile dogs. Taylor and Weber (1951) conclude that oxyphil cells are absent in the dog and cat.

Besides these cells, Pacinian corpuscles also are reported in the canine parathyroid glands (Trautmann and Fiebiger, 1957; Adam et al., 1970).

Unlike the follicular arrangement of the epithelial cells in the thyroid gland, the epithelial cells of the parathyroid glands are arranged in irregular cellular cords or clusters and orientated toward the numerous, sinusoid-like capillaries within the glands (Flint, 1904; Taylor and Weber, 1951; Trautmann and Fiebiger, 1957; Hoskins et al., 1962; Smithcors, 1964; Adam et al., 1970; Dellmann, 1971).

Angioarchitecture of the Canine Thyroid Gland

Arteries

Johnson (1953) credits Beğoune (1884) for doing the first systematic study of the thyroid blood vessels in humans. A review of the English literature reveals that Major (1909) first studied comparatively the thyroid vasculature in the dog, cat, and human.

Major supply The blood flow through the human thyroid gland is estimated to be 560 cc/min/100 g of tissue (Tschuewsky, 1903). This enormous amount of blood is supplied by the superior and inferior thyroid arteries, and sometimes by an inconstant thyroid ima artery (Wilson, 1927; Johnson, 1955; Goss, 1966; Nomina Anatomica, 1966). Controversy exists as to which artery, the superior or the inferior thyroid artery,

provides the major supply to the gland in humans. Fowler and Hanson (1929), and Stewart (1932) believe the inferior thyroid artery is the chief blood supply to the gland. Wangensteen (1929) quotes Eiselsberg (1901) stating the inferior thyroid artery is the most important vessel of the human thyroid gland. Johnson (1953) reports that the inferior thyroid artery supplies two-thirds of the thyroid lobe, while Ichev (1970) states that "the superior thyroid artery supplies the antero-medial portion of the thyroid lobe and the inferior thyroid artery supplies the postero-medial portion of the lobe."

de Quervain (1916) assumes that the inferior thyroid artery is the chief supply to the human goiter, while Wangensteen (1929) cites Sobotta (1915) describing the inferior thyroid artery as usually being larger than the superior thyroid artery in the normal human thyroid gland. Major (1909), Mastin (1923), and Rogers (1929) hold that the inferior thyroid artery is larger than the superior thyroid artery in humans. Rogers (1929) cites Berry (1901) who also believes the superior thyroid artery to be much smaller than the inferior thyroid artery, and Wilson (1927) reports that Williamson (1926) believes the inferior thyroid artery supplies only the parenchyma, while the superior thyroid artery "has a certain nutrient function to the interstitial tissue," similar to the hepatic artery in the liver.

On the contrary, Rogers (1929) states that the superior thyroid artery is the primitive artery to the human thyroid gland and it is never absent. Mastin (1923) reports that Dwight (1894) finds the inferior thyroid artery absent on the right in one case and on the left in five cases out of 437 human specimens studied. Hunt et al. (1968) find the right inferior thyroid artery more often absent than the corresponding left and thus the major supply, in these cases, comes from the superior thyroid artery. Jarvis and Nell (1963) quote Adachi (1928) stating that sometimes the inferior thyroid artery is so small that it does not supply the gland at all, but ends in branches to the trachea and esophagus. Wangenstein (1929) reports that Jaeger-Luroth (1883) believes the superior thyroid artery is the main vessel of the thyroid gland.

All the available literature agree that animals possess a cranial thyroid artery; however, a controversy exists as to the presence of a caudal thyroid artery in different species (Nickel and Schwarz, 1963). Bugge (1967) and Ichev (1967a) state that the caudal thyroid artery is absent in the rabbit and the entire gland is supplied by the cranial thyroid artery. Reilly (1954), on the other hand, affirms the presence of a cranial and caudal thyroid artery in the rabbit and believes the caudal thyroid artery supplies most of the gland, whereas the cranial thyroid artery sends only one small glandular branch to the upper pole of the thyroid lobe, thus supplying

only the upper pole. He believes the caudal thyroid artery supplies the remainder. Reilly also points out that the cranial and caudal thyroid arteries of the rabbit are "not strictly comparable to the human superior and inferior thyroid arteries," but the territory of distribution of the cranial and caudal thyroid arteries of the rabbit is similar to those of humans.

Nickolas and Swingle (1925) state that the cat positively lacks an inferior (caudal)¹ thyroid artery and that the superior (cranial) thyroid artery supplies all the blood to the thyroid gland, whereas Major (1909), and Reighard and Jennings (1966) believe the cat possesses both a superior (cranial) and inferior (caudal) thyroid arteries, but that the cranial thyroid artery supplies the majority of blood to the thyroid gland.

The canine thyroid gland has a mean blood flow of 1.09 cc/min/g of tissue (Folkman and Gimbrone, 1972) and most of the literature states that the canine possesses a cranial thyroid artery, which is the major blood supply to the gland, and a smaller caudal thyroid artery that may be absent in some dogs (Major, 1909; Bradley and Grahame, 1959; Smithcors, 1964;

¹Whenever the literature uses human terminology in describing the vascular supply to the thyroid gland of four-legged quadrupeds, the terminology adopted in *Nomina Anatomica Veterinaria*, 1973, will be placed in parentheses.

Ichev, 1969b). However, Smithcors (1964) adds that when the caudal thyroid artery is well developed in the dog, the cranial thyroid artery is reduced in a reciprocal ratio. Bradley and Grahame (1959) believe the caudal thyroid artery assists in the blood supply to the canine thyroid gland and Nomina Anatomica Veterinaria (N.A.V., 1973) definitely classifies the canine as possessing a caudal thyroid artery and states that a caudal thyroid artery is present in sheep, but inconsistent in the ox and goat. Rogers (1929) affirms the presence of the superior (cranial) thyroid artery and the inconstantly present inferior (caudal) thyroid artery in animals, in general.

Wangensteen (1929) quotes Latarjet and Alamartine (1910) who conclude that the superior (cranial) thyroid artery is the more important vessel of the thyroid gland in any vertebrate, while the inferior (caudal) thyroid artery is only found in higher vertebrates. Nickel and Schwarz (1963) state that the caudal thyroid artery does not occur in all domestic animals and in those species where it is described, it is not constantly present. Thus, they conclude the cranial thyroid artery is the main blood supply to the thyroid gland in domestic animals. In support of their conclusion, Nickel and Schwarz cite Zietzschmann (1943) who believes the caudal thyroid artery is almost always absent in the dog, and Loeffler (1955) who found the artery in only four out of eleven dogs, three cases on both sides and in one case only on the right side.

Caudal (inferior) thyroid artery

In humans, the

inferior thyroid artery arises as the largest branch of the thyrocervical trunk (thyroid axis), which arises from the subclavian artery on each side (Rogers, 1929; Fowler and Hanson, 1929; Stewart, 1932; Goss, 1966). Rogers (1929) cites Quin (1854) that it may arise from the common carotid, vertebral, or subclavian arteries as an independent trunk. Allen (1952) describes a "deep inferior thyroid artery" arising from the superior surface of the subclavian artery. The inferior thyroid artery courses cranial (ascending portion - Swigart et al., 1950) ventral to the longus colli muscle, then turns medially, descends (descending portion - Swigart et al., 1950) dorsal to the carotid sheath and enters the posterior surface of the thyroid lobes (Mastin, 1923; Fowler and Hanson, 1929; Rogers, 1929; Stewart, 1932; Bachhuber, 1943; Goss, 1966).

According to Goss (1966), the inferior thyroid artery gives rise to the following branches:

1. Inferior laryngeal
2. Tracheal branches
3. Ascending cervical
4. Muscular branches
5. Esophageal branches -

distributed to the esophageus. According to Swigart et al.

(1950), the esophageal arteries arise from three sites, viz.

1) the ascending portion, 2) the descending portion, and 3) the

terminal rami of the inferior thyroid artery. Those esophageal branches arising from the ascending portion are larger than those arising from the other two sites. However, the esophageal branches originate from the terminal rami more frequently than from the other two portions of the vessel (Swigart et al., 1950).

The number of terminal branches that reach the thyroid gland from the inferior thyroid artery varies in the literature. Goss (1966) states that the inferior thyroid artery divides into two branches which supply the caudal parts of the gland and anastomose with the superior thyroid artery. Nonidez (1931) believes this anastomosis occurs either outside or within the capsule of the gland. Bachhuber (1943) contends there are three terminal branches, while Fowler and Hanson (1929) hold that four to six small branches enter the posterior portions of the gland. The branches ramify over the surface of the gland (Mastin, 1923).

Swigart et al. (1950) describe a "tracheo-esophageal artery" as arising from the ascending portion of the inferior thyroid artery. It follows the recurrent laryngeal nerve to the superior mediastinum and supplies branches to the trachea and esophagus, and sometimes it anastomoses with the right or left superior bronchial artery. Jarvis and Nell (1963) say that Cairney (1925) describes a small tracheoesophageal artery arising from the right subclavian artery.

The caudal thyroid artery is variably present in the dog (Major, 1909; Bradley and Grahame, 1959; Nickel and Schwarz, 1963; Smithcors, 1964; Ichev, 1969b). When present, it is usually a small vessel and arises either separately or by a common trunk with its fellow from the brachiocephalic trunk (Ellenberger and Baum, 1891; Bradley and Grahame, 1959; Nickel and Schwarz, 1963; Smithcors, 1964). It may arise from the left subclavian and ascending cervical arteries, and the costocervical trunk on the right side (Ellenberger and Baum, 1891; Bradley and Grahame, 1959; Nickel and Schwarz, 1963; Smithcors, 1964). It accompanies the recurrent laryngeal nerve on the ventromedial aspect of the trachea, giving branches to the trachea, esophagus, caudal cervical ganglia, and nerves in the region of the thoracic inlet (Bradley and Grahame, 1959; Smithcors, 1964). According to Smithcors (1964), the cervical portion of the trachea and esophagus is supplied by branches from the caudal thyroid artery, only in those dogs where the caudal thyroid artery is well developed. Smithcors also states that the caudal thyroid artery anastomoses with a branch of the cranial thyroid artery in the middle third of the neck. However, Nonidez (1931) believes this anastomosis occurs on the surface of the gland.

Jarvis and Nell (1963) describe an artery arising from the dorsolateral aspect of the brachiocephalic trunk in dogs, which divides into a cephalic and caudal branch. They trace the

cephalic branch only for a few centimeters and find it giving off small twigs to the trachea and esophagus. The caudal branch courses to the tracheal bifurcation, giving branches to the esophagus and tracheobronchial lymph nodes. They suggest this artery be called the tracheoesophageal branch of the brachiocephalic trunk. In one specimen, Jarvis and Nell observe this tracheoesophageal artery to follow the vagus nerve to the root of the left lung. In another dog, they find it to anastomose with a direct branch from the aortic arch. They further find a tracheoesophageal artery arising from either the right or left subclavian, or from the left common carotid. Occasionally, the cephalic and caudal branches arise from the brachiocephalic separately. Jarvis and Nell believe that because the neck region in the dog is longer than in humans, and the first and only significant branch from the canine common carotid is the cranial thyroid artery, a long blood vascular gap between the thyroid and bronchial blood supply exists. They suggest that this tracheoesophageal branch of the brachiocephalic is provided to bridge this gap.

Thyroid ima artery The thyroid ima artery is described in the literature as being present only in humans. It is present in 4-10 per cent of all humans (Wolpert, 1969).

Wangensteen (1929) states that Haller (1725) accords Nicolai (1725) with its first description; however Wangensteen also quotes Gruber (1872) that it is described by Neubauer (1772).

The thyroid ima artery is also known as Neubauer's artery (Rogers, 1929; Wangensteen, 1929).

The origin of the thyroid ima artery is quite variable. According to Wangensteen (1929), Gruber (1872) finds it to arise from the internal mammary, right and left common carotid arteries, right subclavian, right thyrocervical axis, and right transverse scapular artery; Huerthle (1894) finds it to arise from the brachiocephalic on the right and from the aortic arch on the left; and Streckeisen (1886) states that most frequently it arises from the brachiocephalic trunk. Fowler and Hanson (1929) observe it to arise from the brachiocephalic trunk and enter the isthmus of the thyroid gland. Sometimes it arises from the internal thoracic (Goss, 1966). Wolpert (1969) states that Adachi (1928) believes any thyroid artery originating from the aortic arch, brachiocephalic trunk, right common carotid, or internal mammary artery is a thyroid ima artery. The vessel ascends the ventral aspect of the trachea to supply the inferior portion of the thyroid gland (Goss, 1966).

Wangensteen (1929) finds this artery even when the inferior thyroid artery is present and Rogers (1929) believes the thyroid ima artery "must form an important affluent to the collateral circulation" to the thyroid gland. Wolpert (1969) also believes that the thyroid ima artery is a possible collateral pathway to the thyroid gland and finds that when he

surgically occluded the common carotid artery, the thyroid ima artery enlarged and became the only blood supply to the thyroid gland.

Cranial (superior) thyroid artery The superior thyroid artery of humans is the first branch of the external carotid and arises just caudal to the thyrohyoid bone (Goss, 1966; Fowler and Hanson, 1929; Wangensteen, 1929; Stewart, 1932). Fowler and Hanson (1929) add that only rarely does the superior thyroid artery arise from the common carotid and that it is the only artery in the neck whose blood flow is toward the heart.

According to Stewart (1932) and Goss (1966), the superior thyroid artery gives the following branches:

1. Infrahyoid branch
2. Sternocleidomastoid branch
3. Superior laryngeal branch
4. Cricothyroid branch
5. Glandular branches.

The glandular branches are usually three in number (Mastin, 1923, Fowler and Hanson, 1929), which distribute themselves over the surface of the gland (Johnson, 1953 and 1955). Only occasionally is a large vessel present within the parenchyma of the gland (Mastin, 1923). The largest of the three glandular branches run over the anterior and lateral surface of the gland (Stewart, 1932), sending branches to ramify over these surfaces of the gland and to anastomose with the superior thyroid artery

of the opposite side at the isthmus (Stewart, 1932) and the inferior thyroid artery of the same side (Mastin, 1923). A medial and superior branch (Stewart, 1932) descends the posterior border of the gland and anastomoses with the inferior thyroid artery (Mastin, 1923). Stewart (1932) states that a third branch, smaller than the other two, dips into the gland. Mastin believes this small branch arises from a common trunk formed by the anastomosing of the medial and superior branch with the inferior thyroid artery, and that this branch supplies the external parathyroid gland.

Unlike the superior thyroid artery in humans, the cranial thyroid artery of the canine arises as the first and only branch of the common carotid artery (Nickel and Schwarz, 1963; Smithcors, 1964). Smithcors (1964) states that it arises from the common carotid opposite the caudal part of the larynx, however, Nickel and Schwarz (1963) do not believe this is a constant point of origin. They state that the cranial thyroid artery arises from the common carotid artery approximately opposite the cranial pole of the thyroid gland and thus this point of origin can be displaced either proximal or distal, dependent upon the position of the cranial pole of the thyroid lobe.

The cranial thyroid artery courses past the cranial pole of the thyroid gland (Nickel and Schwarz, 1963) and gives rise to the following branches (Smithcors, 1964; N.A.V., 1973):

1. Sternocleidomastoid branch - arises shortly after the cranial thyroid artery originates from the common carotid. It supplies both the sternomastoideus and sternooccipitalis portions of the sternocephalicus muscle and the cleidomastoideus portion of the brachiocephalicus muscle.

2. Pharyngeal branch - arises from the cranial side of the artery, supplying twigs to the cranial portion of the esophagus and larynx, and ends in the constrictor muscles of the pharynx (hyopharyngeus, thyropharyngeus, cricopharyngeus, palatopharyngeus, and pterygopharyngeus muscles).

3. Cricothyroid branch - supplies the sternohyoideus, sternothyroideus, thyrohyoideus, and cricothyroideus muscles.

4. Caudal laryngeal branch - passes through the cricothyroid membrane to the mucosa on the caudal portion of the larynx and anastomoses with the laryngeal artery (a branch of the external carotid artery).

5. Glandular or thyroid branches - supply the thyroid lobe and their number is variable. Smithcors (1964) states there are two sets of glandular branches in the dog, viz. a dorsal and a ventral group of vessels. The dorsal group are those which enter the dorsal border of the lobe and ramify on its medial surface. The ventral group are those which enter the ventral border of the gland and ramify on its lateral surface.

Nickel and Schwarz (1963) believe the cranial thyroid artery extends from the cranial end of the thyroid gland and

in the case of carnivores, pig, and ox, divides into two branches. One branch enters the medial or lateral aspect of the gland and the other branch enters the ventral aspect of the gland. They state that Loeffler (1955) describes two branches of the cranial thyroid artery, calling them the dorsal and ventral branches. The dorsal branch, Nickel and Schwarz state, is comparable to the medial branch in other domestic animals and the ventral branch is comparable to the lateral branch.

Smithcors (1964) describes one branch usually arising from the dorsal group of glandular branches as being larger than the others. It extends caudally from the cranial pole of the thyroid lobe and, coursing past the dorsal border of the gland, follows the recurrent laryngeal nerve descending in the neck and anastomoses with the caudal thyroid artery, when the caudal thyroid artery is present. In its course, it supplies branches to the esophagus and trachea. Nonidez (1931) calls this vessel the "tracheo-oesophagic branch" of the superior (cranial) thyroid artery in the dog. Bugge (1967) describes a similar branch in the rabbit and calls it the descending branch of the superior (cranial) thyroid artery.

Intrinsic arterial pattern Table 1 gives the comparative nomenclature in use by various investigators for the intrinsic vasculature of the thyroid gland. In addition to the name of the investigator(s) and the year of his publication (all except the present investigator), the species with which

Table 1. Comparative nomenclature used for intrinsic vasculature of the canine thyroid gland via the cranial thyroid artery

Major, 1909 (dog, cat, human)	Wangensteen 1929 (human)	Stewart 1932 (human)	Johnson 1954 (human, dog)	Faller 1964 (human)	Ichev (1965) (human, dog)	Present investigator 1976 (dog)
1 Cranial thyroid a.	Cranial thyroid a.	Cranial thyroid a.	Cranial thyroid a	Cranial thyroid a.	Cranial thyroid a.	Cranial thyroid a.
2 First order aa.	First order aa.	Glandular (main) thyroid aa.	Main aa.	Thyroid aa.	First order aa.	Glandular branches
3 Second order aa.	Second order aa.	Paren- chymal aa.	Inter- lobar aa.	Paren- chymal aa.	Second order aa.	Lobar branches
4 Third order aa.	Lobular aa.	Intra- lobular aa.	Inter- lobular aa.	Lobar aa.	Third order aa.	Lobular branches
5 Fourth order aa.	Follicular aa.	Intra- lobular arterioles	Lobular aa.	Lobular aa.	Fourth order aa.	Inter- follicular branches
6 Follicular aa.		—————	Vesicular arteries	Follicular arteries	Main follicular vessel	Follicular branches
7 Capil- laries	Capil- laries	Periachinar capil- laries	Vesicular capil- laries	Capil- laries	Capil- laries: a. inter- follicular b. leading c. secondary	Follicular capil- laries

he worked is also given. A general description of the intrinsic arterial pattern can be given by comparing each horizontal row in the table, for all investigators agree on the lobular structure of the thyroid gland as described by Major (1909) and they only give different names to the same vessel. The terminology used by Major (1909) will be used as a reference point in the description.

The cranial (superior in humans) thyroid artery (row 1) is the major blood supply to the thyroid gland. It gives rise to a variable number of first order arteries (row 2) which course to the thyroid gland. Although it is reported that the intrinsic arterial patterns of the human and canine thyroid glands are identical (Major, 1909; Ichev, 1967c, 1968a), a minor morphologic difference exists about the initial distribution of these vessels. In humans, these first order arteries course on the surface of the thyroid gland (Major, 1909; Ichev, 1965), whereas in dogs, they penetrate into the interior of the gland (Major, 1909).

These first order arteries give rise to many second order arteries (row 3). According to Major (1909) and Ichev (1965), these arteries are distributed over the surface of the human thyroid gland. Stewart (1932) states that once these second order arteries reach their area of distribution, they penetrate into the interior of the gland. In the canine, these arteries course in the connective tissue trabeculae to supply the

functional lobes (Major, 1909; Johnson, 1955; Ichev, 1965). Johnson (1953) adds that the functional lobe may receive more than one second order artery.

Upon reaching the functional lobe, the second order arteries give rise to many third order arteries (row 4) which invade the functional lobe by following the trabeculae to the lobules. Major describes that each lobule has from two to five third order arteries supplying it. However, Johnson (1953, 1955) believes, as a rule, there is one artery per lobule, although occasionally he finds two arteries supplying one lobule. Arosenius and Nylander (1962) contend that "each lobule is supplied by an artery and its individual follicles by capillaries originating in that artery." Ichev (1965) strongly disagrees with Johnson's assertion for he not only confirms Major's observations, but he also points out that if Johnson is correct, then in thyroid gland resections, where some blood vessels are ligated, death of lobules should occur. Ichev believes, the fact that this does not occur lends support to the observations that the lobules have several sources of blood supply.

Third order arteries penetrate the lobules and divide into fourth order arteries (row 5) which course between the individual follicles (Stewart, 1932). The fourth order arteries release follicular arteries (row 6) which upon reaching the follicles, terminate into capillaries (row 7) surrounding the follicles.

Major states the intrinsic arterial pattern of the thyroid glands of cats differs from that of humans and dogs because fourth order arteries are not as constant and no follicular arteries are present. Wangensteen (1929) equates fourth order arteries with follicular arteries directly and these end in capillary networks completely surrounding the follicles. Stewart (1932) asserts that fourth order arteries end in a clublike process from which four to six capillaries arise to envelope the follicle. He also seemingly implies that the human thyroid gland does not possess follicular arteries.

Major (1909) believes the capillaries lie in the connective tissue that surrounds the follicular cells and states that "compared with the size of the individual cells, the capillaries are very gross structures." Williamson and Pearse (1923) describe the capillary bed as being a ladder-like plexus. Stewart (1932) insists they look like the partially flexed fingers of the hand. Johnson (1955) asserts they form a plexus on the surface of the follicle, while Trautmann and Fiebiger (1957) state they form nets which surround the follicles in a basket-like fashion. Mastin (1923) argues that the capillary network lies immediately beneath the epithelium and Thomas (1945) cites Rienhoff (1931) who believes the epithelial cells of the follicle rest directly on the endothelial walls of the capillaries. Arosenius and Nylander (1962) observe that the follicles lay in direct contact with the capillary wall.

Williams (1944), by microdissection, can not detach the capillaries from the follicular cells.

An area of debate in the literature is the capillary arrangement around the follicles. Major (1909) does not describe the capillaries in detail but he does state the follicular arteries end in a rich capillary network surrounding each follicle. He seems to imply that the capillaries surrounding each follicle in human and canine thyroid glands arise only from the follicular artery; however, he contends that in cats, the follicles can receive their blood supply from branches arising from arteries supplying adjacent follicles, in addition to those arising from "what might be called its own follicular artery."

Wangensteen (1929), Stewart (1932), Johnson (1953, 1955), Arosenius and Nylander (1962) and Faller (1964) all believe that the capillary system around each follicle arises from only one artery (the follicular artery). On the other hand, Arosenius and Nylander (1962) cite Thomas (1945) who reports two capillary systems in the thyroid glands of rats. One system he calls the interfollicular capillary system which is equivalent to that described above and lies on the follicular surface. The other system he calls the intraepithelial system which originates in the interfollicular system and is embedded in the epithelial wall of the follicle. However, Thomas (1945) further states that the capillary network of each follicle is

directly related to only one follicle and the capillaries show no tendency to anastomose with those of adjacent follicles. Johnson (1953) refutes Thomas by saying there is no evidence for a double capillary system in humans.

By far the most staunch supporter of the multiple capillary system is Ichev (1965; 1967b, c; 1968a, b). He (1968a,b) believes that the follicles in both man and dog have their own capillary network arising from vessels that course to the follicles. These vessels, which have a wide lumen, he calls the main follicular vessels. In addition to these main follicular vessels, the follicles also receive capillaries from neighboring follicles. Ichev (1965; 1968a) also describes three types of terminal capillary ramifications within the thyroid gland. In one type of ramification, the main follicular vessel continues into a wide magistral or leading capillary which sends thinner capillaries to surround the follicle. These capillaries are specific to larger follicles. In another type of ramification, the main follicular vessel terminates at once into numerous capillaries over the surface of the follicle. This type he calls secondary capillaries and Ichev says they are the most numerous type of ramification. Both the leading or magistral and secondary capillaries are specific to one follicle. They do not send branches to neighboring follicles and Ichev groups both types of capillaries under perifollicular vessels.

In the last type of ramification, the main follicular vessel divides into several smaller branches which participate in the capillary network of adjacent follicles. These Ichev calls interfollicular capillaries. Interfollicular capillaries are similar to magistral capillaries by having wide lumens, but differ in that they supply at least two follicles, whereas the leading or magistral capillaries supply only one follicle.

Baillif (1937), Thomas (1945), Johnson, (1953, 1955), and Arosenius and Nylander (1962) hypothesize that the capillary pattern around follicles is variable and that the peculiar capillary arrangement is related to the activity or functional state of the follicular cells. Arosenius and Nylander (1962), by subjecting rat thyroid glands to propyl thiouracil, observe some segments of capillaries to dilate into sinusoid-like blood pools, while other segments are of normal width. This gives the appearance of two types of capillaries. Thomas (1945), subjecting rat thyroid glands to Thiourea, observes the same results and states, "it is tempting to consider if under normal conditions the intrinsic capillaries are not always in a state of functional activity, if they are as it were, held in reserve and only open up as required." Baillif (1937) notes that when the thyroid glands of rats are subjected to cold, the interfollicular capillaries enlarge, with a resultant increase in blood flow. When the glands are subjected to heat, the interfollicular capillaries collapse, with a resultant decrease

in blood flow. Williams (1937a) is able to demonstrate that new capillaries can grow around follicles when the need for blood arises. Williams also notes that not all the surface of a follicle is in contact with capillaries and those capillary-bare areas are just as active in hormonal production and secretion as those areas in contact with capillaries. He hypothesizes that thyroid hormone can be secreted into the capillaries directly or into the interfollicular spaces and eventually be picked up by other vessels.

Endothelial buds Endothelial buds (Wangensteen, 1929; Modell, 1933), also known as intimal cushions (Reale and Luciano, 1966), are projections of the intima into the lumen of the thyroid vessels. Wangensteen (1929) states that Horne (1892) is the first to describe them in fetal thyroid glands and Schmidt (1894) shows them to be a normal structure in the thyroid glands of the dog, cat, and human. Ichev (1969c) contends the endothelial buds are more frequent in the capillary vessels of the thyroid glands, however he states they do occur in the spinal cord, salivary glands, and mandibular lip, but to a lesser extent. Modell (1933) finds them most frequently at the branching point of smaller arteries and absent in the larger arterial trunks. Thomas (1945) observes them in the interfollicular capillaries, especially where the intra-epithelial capillaries branch from the interfollicular capillaries. Wangensteen (1929) cites Isenschmid (1883) that they

do not occur in veins.

Modell (1933) cites Schmidt (1894) that these projections have a variety of shapes, viz. (1) spherical, (2) hemi-spherical, and (3) pedunculated. Ichev (1969c) also observes these endothelial evaginations, which narrow the lumen of the vessels, to be of three shapes:

1. Finger-shaped-resembling true pseudopodia
2. Curved finger-shaped-resembling hooks
3. Completely closed with an apparently empty space included in the evagination.

Horne (1892) and Hesselberg (1910) consider the endothelial buds to be proliferations of the endothelial cells and state they are separated from the muscular layer of the vessel wall by the elastica interna. Wangensteen (1929) believes they consist of only intima, while Reale and Luciano (1966) observe them to consist of smooth muscle cells and elastic fibers.

Modell (1933) asserts endothelial buds consist of a bundle of cells internal to the circular muscle layer. These bundles appear on both sides of the junction of the branch and the cells of the bud appear as cushions that seem to be extensions of the circular muscle cells from the branch into the wall of the trunk. This gives the appearance of a lip-like valve. The buds are covered by the endothelial cell layer.

The function of these endothelial buds is not known for certainty, however, Modell (1933), Reale and Luciano (1966),

and Ichev (1969c) hypothesize they regulate blood flow and pressure through the capillary bed of the follicles by acting like a sphincter.

Venous drainage

Intrinsic venous pattern The intrinsic venous pattern is not extensively discussed in the literature. Major (1909) describes that a vein arises from the capillary network on the opposite side where the follicular artery approaches the follicle, and the vein follows the course of the arteries closely. Mastin (1923) and Trautman and Fiebiger (1957) are of the same opinion and Mastin agrees with Major that each artery is accompanied by two veins which anastomose at various places across the artery by way of bar-like veins. Mastin (1923) adds that the veins empty into larger veins which pass out of the gland and anastomose freely on the glandular surface. Johnson (1955) describes that a small vein forms from the capillary plexus which joins other (follicular) veins to form the lobular vein outside the lobule. The lobular vein follows the same pathway as that of the larger arteries to the surface of the gland.

Extrinsic venous drainage Fowler and Hanson (1929), Wangensteen (1929), and Stewart (1932) all are of the opinion that three veins drain the human thyroid gland, viz.:

1. Superior thyroid vein - drains the superior portion of each lobe and, by following the superior thyroid artery,

empties either into the lingual or internal jugular vein.

2. Middle thyroid vein - drains the lateral portion of each lobe and also terminates in the internal jugular vein. Bachhuber (1943) adds that before the middle thyroid vein enters the distal segment of the internal jugular vein, it receives several veins from the larynx and trachea. Bachhuber also states that occasionally a superior and an inferior accessory thyroid vein replaces the middle thyroid vein. These veins also terminate in the internal jugular vein.

3. Inferior thyroid veins - drain the inferior portions of each lobe by two to four branches which may join together and enter the brachiocephalic vein as one trunk or separately as single trunks. Wangensteen (1929) believes the inferior thyroid veins enter the internal jugular vein more frequently than they enter the brachiocephalic vein. Fowler and Hanson (1929) state the inferior thyroid veins follow the recurrent laryngeal nerve to their terminations. Wangensteen (1929) observes a thyroid ima vein accompanying the thyroid ima artery, when one is present.

Wangensteen (1929) does not observe valves in the thyroid veins of humans; however, Stewart (1932) finds that all three veins have valves at their terminations. Modell (1933) states the larger veins of the canine thyroid gland possesses numerous valves.

Two veins drain the canine thyroid gland, viz. the cranial and caudal thyroid veins (Smithcors, 1964). The cranial thyroid vein follows the cranial thyroid artery and enters the internal jugular vein at the cranial pole of the gland. Smithcors believes the caudal thyroid vein is the principal venous drainage of the gland. It is not the satellite of the caudal thyroid artery and it also enters the internal jugular vein at the caudal pole of the gland. Smithcors further states that occasionally a vein drains the middle portion of the left lobe and enters the brachiocephalic vein. He calls this vein the thyroid ima.

Vascular anastomoses

Extrinsic anastomoses The superior and inferior thyroid arteries of man anastomose quite freely with each other, both on the same side and with collateral vessels on the opposite side of the neck, and with other arteries in the region of the neck. The literature describes the following anastomoses:

1. On the same side:
 - a. The superior and inferior laryngeal branches of the superior and inferior thyroid arteries, respectively, anastomose on the posterior side of the human and rabbit thyroid glands (Pettenkoffer, 1914; Caylor and Schlotthauer, 1927; Wangenstein, 1929; Reilly, 1954).

- b. The posterior glandular branches of the superior and inferior thyroid arteries anastomose beneath the posterior border of the gland (Mastin, 1923; Wangensteen, 1929; Mauro, 1950; Reilly, 1954). Mastin (1923) considers this is the most important anastomosis and finds it most consistently occurring along the posterior border of the gland in the groove between the esophagus and trachea.

Reilly (1954) states that Curtis (1930) observes anastomoses existing between the pharyngeal branches of the superior thyroid artery and the ascending pharyngeal artery, and also between the infrahyoid branch of the superior thyroid artery and the suprahyoid branch of the lingual artery in humans. Curtis also finds anastomosis between the tracheal and esophageal branches of the inferior thyroid arteries and the tracheal branches of the bronchial arteries. Reilly (1954) states this last anastomosis becomes the major blood supply to the thyroid gland when the main thyroid arteries of the rabbit gland are ligated.

2. On opposite sides:

- a. The collateral superior thyroid arteries anastomose across the isthmus of the human thyroid gland (Mastin, 1923; Wilson, 1927; Wangensteen, 1929; Ichev, 1967a, 1970). Wangensteen (1929) observes an anastomosis between the superior thyroid artery of one side with the inferior thyroid

artery of the opposite side across the isthmus of the gland.

- b. Mastin (1923) reports no direct anastomosis between the two inferior thyroid arteries. Major (1909) finds a few anastomoses in the dog but only between branches of the same side and not between branches of the superior (cranial) and inferior (caudal) thyroid arteries of opposite sides. However, Major (1909) cites Landström (1907) describing anastomoses between the superior and inferior arteries on the same side and also with those of the opposite side in man.

These extrinsic anastomosis function as collaterals to insure a sufficient blood supply to the thyroid gland in cases of occlusion of the main thyroid vessels (Mastin, 1923; Wangensteen, 1929; Reilly, 1954; Ichev, 1967a). Wangensteen (1929) cites Pettenkoffer (1914), and Enderlen and Hotz (1918) who report injection of the thyroid vessels by way of the ascending aorta after ligation of the two superior and two inferior thyroid arteries at their points of origin in man. Ichev (1967a, 1970) states these anastomoses are not functional in the normal gland and that "there exists a territorial distribution of the blood in the gland." The blood supply to each lobe remains with that lobe. Only when there is a drop in blood pressure, Ichev continues, on one side, due to blockage

of the main vessel, do these anastomoses open up and blood passes from one side to the other side. "Thus, the blood flow in the anastomosis depends on the pressure from either side of the anastomoses" (Ichev, 1967a).

Intrinsic anastomoses The literature reports three types of anastomoses within the thyroid gland, viz.

1) arterial-arterial, 2) venous-venous, and 3) arterial-venous.

1. Arterial-arterial: Major (1909) and Marine (1928) do not find definite arterial anastomoses within the human and canine thyroid gland. Marine is of the opinion they do not occur, however Major states that they may occur even though he does not find them. Modell (1933) states that Landström (1907) believes they exist but could not find them and Shigyo (1923) reports them uniformly throughout the gland. Modell (1933) observes anastomoses between third order arteries in the canine thyroid gland. Williams (1937a) finds arterial anastomoses in the thyroid gland of rabbits. Johnson (1955) insists arterial-arterial anastomoses exist at the lobular level, while Wangensteen (1929) argues that anastomoses occur in the capsule and at the follicular capillary level but few, if any, occur between the larger branches within the normal gland. He does find a few arterial anastomoses of the third order arteries in cases of goiter.

2. Venous-venous: Major (1909) states that the two veins which accompany each artery within the thyroid gland frequently

anastomose with each other by way of bar-like veins coursing over the artery. Johnson (1955) observes many venous-venous anastomoses both on the surface and within the gland.

3. Arterial-venous: Johnson (1955) states that Modell (1933) gives good evidence that arterial-venous anastomoses occur in the canine thyroid gland. Modell reports that capillaries, arising from the follicular arteries, pass directly into veins. He also finds arterial-venous anastomoses arising between third order arteries and veins in the dog. Modell cites Grant and Bland (1931) who demonstrate that arterial-venous anastomoses in the skin of the human hand dilate on mechanical irritation and application of histamine and acetylcholine, and cold. They constrict upon stimulation of the sympathetics and application of epinephrin. Although Modell (1933) provides good evidence for such anastomoses in the canine thyroid gland, no one since has been able to reproduce his findings. Johnson (1953, 1955) and Ichev (1970) have only indirect evidence of the existence of this type of anastomosis. Both investigators observe the filling of arteries and veins with injection masses without the capillary system being filled. Williams (1937a, b) does not observe any arterial-venous anastomosis in the thyroid glands of rabbits.

Modell (1933) and Smithcors (1964) hypothesize arterial-venous anastomoses control the amount of blood flowing through the capillary bed by shunting blood directly to the veins.

Modell believes these shunts act to control the amount of hormone absorbed by the blood. He contends that in time of need, these shunts close and all the blood travels to the follicles with a resultant increase in hormonal absorption. In times of less need, the shunts are open and blood does not reach some of the follicles, with the resultant decrease in hormonal absorption. Modell (1933) also states that, in general, the arterial-venous shunts do not all open and close at the same time. A few capillary beds remain filled with blood. Only when there is a demand for the hormone do all the capillary beds within the gland fill with blood. Williams (1937a) however, does not agree with this because he observes the thyroid vessels do not collapse when the blood flow through the gland is diminished.

Lymphatic drainage

The lymphatic drainage of the thyroid gland is included not only because it is a part of the angioarchitecture of the thyroid gland, but also because thyroxin has been found in the lymphatics draining the thyroid gland in dogs (Biondi, 1892; Carlson and Woelfel, 1910; Carlson et al., 1925; Hicks, 1926). Williamson and Pearse (1930) believe the "lymph is as significant to thyroid function as the portal blood is to liver function."

Williams (1937a) states that Biondi (1892) finds colloid-like material in the thyroid lymph vessels, however since Williams' glands, implanted in the rabbit's ear, were without

lymphatics and functioned normally, he believes the lymphatics are not necessary, but if the lymphatics were present they would remove some secretion. Zechel (1931b) believes there is a normal turnover of follicles within the thyroid gland and that the colloid liberated by the destruction of follicles is picked up by the lymphatics.

Intrinsic lymph drainage The intrinsic lymphatic system of the canine thyroid gland begins as perifollicular capillary nets which surround the individual follicular cells of the follicle (Major, 1909; Williamson and Pearse, 1930; Gordon, 1931; Ramsay and Bennett, 1943; Trautmann and Fiebiger, 1957; Smithcors, 1964). Williamson and Pearse (1930) and Gordon (1931) believe the follicular epithelium is in direct contact with the lymphatic capillaries. Ramsay and Bennett (1943) state that the epithelium has more contact with lymphatic capillaries than with blood capillaries. Smithcors (1964), however, argues that the follicles are not in direct contact with lymphatic capillaries.

The capillaries are all continuous and drain into one vessel which constitutes the lymph sinusoid (Williamson and Pearse, 1930). Williamson and Pearse (1930) also believe that each sinusoid, also containing a blood capillary plexus, represents a gland unit. Several of these gland units drain into a central vessel which drains the lobule and thus is called the lobular lymphatic vessel.

Several lobular vessels join to form the lobar vessel, which drains the functional lobe. The lobar lymph vessel follow the blood vessels to the surface of the gland to form an extra-glandular plexus lying internal to the thyroid gland capsule but external to the blood vessels (Major, 1909; Smithcors, 1964). Gordon (1931) observes lymph vessels situated on both sides of the blood vessels.

From the extraglandular plexus, large lymphatic vessels arise which emerge from the gland (Major, 1909; Smithcors, 1964). Williamson and Pearse (1930) describe two lymphatic systems. One drains the capsule and the other drains the follicles. Gordon (1931) finds no evidence for this double system. He believes there is only one system, that which drains the follicles.

Extrinsic lymph drainage Ramsay and Bennett (1943), studying the lymphatics of the feline thyroid gland, state that the lymphatics draining the gland fall into two groups. One group, the superior (cranial) group, drains the cranial pole of each lobe and ends in the deep cervical lymph nodes. The other group, the inferior (caudal) group drains the caudal pole of each lobe and ends in the deep cervical lymph nodes. They also observe a large lymph vessel connecting each lobe coursing over the area where the isthmus originally existed.

In the canine, Caylor et al. (1927), Schlotthauer (1927), and Chouke et al. (1932) state the lymphatics draining the

gland are in three groups. In the first group, lymph vessels drain the cranial pole and end in the mandibular lymph nodes, which drain into the tracheal lymph trunk. Lymph vessels draining the caudal pole enter the deep cervical lymph nodes, and into the thymus. In the second group, the drainage from the cranial pole is the same as that in the first group however, the drainage from the caudal pole empty directly into the tracheal lymph trunk. These vessels do not pass through lymph nodes. No lymph draining to the thymus gland was observed. In the third group, the cranial drainage is the same as the others, but the caudal vessels empty directly into the internal jugular vein. Again, there were no lymphatics to the thymus in this group.

Mahorner (1927) describes three groups of lymphatics draining the human thyroid gland. A superior group drains the superior pole, following the superior thyroid artery, and enters the deep cervical lymph nodes. A middle group runs laterally from the gland and enters the deep cervical lymph nodes. An inferior group drains the inferior pole and isthmus, and ends in the deep cervical lymph nodes.

Williamson and Pearse (1930) describe a "Thyrothymic Lymph System" which is a separate system connecting the thyroid gland with the thymus in humans. They state that this system is a closed system. They observe it to arise in the thyroid gland and end blindly in the thymus. Because of this finding,

Williamson and Pearse believe "the thyroid and thymus glands are thus not two organs, but different parts of the same organ." However, Mahorner (1927), Chouke et al. (1932), and Smithcors (1964) state that no such system exists in humans or dogs.

Angioarchitecture of the Canine Parathyroid Gland

Arteries

Major supply One separate branch, which arises from either the glandular, muscular, or esophageal branches of the inferior thyroid artery supplies the human parathyroid gland (Halsted and Evans, 1907; Fowler and Hanson, 1929; Curtis, 1930; Hunt et al., 1968). Halsted and Evans (1907) observe this branch to enter a distinct hilus in the gland and they state that this artery is large in comparison to the size of the parathyroid gland. They also strongly believe that the vascular supply of the parathyroid glands is independent of the vascular supply of the thyroid gland. They observe that the capsule of the thyroid gland splits to enclose the parathyroid gland and small thyroid gland capillaries that appear to penetrate the parathyroid gland, only supply the capsule. These capillaries never enter the parathyroid gland.

Smithcors (1964) states that the external parathyroid gland of the dog receives its blood supply by a separate branch from the cranial thyroid artery and occasionally small twigs from the thyroid gland also supply the parathyroid gland.

He also states that the internal parathyroid gland is supplied by small vessels from the thyroid gland.

Intrinsic arterial pattern Halsted and Evans (1907)

contend that the parathyroid artery courses to the center of the gland and gives off branches which ramify at the periphery of the gland. They give rise to capillaries. Halsted and Evans state that this circulation is different than that in the thyroid gland.

Flint (1904) finds the majority of large vascular trunks in the center of the gland and Bensley (1947) states that one or more pairs of arterioles and venules run in the connective tissue which separates the cell cords of the parathyroid gland. The cell cords are surrounded by a rich capillary plexus which cannot be distinguished from the septa when the plexus is collapsed.

Venous drainage

The venous drainage is in common with that of the thyroid gland (Smithcors, 1964).

Vascular anastomoses

There is no mention about their occurrence in the literature.

Lymphatic drainage

The lymphatic drainage is in common with that of the thyroid gland (Smithcors, 1964).

MATERIALS AND METHODS

This investigation was conducted in six stages:

1. Gross dissection of the cervical region was performed on fifty, commercially embalmed dogs,¹ used by the freshmen class of the professional veterinary curriculum in the Department of Veterinary Anatomy, Pharmacology, and Physiology, College of Veterinary Medicine, Iowa State University of Science and Technology, Ames, Iowa. The purpose was to observe the gross morphology of the thyroid gland in reference to the following:

- (a) number of thyroid lobes
- (b) location of lobes (in relation to tracheal rings)
- (c) relationship of lobes to other structures
- (d) size and shape of lobes
- (e) presence of isthmus (glandular/nonglandular)
- (f) number and origins of thyroid arteries and veins
- (g) number and location of parathyroid glands, etc.

The sex of the dogs, whenever possible, was recorded. No attempt was made to ascertain the exact breed, age, body weight, nutrition, diet, estrous cycle, condition or history of

¹Obtained from the Windsor Biological Gardens, P.O. Box 1210, Bloomington, Indiana 47401.

pregnancies, etc. of these dogs since they were obtained from a biological supply company, as mentioned previously. All dogs, however, were of the mesaticephalic breed.

A vernier caliper¹ was used to measure the length, width, and thickness of each thyroid lobe. Length was measured between cranial and caudal poles of each lobe; width and thickness were taken from the middle of the lobes.

Live animals were prepared according to the following procedures for the next four stages (second through fifth stages):

(a) Dogs were anesthetized by cephalic vein injection of a sodium pentobarbital solution (1 cc/5 lbs body weight).

(b) Both common carotid arteries were isolated in the caudal one-third of the neck.

(c) A cannula, connected to a perfusion bottle, was inserted, directed cranially, into each common carotid artery and was held in place by suture.

(d) Another cannula (used for exsanguination) was inserted, directed caudally, into each common carotid artery and was held in place by suture.

(e) Both common carotid arteries were isolated and clamped, with hemostats, cranial to the origins of the cranial

¹Obtained from Scientific and Laboratory Division of Physicians and Hospitals Supply Company, 1400 Harmon Place, Minneapolis, Minnesota; Catalog number 11-1045.

thyroid arteries, but caudal to their bifurcations into internal and external carotids.

(f) As exsanguination begun; the perfusion bottle, now filled with physiological saline (0.09% NaCl solution), was raised to a level of about four feet above the animal and approximately 200 ml of the above solution was perfused through the gland, flushing out blood as much as possible.

(g) The animals were killed by injection of Toxital (1 ml/5 lbs body weight) directly into the heart. A 20 cc syringe and 18 G, 1.5 inch needle were used for the injection.

(h) After death, whatever material to be injected into the gland was accomplished by digital pressure on a 50 cc syringe through the cranially-inserted cannula in each common carotid artery (as described previously in c).

This method provided the best means of injecting materials rapidly and thoroughly into the thyroid gland vasculature, for materials could go nowhere, except through the branches of the cranial thyroid artery.

2. Comprised the microscopic examination of stained serial sections of thyroid glands taken from ten dogs. The purpose was to observe the histologic structure of the gland depicting the intrinsic relationship between blood capillaries to thyroid follicles.

The animals were prepared as stated previously. After death, approximately 400 ml of 10% buffered, neutral formalin

(BNF) was perfused through the glands (approximately 200 ml/lobe). The glands were removed and placed in BNF fixative for 24 hours. They were then embedded in paraffin, serial sectioned (two lobes at 10 μ , and eight lobes at 6 μ), stained, and mounted. Every fifth section was studied microscopically.

The staining method employed was an adapted version of Crossmon's modification of Mallory's triple stain as follows:

PREPARATION:

a. Mordant¹

Part A.	Potassium dichromate	4.5 gm
	Distilled water	150 ml
Part B.	Concentrated HCl	5.0 ml
	95% ethanol	50 ml
Mix 3 parts A with 1 part B; use within 4 hours.		

b. Acid fuchsin - orange G

Acid fuchsin	0.67 gm
Orange G	0.27 gm
Thymol (crystals)	0.13 gm
Acetic acid (glacial)	2.00 ml
Distilled water	200 ml

c. Aniline blue

Aniline blue	4.0 gm
Acetic acid (glacial)	4.0 ml
Distilled water	200 ml

d. Phosphomolybdic acid, 1% aqueous solution, or 1% phosphotungstic acid.

e. Acetic acid, 1% aqueous solution

f. Harris' hematoxylin

¹Adapted by Dr. M. J. Brown and K. K. Booth for quick processing of thyroid gland slides.

- g. Fixative: 10% BNF
Mordanting in potassium dichromate is not required if Zenker's or Helly's fixatives are used.

STAINING:

1. Bring sections to water.
2. Mordant in potassium dichromate mixture for 5-7 minutes.
3. Rinse in distilled water.
4. Stain in Harris' hematoxylin.
Overstain, since this is differentiated in subsequent steps.
5. Blue in tap water.
6. Rinse in distilled water.
7. Stain in acid fuchsin - orange G about 1 minute, or until hematoxylin is properly differentiated.
8. Rinse briefly in distilled water.
9. Mordant in 1% phosphomolybdic acid until collagen is decolorized but smooth muscle retains the stain.

Stain by inspection - examine an arteriole.

Change the solution when the rate of decolorization becomes too slow.

10. Rinse briefly in distilled water.
11. Stain in aniline blue solution for about 5 minutes.
Inspection is not possible at this stage.
12. Rinse briefly in distilled water.
13. Rinse briefly in 1% aqueous acetic acid.
14. Rinse briefly in distilled water.
15. Differentiate the aniline blue during dehydration.
Start with 70 or 85% ethanol. Dehydrate rapidly after the desired degree of differentiation is achieved.
16. Clear and mount.

RESULTS:

Collagen	blue
Smooth muscle	magenta
Nuclei	blue to red
Rbc's	yellow to red

In addition to the above staining method, several sections were silver impregnated using Gomori's Method¹ to reveal

¹As described by Humason, 1967, p. 190.

parafollicular cells within the thyroid gland as well as reticular fibers surrounding the follicles.

3. Included the microscopic examination of serial sections of thyroid glands taken from ten dogs whose intrinsic vessels were filled with an India ink-gelatin injection mass. The purpose was to reveal the branching pattern of relatively larger blood vessels inside the gland and the relationship of capillaries to thyroid follicles internally.

The animals were prepared as described previously and after death, 50 ml of a 10% gelatin solution (to which 10 ml of India ink was added), was injected into each lobe. A 50 cc syringe, connected to the cranially-inserted common carotid arterial cannula (as described in c), was used for injection. The glands were removed and placed in 10% BNF for 24 hours. This method fixed the tissue as well as hardened the gelatin within the vessels. The glands were embedded in paraffin, serially-sectioned at 20 μ , lightly stained with Harris' hematoxylin (just enough to produce a contrast between blood vessels and follicles, but not dark enough to obscure the India ink filled vessels), mounted, and every section was studied microscopically.

4. Consisted of microscopic examination of six intact, transparent thyroid glands whose vascular system was injected with a 10% India ink-BNF solution. This method allowed observation of the direct relationship between the follicles and

their capillary pattern.

The animals were prepared as stated previously, perfused with approximately 400 ml (about 200 ml/lobe) of a 10% India ink-BNF solution, removed, placed in 10% BNF fixative for 24 hours, and made transparent in the following manner¹:

(a) glands were transferred to each of the following ethyl alcohol solutions for 24 hour periods each:

1. 50%
2. 70%
3. 2 changes of 90%
4. 2 changes of absolute

(b) finally, they were transferred to methyl salicylate where, after 24 hours, they achieved their transparent nature and were kept for microscopic examination.

5. Included examination of plastic casts of the thyroid vasculature taken from 10 thyroid lobes. This procedure gave a three dimensional picture of the intrinsic blood supply of the thyroid gland not readily obtainable from serial sections.

The animals were prepared as described previously, and after death, 50 ml of Batson's #17 Anatomical Corrosion Compound² was injected into each lobe by means of a 50 cc syringe

¹ Taken from Nanda, 1970.

² Obtained from Polysciences, Inc., Paul Valley Industrial Park, Warrington, Pennsylvania 18976.

connected to the cranially-inserted common carotid arterial cannula (as described in c). The compound was allowed to harden (about 2 hours), after which the lobes, with their accompanying blood vessels, were removed and placed in concentrated potassium hydroxide (340 g KOH/1000 ml distilled water), for maceration. The thyroid lobes were kept in the KOH solution at 50°C for 24 hours. After every two hours, during the 24 hour period, the plastic casts were removed from the KOH solution, rinsed in distilled water and returned to the KOH solution. This enhanced the maceration process. At the end of the 24 hour period, the plastic casts were removed, rinsed in distilled water, and allowed to dry. Afterwards, the plastic casts were studied by means of a dissecting microscope. A microdissecting needle and forceps were used to tease the vessels apart for study.

6. Finally, every fifth serial section from six thyroid glands, whose lymphatic systems had been injected with India ink was attempted. The purpose was to observe the relationship of the thyroid lymphatics to the blood vessels and follicles inside the thyroid gland.

After the animals were anesthetized as mentioned previously, the thyroid lobes were isolated and 3.0 ml of India ink was injected beneath the ill-defined capsule of each lobe. A 3.0 cc syringe and 26 G, 3/4 inch needle were used for injection. Twenty minutes after injection, the animals were

killed, as described previously. The glands were removed and placed in 10% BNF for 24 hours. The glands were then embedded in paraffin, serially sectioned at 10 μ , mounted, and the lymphatic system was microscopically studied.

RESULTS

Gross Anatomy of the Canine
Thyroid GlandLocation

The thyroid gland consisted of two lobes, one each situated on the right and left ventrolateral aspects of the trachea. The lobes extended between the caudal border of the cricoid cartilage of the larynx and the sixth to eighth tracheal ring. The cranial pole of three lobes (two right and one left, Table II) were found close to the middle of the cricoid cartilage.

Medially, each lobe lay in contact with the deep cervical fascia surrounding the trachea (lamina pretrachealis); laterally, with the carotid sheath; and ventrally, each lobe was partly covered by the ventral border of the sternocephalicus muscle, the dorsal border of the sternohyoideus muscle, and deep to these two muscles the lobes lay in contact with the sternothyroideus muscle. The sternothyroideus muscle was transected across its belly and reflected cranially to expose each lobe. Dorsally, the relationship of each lobe somewhat varied between sides. The dorsal aspects of both lobes were covered by the deep cervical fascia, but on the right, the deep cervical fascia undercovered the longus capitis muscle. The dorsal surface of the left lobe was covered by the esophagus (Figure 1).

Table 2. Size and location of thyroid lobes

Male specimens								
Specimen number	Right lobe				Left lobe			
	Length (mm)	Width (mm)	Thickness (mm)	Location (Tracheal rings)	Length (mm)	Width (mm)	Thickness (mm)	Location (Tracheal rings)
1 ^a	18.9	9.7	4.8	1-4	20.7	10.5	5.4	CBCC ^b -4
2	19.4	7.8	4.1	2-4	20.5	7.6	3.8	2-5
3	22.8	8.1	2.7	1-6	25.9	8.8	2.7	1-7
8	18.9	10.0	4.5	— ^c	21.6	6.6	4.9	CBCC-4
10	26.3	11.1	6.3	MCC ^d -5	30.0	10.9	6.3	CBCC-7
12	21.0	6.9	3.1	CBCC-4	23.9	8.1	3.3	CBCC-6
16 ^a	21.2	4.3	4.3	1-6	17.3	9.1	3.0	MCC-1
18	22.3	6.9	2.6	1-5	26.0	7.5	2.5	1-6
20	20.6	7.3	3.2	2-6	21.2	5.7	3.7	3-7
21 ^a	20.2	4.0	3.0	4-7	20.1	6.7	2.4	3-6
23	21.9	6.6	4.5	CBCC-4	23.9	10.0	2.5	CBCC-4
26 ^a	18.2	8.4	3.7	2-5	20.7	8.3	3.7	1-5
28	23.4	7.1	4.3	CBCC-5	21.7	10.5	3.4	CBCC-6
31	19.7	9.2	3.5	1-5	24.6	8.4	3.0	2-7
33	27.2	7.2	2.5	1-8	26.2	7.0	3.2	1-8
38 ^a	21.6	7.7	3.6	3-7	22.9	6.5	3.2	2-8
39	28.0	7.1	5.2	1-6	26.4	8.5	4.4	2-7
45	19.3	6.6	4.5	CBCC-4	19.8	7.4	4.3	1-6
46	15.2	8.5	3.0	CBCC-5	14.1	10.1	2.6	1-6
47 ^a	19.3	8.4	4.1	3-7	20.5	8.4	4.0	1-5
48 ^a	22.5	11.5	4.7	1-6	22.2	13.0	5.8	CBCC-5

^aLeft lobe cranial to right lobe.

^bCaudal border of cricoid cartilage.

^cLobe displaced by student dissection.

^dMiddle of cricoid cartilage.

Female specimens								
Specimen number	Right lobe				Left lobe			
	Length (mm)	Width (mm)	Thickness (mm)	Location (Tracheal rings)	Length (mm)	Width (mm)	Thickness (mm)	Location (Tracheal rings)
4	16.0	6.9	3.4	2-6	16.8	6.2	2.9	3-7
5	15.3	7.4	2.9	3-5	16.9	6.0	3.3	—
7 ^a	25.5	9.0	4.2	1-6	28.2	9.0	4.6	CBCC-6
9	20.0	9.9	3.5	CBCC-5	20.7	7.0	3.0	—
13 ^a	25.8	9.8	4.8	2-6	26.2	11.2	4.9	CBCC-5
14	27.1	8.4	3.5	3-8	28.2	7.9	4.2	3-8
15	22.3	5.8	4.6	1-7	21.8	6.7	3.5	—
17	19.7	10.5	3.0	1-4	21.4	8.2	3.2	2-6
22	19.1	10.0	3.3	CBCC-4	22.7	8.1	4.1	CBCC-5
24 ^a	17.1	7.3	4.2	3-5	21.4	7.4	4.6	CBCC-5
25	21.8	6.9	3.6	MCC-5	22.3	7.1	3.0	CBCC-4
27	20.9	6.4	4.0	—	20.5	7.8	3.9	2-7
29	17.8	6.7	3.7	2-6	23.2	7.0	2.7	3-8
30 ^a	16.8	8.7	3.1	2-5	18.7	7.1	3.4	1-6
32	16.0	6.4	3.4	CBCC-5	19.0	6.3	3.3	2-6
34 ^a	21.1	8.7	3.9	3-6	22.2	10.0	5.2	2-6
35	22.8	7.3	4.7	CBCC-4	22.4	9.1	3.1	1-5
36 ^a	27.8	6.0	2.4	3-6	29.8	7.7	3.0	2-7
37 ^a	19.0	9.0	4.0	1-5	22.2	7.0	4.3	CBCC-4
40 ^a	19.0	6.0	3.9	3-7	20.4	6.9	3.2	1-7
41	19.1	7.1	2.6	1-6	21.7	7.5	2.9	1-8
42	16.6	5.1	4.1	CBCC-4	17.8	6.9	3.0	CBCC-4
44 ^a	24.2	7.0	3.9	1-7	24.4	7.8	2.7	CBCC-6
49	20.9	8.3	3.9	2-5	23.6	7.9	4.0	—
50 ^a	19.5	7.9	3.6	1-5	25.5	8.5	3.7	CBCC-6

A comparison of the position of the left lobe to that of the right (within the same animal) showed the left lobe lay either cranial, at the same level, or caudal to the corresponding right lobe. The left lobe was found cranial to the right lobe in 17 out of 40 cases (42.50%), at the same level in 11 out of 40 cases (27.50%), and caudal in 12 out of 40 cases (30.00%), respectively. In the remaining 10 cases, 6 lobes were displaced and 4 lobes (numbers 6, 11, 19, 43) were completely dissected away by the freshman veterinary students and no comparison could be made.

Shape and size

The shape of the lobes, within the same animal, was symmetrical; elongated oval with narrowing extremities. A few lobes were almost circular in shape and several others were pyramidal in shape.

Within each specimen, the length of each lobe was variable (Table II). A t-test (Table III) with the hypothesis that the difference between right and left lobes, in each specimen, was zero was calculated for the length, width, and thickness of the lobes. The t-test showed that there was a significant difference of the right to that of the left lobe of -1.50 mm in length. This meant that the left lobe, in both sexes, was longer than the right lobe by 1.50 mm. No side difference in the other dimensions was demonstratable here. Also there was no evidence that the side differences were dependent on sex.

Table 3. Statistical analysis of data from Table 2

Variable	Males (21)		Females (25)	
	Right	Left	Right	Left
	<u>Means</u>			
Length	21.32	22.39	20.45	22.32
Width	7.83	8.55	7.70	7.69
Thickness	3.91	3.72	3.69	3.58
	<u>Standard deviations</u>			
Length	3.07	3.50	3.53	3.38
Width	1.86	1.78	1.47	1.19
Thickness	0.96	1.12	0.61	0.72
	<u>Range</u>			
Length	15.2-28.0	14.1-30.0	15.3-27.8	16.8-29.8
Width	4.0-11.5	5.7-13.0	5.1-10.5	6.0-11.2
Thickness	2.5- 6.3	2.4- 6.3	2.4- 4.8	2.7- 5.2
Difference between sides (right-left) averaged over sex				
		Difference	Standard error difference	
Length		-1.50 ^a mm	0.28	
Width		-0.32 mm	0.24	
Thickness		+0.14 mm	0.11	

^aProbability of a difference this large when the true difference between sides is zero is less than 0.001.

Thyroid isthmus

An isthmus was found connecting the ventral aspects of the caudal poles of each thyroid lobe in 20 out of 50 specimens. A glandular isthmus (Figures 2 & 3) was found in 6 out of these 20 specimens (1 in a male, 5 in females). The other 14 were represented by fibrous bands (7 - males, 7 - females).

Gross Anatomy of the Canine Parathyroid Glands

There were one pair (one external and one internal) of parathyroid glands associated with each thyroid lobe. The white to cream color of the parathyroid glands made them easily distinguishable from the dark colored thyroid lobes.

The external parathyroid gland was a large, round nodule found along the lateral surface of the thyroid lobes. In the majority of cases, the external parathyroid gland was found resting on the lateral surface of the cranial pole of the thyroid lobes. However, it was not uncommonly found on the lateral surface of the middle portion of the lobes. It was less frequently found on the lateral surface of the caudal pole. In all cases, however, it was found external to the thyroid capsule.

In 12 cases, the external parathyroid gland was not found on the thyroid lobes at all. Its most frequent position off the lobes was in the fascia cranial to the cranial pole, as well as in the fascia caudal to the caudal pole, and medial to

the lobes on the trachea.

The right and left external parathyroid glands were not always symmetrical in position. Of the 20 external parathyroid glands observed about the cranial pole on the right lobe, only 11 parathyroid glands were noticed about the cranial pole of the corresponding left lobe. Of the 15 parathyroid glands found on the middle portion of the thyroid lobes, only 7 were symmetrical in position, and of those found on the caudal poles of the thyroid lobes, none were symmetrical.

Occasionally, several smaller parathyroid nodules were found (in addition to the large external parathyroid gland) scattered along the lateral surface of the thyroid lobes from the middle of the lobes to the caudal pole. These smaller nodules were considered accessory parathyroid tissue. One interesting variation was multiple (usually 2) external parathyroid nodules of equal size instead of one large gland (Figure 4).

The internal parathyroid gland was always found along the medial surface of the thyroid lobes from the cranial to the caudal pole. Seemingly, it was relatively smaller than the external parathyroid gland, but was always found lying inside the thyroid capsule.

Histology of the Canine Thyroid Gland

Capsule and trabeculae

The canine thyroid gland was enveloped by the deep cervical fascia, which was intimately related to the thyroid parenchyma and thus participated in the formation of its capsule. The capsule gave rise to trabeculae (septa) which divided the thyroid lobes into the following functional units:

1. Functional lobes (first division of the anatomical lobes). The trabeculae were relatively thick and easily observed at this level. Each functional lobe consisted of a variable number of:

2. Lobules (second division of the anatomical lobes). At this level the trabeculae became thinner and were not easily observed. Each lobule consisted of a variable number of:

3. Follicles (basic units of the thyroid gland). They were surrounded by reticular fibers; the terminations of the trabeculae and the reticular fibers were only observed in silver impregnated sections (Figure 5).

The arteries, veins and lymphatics accompanied the trabeculae to the interior of the gland and, in many instances, the tunica adventitia of the vessels appeared to be the only connective tissue component within the gland.

Thyroid follicles

The follicles were round to oval shaped and varied in size. The variable sized follicles were uniformly dispersed throughout the lobes, except at the periphery where the larger follicles prevailed. They were composed of a single layer of cells with variable heights. In small follicles the cells were columnar and in large follicles squamous. The rounded, euchromatin nuclei were situated at the base of the cells.

The lumina of the follicles contained colloid which was frequently vacuolated and demonstrated a variety of staining reactions. Most follicles displayed a homogeneous acidophilic colloid, however, equally present were follicles with partially acidophilic and partially basophilic colloid (Figure 6).

Parafollicular cells and other cellular masses

Parafollicular cells were observed either as single cells (Figure 7) within the basement membrane (reticular fibers) of the follicles, or as clusters of usually four cells (Figure 8) surrounded by reticular fibers in the interstitial tissue. These rounded cells were larger than follicular cells and contained centrally located, vesicular nuclei. Their cytoplasm was clear. The cells were sparingly scattered throughout the lobes.

In one lobe, a remnant of the ultimobranchial body was found (Figure 9). The remnant was in the form of a tube, measuring 400 μ in length and somewhat inclosed in a connective

tissue capsule. Its walls consisted of a stratified, partially ciliated epithelium. The lumen of this ultimobranchial tube contained a clear homogeneous substance with cellular debris. The homogeneous substance did not give the typical staining reaction of the follicular colloid as described earlier.

From the ultimobranchial tube arose many ducts, which dilated to form ultimobranchial follicles. The walls of the ducts consisted of stratified epithelium, however, the ultimobranchial follicles were composed of a single layer of squamous epithelium. The lumina of both the ducts and the follicles contained the same type of material as did the tube.

The ducts were also connected to mixed follicles (Figure 9). The walls of the mixed follicles consisted primarily of a single layer of squamous cells, except at the ultimobranchial ducts where the epithelium tended to become stratified squamous. The lumina of these mixed follicles contained typical follicular colloid situated around material similar to that in the ultimobranchial tube.

Histology of the Canine Parathyroid Glands

The external parathyroid glands (III) were surrounded by a thin connective tissue capsule formed from the deep cervical fascia. Although separate, it was continuous with the thyroid gland capsule.

Delicate trabeculae arose from the capsule and traveled inside the gland with the arteries and veins. It was exceedingly difficult to distinguish the trabeculae from the tunica adventitia of the accompanying vessels in the interior of the gland.

The epithelium of the external parathyroid gland possessed a basophilic cytoplasm and was arranged into columns facing the sinusoidal-like capillaries. This arrangement was reminiscent of that within the liver.

The internal parathyroid glands (IV) differed from the external parathyroids only in that they were occasionally embedded within the thyroid parenchyma and did not possess a distinct capsule.

Angioarchitecture of the Canine Thyroid Gland

Arteries

Tracheoesophageal (caudal thyroid - N.A.V., 1973) artery

A small, bilateral (right and left) tracheoesophageal artery was found in all 50 specimens. Its origin was quite variable between sides, stretching from the costocervical trunk cranially and the bronchoesophageal artery caudally. Except in those cases where the right and left arteries arose from a common trunk, the origin of the right tracheoesophageal artery was always cranial to the corresponding left. Also, in six

cases, the left tracheoesophageal artery originated from the bronchoesophageal artery (Figure 1).

The left tracheoesophageal was relatively larger than the corresponding right artery and despite its variable origin, the left tracheoesophageal artery always gained the ventral aspect of the thoracic portion of the esophagus and bifurcated into an ascending and a descending branch. The smaller descending branch was difficult to trace about the level of origin of the bronchoesophageal artery, however, it coursed caudally along the ventral aspect of the esophagus and supplied small twigs to same. The larger ascending branch coursed cranially along the left ventrolateral aspect of the trachea, in company with the left recurrent laryngeal nerve, which lay ventral to the artery. The ascending branch supplied many twigs to the trachea and cervical portion of the esophagus and it anastomosed with the dorsal branch of the left cranial thyroid artery at approximately the level of the cranial thoracic aperture (Figure 1).

The relatively smaller right tracheoesophageal artery did not bifurcate similar to that of the left artery. From its variable origin, the right tracheoesophageal artery gained the right ventrolateral aspect of the trachea and ascended the neck, accompanying the corresponding recurrent laryngeal nerve. It supplied twigs to the trachea and anastomosed with the dorsal branch of the right cranial thyroid artery at the

cranial thoracic aperture.

Cranial thyroid artery The right and left cranial thyroid arteries originated from the respective common carotid approximately 1 cm cranial to the cranial pole of each thyroid lobe. Shortly after its origin, the cranial thyroid artery gave rise to the sternocleidomastoid branch (Figure 10), which supplied the sternomastoideus and sternooccipitalis portions of the sternocephalicus muscle, the cleidomastoideus portion of the brachiocephalicus muscle, and the medial retropharyngeal lymph node. Occasionally, several small twigs ramified in the mandibular gland.

The continuation of the cranial thyroid artery then bifurcated into a dorsal and a ventral branch (Figure 10). In 32 out of 50 specimens, the dorsal branch coursed caudally along the dorsal border of the lobe and supplied a variable number of glandular branches to the dorsal and medial aspects and the caudal pole of the lobe. In the remaining specimens, the dorsal branch did not supply glandular branches to the lobe.

The dorsal branch emerged from the caudal pole of the thyroid lobe, descended along the ventrolateral aspect of the trachea, and supplied twigs to the cervical portions of the trachea and esophagus. The dorsal branch anastomosed with the tracheoesophageal artery near the cranial thoracic aperture (Figure 10). Frequently, near the origin of the dorsal branch,

a pharyngeal branch (Figure 10) was given off, which ascended the ventral aspect of the esophagus on the left side and the longus colli muscle on the right. The pharyngeal branch supplied twigs to the cranial portion of the esophagus and larynx, and terminated in the constrictor muscles of the pharynx. Occasionally, the pharyngeal branch arose directly from the cranial thyroid artery near the origin of the sternocleidomastoid branch.

The ventral branch of the cranial thyroid artery coursed medially towards the larynx, above the cranial pole of the lobe, and supplied a variable number (1-3 or 4) of glandular branches to the cranial pole. When an external parathyroid gland (III) was situated at the cranial pole, these glandular branches ran beneath it and entered the thyroid lobe. Slightly beyond the cranial pole of the lobe, the ventral branch gave off the cricothyroid branch (Figure 10), which ascended the ventrolateral aspect of the larynx and supplied twigs to the sternohyoideus, sternothyroideus, thyrohyoideus, and cricothyroideus muscles. The caudal laryngeal branch, which passed through the cricothyroid membrane, arose from the cricothyroid branch.

The continuation of the ventral branch gave rise to a twig which anastomosed with a corresponding twig from the opposite side across the cricotracheal membrane. The ventral branch then descended along the ventral border of the thyroid lobe and supplied twigs to this border. Its termination was dependent

upon the branching of the dorsal branch and the presence of a glandular isthmus. In specimens where the dorsal branch supplied the caudal half of the lobe, the ventral branch terminated in the cranial half of the lobe. In the absence of glandular branches off the dorsal branch to the lobe, the ventral branch compensated the blood supply for the caudal pole of the lobe instead. The ventral branch also supplied the glandular isthmus, when one was present, and occasionally entered the caudal pole of the opposite thyroid lobe via this route (Figure 2).

Intrinsic arterial pattern The glandular branches pierced the thyroid gland capsule and entered the thyroid parenchyma. The glandular branches, usually from the ventral branch, which entered near the cranial pole of the thyroid lobe, usually traveled within the parenchyma for some distance before they gave rise to lobar branches. Within the thyroid lobe, the long glandular branches usually trifurcated into lobar branches (Table 1), which coursed within the connective tissue trabeculae between the functional lobes (Figure 12). The glandular branches, which entered the dorsal and ventral borders of the lobe, almost immediately divided into lobar branches.

The lobar branches ran between functional lobes and released lobular branches (Table 1) into the functional lobes. The number of lobar branches sending lobular branches and the

number of lobular branches entering each functional lobe were dependent upon the size of the functional lobe; with larger functional lobes being supplied by a greater number of lobular branches arising from a greater number of lobar branches.

The lobular branches traveled within the connective tissue between lobules and gave rise to the interfollicular branches (Table 1), which entered the lobules. The number of interfollicular branches was dependent upon the size of the lobule. Larger lobules received interfollicular branches from several different lobular branches, while smaller lobules usually received interfollicular branches from only one lobular branch.

The interfollicular branches coursed between follicles of the lobule. Opposing follicles frequently appeared to contact the vascular wall of the interfollicular branches (Figure 6). The interfollicular branch usually supplied one, short follicular branch (Table 1, page 44) to each follicle (Figure 13). Frequently, different follicles within the same lobule were supplied by different interfollicular branches, but the general rule of one follicular branch per follicle prevailed. The interfollicular branches usually terminated by bifurcation into follicular branches (Figure 15). In larger lobules, the interfollicular branch occasionally divided into equal sized branches, which coursed in different directions and supplied follicular branches to different follicles.

Upon reaching the follicle, the follicular branches terminated into many follicular capillaries (Table 1, page 44), which ramified into a capillary bed over the surface of the larger follicles (Figure 13), whereas the capillaries of small follicles remained unbranched and consequently there was no capillary bed around them (Figure 14).

In histologic sections, the lobular branches resembled typical arterioles; e.g., decreased luminal size, lesser amount of smooth muscle cells in the tunica media, and the tunica adventitia appeared to be continuous with the perivascular connective tissue. The interfollicular branches had the appearance of dilated capillaries (Figure 16); their walls were composed of a single layer of endothelial cells. Both follicular branches and capillaries had the appearance of undilated capillaries. Also, compared to the size of individual follicular cells, the follicular capillaries were large structures (Figure 13).

Venous drainage

Intrinsic venous pattern The intrinsic veins of the canine thyroid gland followed the general pattern as that of the arteries. From the capillary bed around the large follicles arose the venous bed, which, after converging, formed the follicular vein. The capillaries around small follicles continued into veins which formed the follicular vein. The follicular vein left the follicle on the side almost directly

opposite to where the follicular branch gained the surface of the follicle; adjacent follicular veins joined to form interfollicular veins, which coursed between follicles and emerged from the lobule (Figure 17). Adjacent interfollicular veins, after their confluence, formed lobular veins, which drained the lobules by following the trabeculae between them. Adjacent lobular veins, in turn, formed lobar veins, which drained the functional lobes and adjacent lobar veins formed glandular veins which, for the most part, followed the course of the glandular arterial branches out of the thyroid lobe.

Extrinsic venous pattern The glandular veins, draining the cranial half of the thyroid lobe, joined to form the cranial thyroid vein near the cranial pole of the lobe. The cranial thyroid vein followed the corresponding artery and drained into the internal jugular at approximately the same level as the cranial thyroid artery originated from the common carotid. The glandular veins which drained the caudal half of the thyroid lobe united to form the caudal thyroid vein near the caudal pole of the lobe. The caudal thyroid vein usually drained into the internal jugular approximately 20-30 mm caudal to the caudal pole of the lobe. Occasionally, it entered the internal jugular vein directly opposite the caudal pole of the lobe and in some cases, the caudal thyroid vein descended the neck with the dorsal branch of the cranial thyroid artery and emptied into the brachiocephalic vein.

Numerous valves were observed in the veins within the canine thyroid lobes, as well as, outside the lobes (Figure 18). The valves occurred most frequently at the branching points of the veins (or where smaller veins joined to form larger veins).

Vascular anastomoses

Extrinsic anastomoses Only a few extrinsic arterial anastomoses were observed. The collateral cranial thyroid arteries anastomosed by a small twig arising from collateral ventral branches across the cricotracheal membrane. Collateral ventral branches occasionally anastomosed over the glandular isthmus, when one was present. Cranial thyroid arteries of each side anastomosed with tracheoesophageal arteries of the same side near the cranial thoracic aperture.

Intrinsic anastomoses The arterial-arterial anastomoses were observed at the lobar and lobular divisions of the intrinsic arterial pattern and these anastomoses usually occurred at the terminations of these vessels. Beyond the lobular level, it was difficult to ascertain the arterial-arterial anastomosis in the plastic casts and no anastomosis of any kind was observed in histologic sections. Occasionally, a follicular capillary appeared to anastomose with a follicular capillary of an adjacent follicle.

The venous-venous anastomoses were observed at the same level as those for the arterial-arterial anastomoses, however, no anastomosis prior to that level was observed.

Apparently there were no arterial-venous anastomoses, although several glands injected with red plastic demonstrated red arteries and red veins, with an intervening colorless capillary bed. In other specimens, the entire vascular system was uniformly colored red.

Lymph drainage

Lymph vessels were satellites to the arteries and veins as they followed the trabeculae within the thyroid lobe. No injection material (India ink) was found in the accompanying arteries or veins.

The lymph capillaries surrounded individual follicular cells (Figure 19). The follicular lymph capillaries were all interconnected and formed a lymphatic plexus within the follicle. They appeared to be smaller in diameter and more closely associated to the follicular epithelium than were the blood capillaries. The lymphatic plexus drained into a larger follicular lymph vessel, which drained the follicle. The follicular lymph vessels converged into the interfollicular lymph vessels, which emerged from the lobule.

Within the connective tissue trabeculae between lobules, the interfollicular lymph vessels drained into lobular lymph vessels (Figure 20). The lobular lymph vessels followed the course of the lobular veins and it was not uncommon to find a vascular triad, with the lymph vessel positioned between an artery and a vein (Figure 21).

The lobular lymph vessels converged into the lobar lymph vessels, which drained the lobules and lobar lymph vessels joined the glandular lymph vessels, draining the functional lobes. The glandular lymph vessels emerged from the thyroid lobe in company with the glandular veins.

Angioarchitecture of the Canine Parathyroid Gland

Arteries

Major supply The external parathyroid gland (III) was supplied by a single parathyroid artery, which arose from one of the glandular branches of the cranial thyroid artery. When the external parathyroid gland was situated at the cranial pole of the thyroid lobe, its parathyroid artery arose from a glandular branch off the ventral branch of the cranial thyroid artery. When it was located at the middle or at the caudal pole of the lobe, its parathyroid artery originated from a glandular branch off the dorsal branch of the cranial thyroid artery. When present, the internal parathyroid gland (IV) received its blood supply from small thyroid vessels within the thyroid gland.

Intrinsic arterial pattern The parathyroid artery was large as compared to the size of the parathyroid gland and it entered the gland through a hilus. The artery coursed towards the center of the gland and gave rise to collateral branches, which coursed towards the periphery of the gland. From these

branches arose sinusoid-like capillaries which were in close contact with the epithelial cells of the parathyroid gland.

Venous drainage

The sinusoid-like capillaries continued into veins which followed the course of the arterial branches out of the gland. The veins converged into one large vein which left the external parathyroid gland at the hilus. When the external parathyroid gland (III) existed as multiple nodules, each nodule was drained by a vein, which joined to form one parathyroid vein (Figure 4). The parathyroid vein drained into one of the glandular veins of the thyroid lobe.

Vascular anastomoses

No anastomosis of any kind was observed.

Lymph drainage

The lymph vessels of the external parathyroid gland (III) were not injected with India ink when the injection was made beneath the capsule of the thyroid gland. In six thyroid lobes injected with India ink, no internal parathyroid glands were observed in histologic sections.

DISCUSSION

Gross Anatomy of the Canine
Thyroid GlandLocation

The canine thyroid gland consisted of two lobes, one each situated on the right and left ventrolateral aspects of the cranial portion of the trachea. The medial surface of each lobe contacted the deep cervical fascia surrounding the trachea, the lateral surface faced the carotid sheath, and the ventral border lay in contact with the sternothyroideus muscle. The dorsal border of the left lobe was in contact with the esophagus, while that of the right lobe was covered by the longus capitis muscle. With the exception of three lobes whose cranial poles were found at the middle of the cricoid cartilage, in the remaining specimens the lobes extended from the caudal border of the cricoid cartilage to the sixth to eighth tracheal ring (Table 2). These relationships were concordant with those reported by Bradley and Grahame (1959), Hoskins et al. (1962), Smithcors (1964), and Adam et al. (1970).

Smithcors (1964) stated that the cranial pole of the left lobe was usually found one to three tracheal rings caudal to that of the corresponding right. In this study, 30.00% of the specimens demonstrated the cranial pole of the left lobe caudal to that of the right lobe, while the cranial pole of the left

lobe in 42.50% of the specimens was cranial to that of the right and the cranial pole of the left lobe was found at the same level as that of the right in 27.50% of the specimens. Thus, more frequently, the left lobe was located cranial to the right lobe, contrary to the description given by Smithcors.

Shape and size

The majority of lobes were elongated oval with narrowing extremities. The shape was symmetrical on both sides of the animal.

The relationship between weight of the thyroid gland to body weight was not considered in this study, mainly because the factors that influence this relationship (e.g., sex, breed, etc.) were not available since the animals were obtained from a biological supply company (refer to materials and methods). However, size in regard to length, width, and thickness was measured, and the left lobe was statistically found to be significantly longer than the right lobe by 1.50 mm, in both sexes. The width and thickness were not found to be significantly different between sides. Also, there was no evidence that differences in sides were dependent on sex, concordant with the findings of Haensly et al. (1964), who reported no sex difference in the weight of the thyroid glands of beagles.

Thyroid isthmus

An isthmus (both glandular and nonglandular) was found connecting the caudal poles of the right and left thyroid lobes in 20 out of 50 dogs of mesaticephalic breeds (40.00%). Fourteen of the 20 specimens had a nonglandular isthmus, i.e., the isthmus was represented by a white fibrous band and, therefore, probably was nonfunctional in the living animal. However, the remaining six had a glandular isthmus, because they were of the same color as the bilaterally placed thyroid lobes, and assumingly were functional in the living animal. These findings contradicted the observations of Adam et al. (1970), who stated that the dog lacked a well-developed isthmus, but were in agreement with Smithcors (1964), who found that in some dogs there was a small fibrous band, which represented a fetal vestige of the isthmus. Smithcors also described that a glandular isthmus was most frequently found in brachycephalic breeds. Twelve per cent of the specimens in this study possessed a glandular isthmus.

Of the six specimens with a glandular isthmus, five were females and only one was a male. This may have had some correlation to the findings of Latimer (1967), that females had larger thyroid glands than males and that there was a normal enlargement during estrus and pregnancy with heavier thyroids occurring in repeatedly pregnant females. He seemed to imply that pregnant females had large thyroid glands complementing

the increased need of thyroid hormones required during pregnancy. A functional and glandular isthmus would apparently increase thyroid hormone production as well as relative weight of the gland. Since status of pregnancy was not available for this investigation, the correlation that females more frequently possessed a glandular and functional isthmus due to the needs arising from estrus and pregnancy could only be implied.

Gross Anatomy of the Canine Parathyroid Glands

Location

There was one pair of parathyroid glands associated with each thyroid lobe. The external parathyroid gland (III) was a large white to cream colored nodule, most frequently found resting on the lateral surface of the cranial pole of the thyroid lobe, lying outside the thyroid gland capsule. It was also found almost as frequently on the lateral surface of the middle portion of the lobes and less frequently on the caudal pole. In cases where the external parathyroid gland was not found on the thyroid lobe, it was most frequently located in the fascia about the cranial pole of the thyroid lobe. This contrasted sharply with Hoskins et al. (1962), who reported the external parathyroid gland usually in the fascia above the cranial pole of the lobe. The right and left external parathyroid glands were not always symmetrical in position, con-

cordant with the findings of Vicari (1938) and Smithcors (1964).

Fowler and Hanson (1929) found only one parathyroid gland in close contact with the lateral surface of the middle third of each lobe. This parathyroid gland probably was an external parathyroid gland as observed in the same location during this study. They probably missed the smaller internal parathyroid gland (IV) along the medial surface of the thyroid lobe, since it was located beneath the thyroid gland capsule. Usually, histologic sections revealed its presence, however this was not always the case. In those cases, the internal parathyroid glands were probably removed when the thyroid gland capsule was stripped from the lobes for histological processing.

Shape and size

Both the external and internal parathyroid glands were circular in shape. The external parathyroid gland (III), in general, was relatively larger than the corresponding internal parathyroid gland (IV).

Accessory parathyroid tissue

Accessory parathyroid tissue was not looked for because it was not within the scope of this investigation; however, very small nodules, scattered along the lateral and medial surfaces of the thyroid lobes, were occasionally observed. These probably represented accessory external and internal parathyroid tissue, respectively. The multiple external

parathyroid nodules (Figure 4), occasionally found, were not considered accessory parathyroid tissue because they were almost of equal size and situated quite close to each other, contrary to smaller clumps of parathyroid tissue which were not closely associated with the main parathyroid mass. They probably occurred from an equal division of the main parathyroid mass during development.

Histology of the Canine Thyroid Gland

Capsule and trabeculae

The lobes of the canine thyroid gland were enveloped by the deep cervical fascia, which formed the capsule. The capsule was intimately related to the thyroid parenchyma and it was difficult to remove from several lobes. Also, histologic sections of those lobes stripped of their capsule, demonstrated only a few strands of connective tissue surrounding them, whereas lobes with intact capsules revealed a thick connective tissue layer.

Flint (1904), Regant and Pettijean (1905), and Rienhoff (1929) believed the canine thyroid gland was not divided into lobes or lobules. In this study, the thyroid lobes demonstrated trabeculae from the thyroid capsule, which divided the anatomical lobes into functional lobes and, further, into lobules. This confirmed the observations of Major (1909), Johnson (1955), Trautmann and Fiebiger (1957),

Smithcors (1964), and Dellmann (1971). However, in accord with the description of Johnson (1955) and Dellmann (1971), the trabeculae were relatively thin and the boundaries of the lobular structure were difficult to delineate. In most cases, the only connective tissue within the lobes appeared to be associated with the tunica adventitia of the blood vessels. The trabeculae were fairly thick at first (in reference to the larger glandular branches of the blood vessels) and became progressively thinner as the blood vessels divided into lobar, lobular, and interfollicular branches. The trabeculae ended as reticular fibers which completely surrounded the follicles. These reticular fibers appeared to be associated with the capillary bed surrounding the follicles.

Usually, due to the plane of section, the capillary beds of the follicles were not visible, though reticular fibers were seen surrounding the follicles. This tended to disagree with the hypothesis that the connective tissue observed within the thyroid lobes was that associated with the blood vessels. However, the lymphatic capillary bed, which appeared to be more closely related to the follicular cells and more numerous (Figure 19) than the arterial capillary bed (Figure 13), must not be overlooked. In sections where the lymph vessels were not injected, the smaller lymph vessels were not observed (probably because they were collapsed) and only their reticular fibers were seen. Thus, the reticular fibers of the lymphatic

and arterial capillary beds were seen surrounding the follicles.

The follicular cells rested against the reticular fibers surrounding the follicles and thus the reticular fibers appeared to form the basement membrane of the follicles, in agreement with the description of Dellmann (1971). Each follicle possessed this reticular basement membrane and thus the follicles were completely separated from each other. This disagreed with Gilmore et al. (1940), who stated that the reticular fiber boundary was not always present in the canine thyroid gland. They based their findings on sections stained with hematoxylin and eosin (H & E). In the present investigation, those sections stained with Crossmon's modification of Mallory's triple showed many follicles which appeared to contact each other, while the silver impregnated sections demonstrated that each follicle was separated from adjacent follicles by argyrophilic reticular fibers. Isler et al. (1969) also studied H & E stained sections, but, in addition, they studied silver impregnated sections. They observed follicles, in the thyroid glands of rats, in direct contact with each other with no intervening basement membrane between adjoining follicles, in an area of approximately 12 follicular cells. This difference may be due to species variations.

Thyroid follicles

The follicles were round to oval and variable in size. The different sized follicles were uniformly dispersed through-

out the lobes, except toward the periphery, where the larger follicles prevailed. This contrasted with the description of Bloom and Fawcett (1968) who stated that in animals, the follicles were of uniform size, but agreed with the reports by Reinhold (1949) and Dellmann (1971) that the follicles in the dog and domestic animals, respectively, varied in size. This variation in size was most likely due to the state of physiological activity of the follicles.

The follicles were composed of a single layer of cells with variable heights, containing a rounded, euchromatin nucleus situated toward the base of the cells. In small follicles the cells were columnar and in large follicles squamous. This variation in cell heights was believed to be due to the activity of hormone production; columnar cells engaged in hormonal production and squamous cells in an inactive or resting phase (Baillif, 1937; Taylor and Weber, 1951; Sugiyama, 1954; and Dellmann, 1971). It was not due to some pathological condition as believed by Wilson (1927).

A homogeneous, acidophilic colloid was observed within the lumina of most follicles, however, equally present were follicles with partially acidophilic and partially basophilic colloid (Reinhold, 1949; Hoskins et al., 1962). This variation in the staining reaction was probably produced by the differential penetration of fixing agent and its chemical effect on the iodinated colloid as believed by De Robertis

(1941). The vacuolated colloid, frequently found, was probably a fixation artifact, for lobes which were perfused with buffered neutral formalin (BNF) did not demonstrate vacuolated colloid, whereas lobes fixed by infiltration of BNF demonstrated vacuoles.

Parafollicular cells and other cellular masses

Parafollicular cells (C-cells) were more frequently found as single cells contained within the reticular basement membrane of the follicles, than as clusters of cells (usually four), surrounded by reticular fibers in the interstitial tissue. The parafollicular cells were differentiated from typical follicular cells by being larger, more rounded, and containing slightly larger, centrally located, vesicular nuclei. Their cytoplasm was more clear in appearance than that of the follicular cells. The parafollicular cells were scattered throughout the lobes as observed by Roediger (1973) in older dogs.

A remnant of an ultimobranchial body, identified by its similarity to ultimobranchial bodies normally found in other animals (cats - Mason, 1931 and Haensly, 1975; Sheep - Jordan et al., 1973; Rats - Calvert, 1975), was found in one lobe. The so-called ultimobranchial body was in the form of a tube, measuring 400 μ in length and surrounded by a conspicuous connective tissue layer, similar to the description of ultimobranchial cysts given by Jordan et al. (1973) in the sheep and

Calvert (1975) in rats. The walls of the ultimobranchial tube consisted of a stratified, partially ciliated epithelium (Jubb and Kennedy, 1963 and Tashiro, 1963) and its lumen contained a clear homogeneous substance with cellular debris, which did not give the typical staining reaction of follicular colloid, i.e., either eosinophilic or partially eosinophilic and partially basophilic. This was in accord with the descriptions of Jubb and Kennedy (1963) and Calvert (1975).

Many small ducts arose from the so-called ultimobranchial tube and the ducts dilated to form ultimobranchial follicles, as described by Jubb and Kennedy (1963), Jordan et al. (1973), and Calvert (1975). The walls of the ducts consisted of stratified epithelium, whereas the ultimobranchial follicles were composed of a single layer of squamous epithelium, indistinguishable from the follicular epithelium, as was found to be true by Calvert (1975). The lumina of both the ducts and the follicles contained the same type of material as did the ultimobranchial tube, concordant with the findings of Calvert (1975). Besides forming ultimobranchial follicles, the ducts were connected to what was designated as mixed follicles (Figure 9). The walls of the mixed follicles consisted primarily of a single layer of squamous cells, except at the ultimobranchial ducts where the epithelium tended to become stratified squamous.

Mixed follicles were supposed to be composed of follicular and ultimobranchial cells, however, at the light microscopic level, these two cell types were indistinguishable from each other (Calvert, 1975); thus, the mixed follicle could be mistaken for a typical thyroid follicle, if its connection to the ultimobranchial tube was not evident. The only evidence for mixed follicles observed in this study was that the lumina of the mixed follicles contained typically stained follicular colloid, situated around material similar to that found in the ultimobranchial tube, in agreement with the observations of Calvert (1975).

Histology of the Canine Parathyroid Glands

The external parathyroid glands (III) were surrounded by a thin connective tissue capsule, which, although separate, was continuous with the thyroid gland capsule. Delicate trabeculae arose from the capsule and accompanied the blood vessels into the gland. It was exceedingly difficult to distinguish the trabeculae from the tunica adventitia of the accompanying vessels, and thus the connective tissue within the parathyroid gland appeared to be that of the tunica adventitia of the blood vessels. The epithelium of the external parathyroid gland possessed a basophilic cytoplasm and nucleus, and was arranged into columns (cords), facing the sinusoid-like capillaries, thus being reminiscent of the

cellular arrangement within the liver.

Histologic sections only revealed internal parathyroid glands (IV) embedded within the thyroid parenchyma. Those glands not embedded within the thyroid parenchyma, but beneath the thyroid gland capsule, were probably removed when the capsule was stripped from the thyroid gland. Those internal parathyroid glands observed, differed grossly from the external parathyroid glands only by not possessing a distinct capsule.

These findings were in agreement with those of Flint (1904), Taylor and Weber (1951), Trautmann and Fiebiger (1957); Hoskins et al. (1962), Smithcors (1964), Adam et al. (1970), and Dellmann (1971).

Angioarchitecture of the Canine Thyroid Gland

Arteries

Tracheoesophageal (Caudal thyroid- N.A.V., 1973) artery

A controversy exists in the literature regarding the occurrence of a caudal thyroid artery in the canine. The Nomina Anatomica Veterinaria (1973), similar to the descriptions of previous investigators, classified the dog as possessing a caudal thyroid artery, while Zietzschmann (1943) believed that it was almost always absent in the dog. In the literature, most authors stated the caudal thyroid artery was variably present in the dog (Major, 1909; Latarjet and Alamartine, 1910; Rogers, 1929; Wangensteen, 1929; Bradley and Grahame, 1959; Nickel and

Schwarz, 1963; Smithcors, 1964; Ichev, 1969c, d).

This controversy seemed to center around the concept of homologous (meaning likeness in structure or function between parts of different organisms due to evolutionary differentiation from the same or a corresponding part)¹ arteries. An artery, named the caudal thyroid artery, was occasionally found in the dog that appeared to be partly homologous to the human inferior thyroid artery, in regard to the following aspects:

1. It had a variable origin extending from the costo-cervical trunk cranially to the brachiocephalic trunk caudally, similar to the inferior thyroid artery (Ellenberger and Baum, 1891; Bradley and Grahame, 1959; Nickel and Schwarz, 1963; Smithcors, 1964).

2. It supplied twigs to the esophagus and trachea, similar to the inferior thyroid artery (Bradley and Grahame, 1959; Smithcors, 1964).

3. It appeared to approach the canine thyroid gland from its caudal aspect and assisted in the blood supply to the gland (Bradley and Grahame, 1959).

However, comparing the canine caudal thyroid artery and the human inferior thyroid artery, as described in the literature, it was quite obvious that dissimilarities, too, existed

¹Taken from Webster's Seventh New Collegiate Dictionary, 1965.

between the two arteries. The dissimilarities were the following:

1. The human inferior thyroid artery was believed to be almost always present. Dwight (1894) found it absent in only six cases out of 437 human specimens (absent in one case on the right side and in five cases on the left). Those investigators who described a caudal thyroid artery, stated it was variably present in the dog (Major, 1909; Latarjet and Alamartine, 1910; Bradley and Grahame, 1959; Nickel and Schwarz, 1963; Smithcors, 1964; Ichev, 1969c, d). Loeffler (1955) found that the caudal thyroid artery was present in 4 out of 11 dogs (in three cases on both sides and in one case only on the right side). It was believed that if the canine caudal thyroid artery was homologous to the human inferior thyroid artery, its frequency of occurrence should have been somewhat comparable with that of the human inferior thyroid artery.

2. The inferior thyroid artery was considered to be a major (and in most cases "the" major) contributor to the blood supply of the human thyroid gland (Berry, 1901; Eiselsberg, 1901; Major, 1909; Sobotta, 1915; de Quervain, 1916; Mastin, 1923; Fowler and Hanson, 1929; Rogers, 1929; Stewart, 1932; Johnson, 1953; Ichev, 1970). Adachi (1928) found that occasionally the human inferior thyroid artery was so small that it did not supply the gland at all, but ended in branches to the trachea and esophagus. Hunt et al. (1968) stated that when

the inferior thyroid artery was absent, the superior thyroid artery became the major blood supply to the gland. In the dog, the cranial thyroid artery was considered to be the major contributor (Major, 1909; Latarjet and Alamartine, 1910; Bradley and Grahame, 1959; Nickel and Schwarz, 1963; Smithcors, 1964; Ichev, 1969c, d). Bradley and Grahame (1959) described that the caudal thyroid artery assisted in the blood supply to the canine thyroid gland, however, they did not specifically state it was the major contributor.

3. Berry (1901), Major (1909), Sobotta (1915), Mastin (1923), and Rogers (1929) observed that the inferior thyroid artery was usually larger than the superior thyroid artery in humans, while Ellenberger and Baum (1891), Bradley and Grahame (1959), Nickel and Schwarz (1963), and Smithcors (1964) stated that when the canine caudal thyroid artery was present, it usually was the smaller of the two vessels. Smithcors added that occasionally the caudal thyroid artery was well developed and, in those cases, the cranial thyroid artery was reciprocally reduced. Although no exact figures were provided with the above statements, it appeared the literature implied that of the two arteries in humans and dogs, the inferior thyroid artery was the larger more frequently in humans, than the caudal thyroid artery was in the dog.

4. The inferior thyroid artery was reported to course cranially, ventral to the longus colli muscle, and as it

approximated the inferior pole of the thyroid gland, it turned medially and descended, dorsal to the carotid sheath, to enter the posterior surface of the thyroid gland (Mastin, 1923; Fowler and Hanson, 1929; Rogers, 1929; Stewart, 1932; Bachhuber, 1943; Goss, 1966). Thus, the human inferior thyroid artery, for the most part, lay dorsal to the carotid sheath. Bradley and Grahame (1959) and Smithcors (1964) stated that the canine caudal thyroid artery accompanied the recurrent laryngeal nerve on the ventromedial aspect of the trachea, placing the caudal thyroid artery ventral to the carotid sheath. Therefore, its course was not similar to the human inferior thyroid artery.

5. According to Goss (1966), the human inferior thyroid artery gave rise to, a). inferior laryngeal, b). tracheal, c). esophageal, d). ascending cervical, and e). muscular branches. Bradley and Grahame (1959) and Smithcors (1964) reported that the canine caudal thyroid artery only supplied branches to the trachea, esophageal, caudal cervical ganglion, and nerves in the region of the cranial thoracic aperture. Smithcors added that the cervical portions of the trachea and esophagus were supplied only in those dogs where the caudal thyroid artery was well developed. Thus, even the branching pattern of the canine caudal thyroid artery was not homologous in all respects to the human inferior thyroid artery.

6. Finally, the inferior thyroid artery was found to terminate by supplying direct branches to the human thyroid

gland (Mastin, 1923; Fowler and Hanson, 1929; Nonidez, 1931; Bachhuber, 1943; Goss, 1966). In the literature reviewed, only Bradley and Grahame (1959) stated the caudal thyroid artery assisted in the blood supply to the canine thyroid gland. However, they did not state if this occurred by direct branches. Also, both the human inferior thyroid artery and the canine caudal thyroid artery were found to anastomose with a branch of the superior and cranial thyroid arteries, respectively, a possible point of similarity. However, this anastomosis, in the human, occurred on the surface of the thyroid gland (Nonidez, 1931), whereas Smithcors (1964) reported it took place in the middle third of the neck in dogs. Therefore, because of the above dissimilarities between the two arteries, it appeared the literature did not provide sufficient evidence to warrant calling this vessel, which was occasionally found to accompany the recurrent laryngeal nerve, a caudal thyroid artery.

A similar situation existed for what was termed the tracheoesophageal artery in this investigation. This artery was observed to have a few characteristics similar to the canine caudal thyroid artery and the human inferior thyroid artery, as previously mentioned, viz:

1. It had a variable origin, stretching from the costo-cervical trunk cranially to the brachiocephalic trunk caudally.

2. It coursed cranially, in company with the recurrent laryngeal nerve, on the ventrolateral aspect of the trachea and supplied twigs to the esophagus and trachea, similar to the canine caudal thyroid artery, when it was well developed (Smithcors, 1964).

3. It anastomosed with a branch of the cranial thyroid artery.

4. Seemingly it approached the caudal aspect of the canine thyroid gland.

However, detailed examination of this artery disclosed it was not similar to either the caudal thyroid artery or the inferior thyroid artery. The following observations were made:

1. This vessel was observed as a bilateral (right and left) artery in all 50 specimens. This 100 per cent occurrence was similar to the human inferior thyroid artery, believed to be almost always present, but it was not similar to the caudal thyroid artery, reported as only being occasionally present in dogs.

2. Its course on the ventrolateral aspect of the trachea was similar to that of the canine caudal thyroid artery, but not similar to that of the human inferior thyroid artery.

3. This artery was observed to be much smaller than the cranial thyroid artery, similar to that described for the caudal thyroid artery, but not similar to that described for the inferior thyroid artery.

4. Both the right and left arteries in this investigation were observed to terminate by anastomosing with the dorsal branch of the cranial thyroid artery near the cranial thoracic aperture. The site for this anastomosis was ascertained based upon the generally accepted premise that arteries branched at acute angles to the direction of flow (Shellshear, 1920). It was near the cranial thoracic aperture that the angles of the caudally directed twigs from the dorsal branch of the cranial thyroid artery, and the angles of the cranially directed twigs of this tracheoesophageal artery abruptly changed courses (Figure 1). This anastomosis was caudal to those described for the canine caudal thyroid artery and the human inferior thyroid artery in the literature.

5. Since this artery terminated by the anastomosis described in (4) above, this artery was not observed supplying direct branches to the thyroid gland. Thus, it was not homologous to the human inferior thyroid artery, whose terminal branches directly supplied the thyroid gland. It was hypothesized that under normal physiological conditions, this artery did not supply blood to the canine thyroid gland, because of the pressure gradient existing in the dorsal branch of the cranial thyroid artery. Since this artery was not believed to supply blood to the thyroid gland, it was considered not appropriate to call this artery a caudal thyroid artery. However, under pathological conditions, where there was reduced

pressure in the dorsal branch, due to prolonged interruption of blood flow in either the common carotid or cranial thyroid artery, this artery can act as an important collateral blood supply to the canine thyroid gland. This consideration was concordant with the findings of Reilly (1954) and Wolpert (1969). Reilly observed that when the main vessels to the rabbit thyroid gland were closed, a collateral supply was achieved through a vessel formed by the enlargement of the anastomosis between the tracheal branch of the inferior (caudal) thyroid artery and the tracheal branch of the bronchial artery on each side. Wolpert observed that the thyroid ima artery became the collateral when the blood supply (both superior and inferior thyroid arteries) to the human thyroid gland was occluded. This hypothesis of a possible collateral supply nullified any similarity between the tracheoesophageal artery in this investigation and the fact that Adachi (1928) occasionally found the inferior thyroid artery so small that it did not supply blood to the gland at all, but ended in branches to the trachea and esophagus.

6. In support of the hypothesis that this artery did not supply blood to the canine thyroid gland under normal physiological conditions, was the observation that in 18 out of 50 specimens, the dorsal branch of the cranial thyroid artery supplied no glandular branches to the thyroid gland. The blood supply in those instances was compensated by the ventral branch

of the cranial thyroid artery. Thus, if blood was to reach the gland from this artery, it would have to ascend the entire length of the neck region, enter the cranial thyroid artery, and be distributed by the glandular branches from the ventral branch of the cranial thyroid artery. It was believed that under normal physiological conditions, the blood possibly did not flow in this manner. Fowler and Hanson (1929) stated that the human superior thyroid artery was the only artery in the neck in which the blood flow was toward the heart. It was believed that the blood within the dorsal branch of the canine cranial thyroid artery also flowed towards the heart.

7. The esophagus in the cranial mediastinum of humans was supplied by twigs from an artery arising from the left subclavian (Demel, 1924). This unnamed artery also anastomosed with branches of the inferior thyroid artery above and the bronchoesophageal artery below. Smithcors (1964) described this same area in the dog as being supplied by a small descending branch from the left caudal thyroid artery which anastomosed with an ascending branch off the bronchoesophageal artery. Thus, in humans, the blood supply of the esophagus in the cranial mediastinum involved three arteries, viz., the bronchoesophageal, the unnamed artery of Demel, and the inferior thyroid artery, whereas in the dog, this same region involved only two arteries, viz., the bronchoesophageal and the caudal thyroid artery. In this investigation, the esophagus in the

cranial thoracic region was supplied by only one artery, the tracheoesophageal. In the majority of cases, as this artery gained the ventral aspect of the esophagus, it bifurcated into an ascending and a descending branch. The ascending branch supplied twigs to the esophagus and trachea, before it anastomosed with the dorsal branch of the cranial thyroid artery, near the cranial thoracic aperture. The descending branch supplied twigs to the esophagus to about the level of the root of the left lung. In 6 out of 50 cases, this tracheoesophageal artery originated from the bronchoesophageal artery (Figure 1), ascended the ventral aspect of the esophagus and supplied twigs to the trachea and esophagus before it anastomosed with the dorsal branch of the cranial thyroid artery near the cranial thoracic aperture. This artery was the only vessel supplying the esophagus and trachea in the cranial thoracic region in this investigation, and it did not anastomose with any artery which resembled entirely either an inferior thyroid or a caudal thyroid artery. Since this artery did not resemble or anastomose with a vessel that resembled a caudal thyroid artery, it was believed that all 50 dogs in this investigation did not possess a caudal thyroid artery. Since this artery appeared to be primarily concerned with the blood supply to the esophagus and trachea in the cranial mediastinum, it was considered appropriate to call this artery the tracheoesophageal artery instead of the caudal thyroid, in compliance with the

usually accepted criteria for naming other blood vessels which reflect their course and major area of supply.

8. Jarvis and Nell (1963) described a tracheoesophageal artery in the dog that was very similar to the left tracheoesophageal artery in this investigation. They found this tracheoesophageal artery to arise from the dorsolateral aspect of the brachiocephalic trunk and to bifurcate into a cephalic and a caudal branch, similar to the ascending and descending branches of the tracheoesophageal artery in this investigation. They only traced the cephalic branch for a few centimeters, but found it supplying twigs to the trachea and esophagus. The caudal branch coursed to the root of the left lung, supplying twigs to the esophagus in this region, similar to the descending branch of this investigation. Jarvis and Nell hypothesized that the tracheoesophageal artery is provided, in the dog, to bridge the vascular gap existing between the thyroid and bronchial blood supplies due to the relatively longer cervical region in the dog than in humans and the fact that the first and only significant branch from the common carotid artery in dogs was the cranial thyroid artery. The observations of this investigation tended to support their hypothesis. The only arteries supplying the canine trachea and esophagus in the cervical and cranial mediastinum were observed to arise from the dorsal branch of the cranial thyroid artery, which Nonidez (1931) called the "tracheo-oesophagic branch" of the canine

cranial thyroid artery, and from the tracheoesophageal artery, respectively.

It was concluded that the mesaticephalic dogs used in this study, did not possess an artery homologous to the human inferior thyroid artery and there was no artery that would appropriately be called a caudal thyroid artery. The artery, in this investigation, which coursed with the recurrent laryngeal nerve, was not considered a caudal thyroid artery because of the following:

1. It was observed as a bilateral artery in all 50 specimens.

2. It terminated by anastomosing with the dorsal branch of the cranial thyroid artery near the cranial thoracic aperture and therefore did not supply direct branches to the thyroid gland. Also, under normal physiological conditions, the artery was not believed to supply blood to the thyroid gland; therefore, the artery would not appropriately be called a caudal thyroid artery. However, under pathological conditions where there was prolonged interruption of blood flow in either the common carotid or cranial thyroid artery, this vessel could act as an important collateral blood supply.

3. This artery appeared to be concerned only with the blood supply to the trachea and esophagus in the caudal cervical and cranial thoracic regions.

4. It was homologous to the tracheoesophageal artery described by Jarvis and Nell (1963), who hypothesized the tracheoesophageal artery was provided to bridge the vascular gap existing between the cranial thyroid and bronchial blood supplies in the dog.

A more appropriate name for this artery was considered to be the tracheoesophageal artery on the basis of accepted criteria for naming other blood vessels which reflect their course and major area of supply.

The possibility existed that breed variation may have been the reason that the mesaticephalic dogs in this study did not possess an artery that would appropriately be called a caudal thyroid artery. However, until further investigations along this line are undertaken, there is a strong possibility that the canine, in general, does not possess a caudal thyroid artery per se. This possibility was supported by the results of this investigation, coupled with the facts that, a). a controversy exists in the literature as to the presence of a caudal thyroid artery in the dog, and b). even in those cases where a caudal thyroid artery was described, the evidence was not conclusive to warrant calling any artery, a caudal thyroid.

Cranial thyroid artery The cranial thyroid artery arose from the common carotid approximately 1 cm opposite the cranial pole of the thyroid lobe. Thus, similar to the findings of Nickel and Schwarz (1963), the origin of the

cranial thyroid artery can be displaced, either proximal or distal, dependent upon the position of the thyroid lobe.

The sternocleidomastoid was the first branch of the cranial thyroid artery. It arose from the cranial aspect of the cranial thyroid artery and supplied the sternomastoideus and sternooccipitalis portions of the sternocephalicus muscle, the cleidomastoideus portion of the brachiocephalicus muscle, the medial retropharyngeal lymph node, and occasionally the mandibular gland. The continuation of the cranial thyroid artery then bifurcated into a dorsal and a ventral branch (Loeffler, 1955), which were comparable to the medial and lateral branches, respectively, in other animals (Nickel and Schwarz, 1963).

The dorsal branch coursed caudally, along the dorsal border of the thyroid lobe, and in 32 out of 50 specimens, it supplied a variable number of glandular branches to the dorsal and medial aspects and the caudal pole of the corresponding lobe, comparable to the dorsal group of glandular branches described by Smithcors (1964). In the remaining specimens, the blood supply to the lobe was compensated by the ventral branch of the cranial thyroid artery. Usually, the dorsal branch gave rise to a pharyngeal branch, near its origin from the cranial thyroid artery. The pharyngeal branch ascended the ventral aspect of the esophagus on the left side and the longus colli muscle on the right, and supplied twigs to the cranial portion

of the esophagus and larynx. It terminated in the constrictor muscles of the pharynx. Occasionally the pharyngeal branch, instead, arose directly from the cranial thyroid artery near the origin of the sternocleidomastoid branch.

After emerging from the deep face of the caudal pole of the thyroid gland, the dorsal branch descended the cervical region along the ventrolateral aspect of the trachea, in company with the recurrent laryngeal nerve. It supplied twigs to the cervical portion of the trachea and esophagus and anastomosed with the tracheoesophageal artery (caudal thyroid artery of the N. A. V., 1973) near the cranial thoracic aperture (Figure 1). This dorsal branch was identical to the large branch, described by Smithcors (1964), which usually arose from the dorsal group of glandular branches, followed the recurrent laryngeal nerve caudally and anastomosed with what Smithcors called the caudal thyroid artery, when present, in the middle third of the neck. Nonidez (1931) called this vessel the "tracheo-oesophagic branch" of the canine cranial thyroid artery. In the rabbit, Bugge (1967) described it as the descending branch of the cranial thyroid artery.

The ventral branch of the cranial thyroid artery coursed medially towards the larynx, cranial to the cranial pole of the thyroid lobe, and supplied a variable number (1-3 or 4) of glandular branches to the cranial pole. These branches comprised the ventral group of glandular branches described by Smithcors (1964). Slightly beyond the cranial pole of the

thyroid lobe, the ventral branch gave rise to the cricothyroid branch, which ascended the ventrolateral aspect of the larynx and supplied twigs to the sternohyoideus, sternothyroideus, thyrohyoideus, and cricothyroideus muscles. Smithcors (1964) and N.A.V. (1973) listed the caudal laryngeal as a branch from the cranial thyroid artery. In this study, it was observed to arise from the cricothyroid branch instead. The caudal laryngeal branch was traced to the point where it entered the larynx by passing through the cricothyroid membrane.

After giving rise to the cricothyroid branch, the ventral branch of the cranial thyroid artery supplied a twig, which anastomosed with a corresponding twig from the opposite side, across the cricotracheal membrane. The ventral branch then descended along the ventral border of the thyroid lobe, supplying twigs (also considered part of the ventral group of glandular branches) to the ventrolateral aspect of the lobe. Its termination was dependent upon the branching of the dorsal branch and the presence of a glandular isthmus. When the caudal half of the thyroid lobe was supplied by the dorsal branch, the ventral branch terminated within the cranial half of the lobe. In the absence of glandular branches from the dorsal branch, as mentioned previously, the ventral branch terminated in the caudal pole of the thyroid lobe compensating them. When a glandular isthmus was present, the ventral branch supplied it and occasionally entered the caudal pole of the

opposite thyroid lobe via the isthmus. Thus the right and left thyroid lobes may exchange blood via this route.

Intrinsic arterial pattern The intrinsic arteries of the thyroid gland have been called by a variety of names in the literature. After compiling Table 1 (page 44), based on the descriptions of these arteries given by the various investigators, it was recognized that they all gave different names to the same vessel, except for Wangensteen (1929), who equated the fourth order arteries (Major, 1909) with the follicular arteries and Stewart (1932), who believed no follicular arteries existed in humans.

Since the canine thyroid gland was found to be structurally divided into lobes, lobules, etc., it was considered appropriate to give corresponding names to the arterial branches which supplied these internal divisions, adopting the usually accepted criteria for naming other blood vessels which reflect their course and major area of supply. Thus, the intrinsic arterial pattern was observed as follows:

1. The cranial thyroid artery was the major blood supply to the canine thyroid gland. Usually, it gave rise to both dorsal and ventral groups of glandular branches (arising from the dorsal and ventral branches of the artery, respectively). Frequently, no dorsal group of glandular branches arose from the dorsal branch, in which case, the blood supply was compensated by the ventral branch of the cranial thyroid artery, as stated previously.

2. The glandular branches usually penetrated the thyroid capsule and gave rise to lobar branches within the substance of the thyroid gland (Major, 1909; Johnson, 1955; Ichev, 1965). Thus, they were unlike corresponding branches in humans, which coursed on the surface of the thyroid gland and gave rise to similar branches which penetrated the capsule of the human thyroid gland (Major, 1909; Stewart, 1932; Ichev, 1965). The glandular branches, usually from the ventral branch, which entered near the cranial pole of the thyroid lobe, usually traveled within the parenchyma for some distance before they gave rise to lobar branches. If an external parathyroid gland (III) was situated near the cranial pole of the specimen, these glandular branches usually coursed beneath it before they entered the gland. Within the thyroid lobe, the long glandular branches usually trifurcated into lobar branches, which coursed within the connective tissue trabeculae between the functional lobes (Figure 12). The glandular branches, which entered the dorsal and ventral borders of the thyroid lobe, almost immediately divided into lobar branches.

3. The lobar branches ran between functional lobes and released lobular branches into the functional lobes. The number of lobular branches supplied to each functional lobe depended upon its size. Thus, the larger functional lobes received a greater number of lobular branches from a greater number of lobar branches than did smaller functional lobes.

This was in agreement with the findings of Johnson (1953) who reported that the functional lobe may receive more than one artery.

4. The lobular branches traveled within the interlobular septa and gave rise to interfollicular branches, which entered the lobules. Again, the number of branches was dependent upon the size of the lobule. Larger lobules received a greater number of interfollicular branches from several different lobular branches, while very small lobules usually received interfollicular branches from only one lobular branch. This observation appeared to be a compromise between Johnson (1953, 1955) and Arosenius and Nylander (1962), who believed that only one artery supplied each lobule, and that of Major (1909) and Ichev (1965), who observed many arteries supplying each lobule. Besides, being a reasonable compromise between divergent views of the above authors, this observation had a practical consideration. The smaller lobules, consisting of only a few follicles, usually were adequately supplied by one interfollicular branch, whereas the larger lobules, consisting of many more follicles, required a larger number of interfollicular branches. Therefore, it seemed logical that a larger area would require a relatively larger blood supply as compared to a smaller area.

5. The interfollicular branches coursed between follicles, whose cells appeared to contact the vascular wall (Figure 6).

As the interfollicular branch coursed past a follicle, it detached one, short follicular branch to each follicle (Figure 13). Frequently, different follicles within the same lobule were supplied by different interfollicular branches, but the general rule of one follicular branch per follicle prevailed. The interfollicular branches usually terminated by bifurcation into follicular branches (Figure 15).

6. Upon reaching the follicle, the follicular branch ended into many follicular capillaries, which ramified into a capillary bed over the surface of the larger follicles (Figure 13), whereas the capillaries of smaller follicles remained unbranched and consequently there was no capillary bed around them (Figure 14).

The terminal arterial pattern described in (5) and (6) above, is an area of controversy in the literature. Wangenstein (1929), Stewart (1932), Johnson (1953, 1955), Arosenius and Nylander (1962), and Faller (1964) believed that the capillary bed, around each follicle, arose from only one artery (the follicular branch). Thomas (1945), on the other hand, reported two capillary systems in the rat thyroid gland; an interfollicular system, equivalent to the follicular capillaries described in this investigation, and an intraepithelial system, which originated in the interfollicular system, but was embedded in the epithelial wall of the follicle. Ichev (1965, 1967b, c, 1968a, b) believed the follicles in both man and dog

had its own capillary network, but also received capillaries from neighboring follicles. Thomas (1945) did not find the capillary networks of adjacent follicles anastomosing with each other.

In this investigation, the capillary network of each follicle was observed to arise from only one follicular vessel, thus in agreement with Wangensteen (1929), Stewart (1932), Johnson (1953, 1955), Arosenius and Nylander (1962), and Fallner (1964). In the thyroid glands, made transparent with methyl salicylate in this investigation, occasionally the capillary beds of two adjacent follicles appeared to anastomose with each other by way of a single vessel, seemingly supporting the findings of Ichev (1965, 1967b, c, 1968a, b). However, since the vascular system was filled with an India ink-formalin solution, at this level, it was not clearly distinguishable whether this anastomotic vessel was part of the arterial or venous system. It could just as well have been two follicular veins joining to form an interfollicular vein, as it could have been an anastomosis between two capillary beds. The fact that only two vessels radiated from each follicle, tended to support the concept that the anastomotic branch was formed by the convergence of two adjacent follicular veins and the other two, coming from the opposite direction, were follicular arteries. However, this could not be stated with certainty. Ichev used a similar method (India ink filled vessels) to observe the

vascular pattern in the canine thyroid gland. It could be possible that what he observed was adjacent veins joining to form an interfollicular vein. It is also possible that Ichev was correct because he offers a strong argument that follicles need an additional system to ensure a blood supply in pathological conditions. However, three different techniques were employed in this investigation to study the intrinsic vasculature of the canine thyroid gland and all three failed to give conclusive evidence that follicles received a blood supply from adjacent follicles.

No intrafollicular system, as described by Thomas (1945), was observed; however, the lymph capillaries, in this investigation, were found to surround the follicular cells within the follicle, and thus appeared to be similar to the intrafollicular system. Perhaps, Thomas observed the lymph capillaries, instead of the blood capillaries. However, it was also possible that the observations of Thomas were due to species variations.

Ichev (1965, 1968a) described three types of terminal arterial ramifications, viz.:

1. The main follicular vessel continued into a wide magistral or leading capillary, which ramified into thinner capillaries surrounding the follicles. This type was specific to larger follicles.

2. The main follicular vessel terminated immediately into numerous capillaries over the surface of the follicle (secondary capillaries of Ichev).

3. The main follicular vessel divided into several smaller branches, which formed the capillary network of adjacent follicles (interfollicular capillaries of Ichev).

In this investigation, similar terminations appeared to exist. These were the following:

1. The interfollicular branch coursed between follicles and gave rise to a follicular branch, which terminated as either a capillary bed on the surface of large follicles, or as an unbranched capillary on small follicles. This was comparable to the magistral or leading capillary described by Ichev.

2. The interfollicular branch usually terminated into two follicular branches, which gave rise to typical capillary beds. This was comparable to the secondary capillaries of Ichev.

3. Occasionally, in large lobules, the interfollicular branch divided into several equal sized branches. These coursed in different directions and gave rise to follicular branches, which terminated as capillaries. This was comparable to the interfollicular capillary of Ichev.

Thus, there appeared to be three different types of arterial ramifications, however, in as much as they all contained the same basic vessels, e.g., interfollicular,

follicular, and capillary, they were classified the same. Therefore, only one type of terminal arterial ramification was observed in this study.

Venous drainage

Intrinsic venous pattern The intrinsic venous pattern was not extensively discussed in the literature. This probably resulted from the fact that most investigators believed veins were satellites of arteries and also because, usually being collapsed, veins were difficult to distinguish in histologic sections. Through the use of plastic casts of the vascular pattern the intrinsic venous drainage was well demonstrated in this study. Even the venous valves, used to distinguish arteries from veins, were well demonstrated by this technique.

The intrinsic veins of the canine thyroid gland followed the general pattern as that of the arteries and thus were given corresponding names. The venous system was observed as follows:

1. From the follicular capillary bed of large follicles arose the venous bed, which after converging, formed the follicular vein. The capillaries of small follicles continued into venous channels which formed the follicular vein, in accord with the observations of Major (1909), Mastin (1923), and Trautmann and Fiebiger (1957).

2. The follicular vein left the follicle on the side almost directly opposite to where the follicular branch

(arterial) gained the surface of the follicle, similar to the description of Major (1909).

3. Adjacent follicular veins joined to form interfollicular veins, which usually coursed in company with the corresponding arterial branch between follicles. Unlike the findings of Mastin (1923), only one vein was observed accompanying the corresponding arterial branch.

4. The interfollicular veins emerged from the lobules and converged with adjacent interfollicular veins, forming lobular veins (Johnson, 1955), which drained the lobules by following the trabeculae between them.

5. Adjacent lobular veins formed lobar veins, draining the functional lobes.

6. Lobar veins converged and formed glandular veins which emerged from the thyroid gland.

Extrinsic venous drainage The extrinsic venous drainage was not extensively studied, since the veins were not injected in the specimens, though some observations were grossly made. The glandular veins, draining the cranial half of the thyroid lobe, joined to form the cranial thyroid vein, which entered the internal jugular at approximately the same level as the cranial thyroid artery originated from the common carotid. The glandular veins, draining the caudal half of the gland, joined to form the caudal thyroid vein. The caudal thyroid vein usually drained into the internal jugular

approximately 20-30 mm caudal to the caudal pole of the thyroid lobe. Occasionally it entered the internal jugular vein directly opposite the caudal pole of the lobe, and in some cases, it accompanied the dorsal branch of the cranial thyroid artery and entered the brachiocephalic vein, slightly cranial to the beginning of the cranial vena cava.

In addition to the above two veins observed in this study, Smithcors (1964) described a thyroid ima vein, which occasionally drained the middle portion of the left lobe and entered the brachiocephalic vein. Rümpler (1967) described this vein as usually arising from the laryngeal impar vein and draining the sternohyoideus and canine thyroid gland as it descended the ventral aspect of the trachea, deep to the sternohyoideus muscle. No such vein was observed in this study.

Many valves were found in the veins both internal and external to the gland. Modell (1933) found valves only in the larger veins of the canine thyroid gland. The valves found in this investigation occurred most frequently at the branching points of the veins.

Vascular anastomoses

Extrinsic anastomoses A survey of the literature revealed that in humans, the superior and inferior thyroid arteries anastomosed freely with each other, both on the same side and with collateral vessels of the opposite side, and with other arteries in the cervical region (Landström, 1907;

Pettenkoffer, 1914; Enderlen and Hotz, 1918; Mastin, 1923; Caylor and Schlotthauer, 1927; Wilson, 1927; Wangensteen, 1929; Mauro, 1950; Reilly, 1954; Ichev, 1967a, 1970). In the dog, Major (1909) noticed a few anastomoses which were limited only to branches of the same side.

In this investigation, two to three extrinsic anastomoses were observed, however, they were major communications which were believed to function as important collateral blood supplies should occlusion of the blood flow in the major vessels, supplying the gland, occur. These anastomoses were the following:

1. The right and left cranial thyroid arteries anastomosed by a small twig arising from their corresponding ventral branches across the cricotracheal membrane.

2. The right and left ventral branches of the cranial thyroid arteries anastomosed across the glandular isthmus, when present.

3. The cranial thyroid arteries of each side anastomosed with corresponding tracheoesophageal arteries near the cranial thoracic aperture. Curtis (1930) found a similar anastomosis between the tracheal and esophageal branches of the inferior thyroid arteries and the tracheal branches of the bronchial arteries in humans. Reilly (1954) stated that this anastomosis became the major supply to the rabbit thyroid gland when the main thyroid arteries were ligated. It was reported that,

blood can reach the canine thyroid gland from as far caudal as the celiac artery through a series of anastomoses from the left gastric artery to the bronchoesophageal to the caudal thyroid artery (Miller et al., 1964).

Intrinsic anastomoses Descriptions available in the literature classified three types of anastomoses within the human and canine thyroid gland, viz.:

1. Arterial-arterial: Landström (1907) and Major (1909) did not notice this type of anastomosis in either the human or canine thyroid gland, but these investigators believed they existed, whereas Marine (1928) was of the opinion that they did not exist at all. However, Shigyo (1923) found them throughout the human thyroid gland and Wangenstein (1929) and Modell (1933) observed anastomoses between third order (lobular branches) arteries in the dog.

Arterial-arterial anastomoses were clearly observed at the lobar and lobular levels in this investigation and they were usually seen at the terminations of these arterial branches. However, there was no conclusive evidence that they existed below this level. The function of these anastomoses was believed to insure a blood supply to the follicles in pathological cases. Ichev (1967a, 1970) believed that these

anastomoses did not function in the normal gland because of equal pressure on either side of the anastomosis. He contended that only when the blood pressure on one side of the anastomosis dropped, due to interrupted blood flow, these anastomoses became functional.

2. Venous-venous: Major (1909) observed that usually two veins accompanied each intrinsic thyroid artery and they frequently anastomosed with each other across the artery in the dog. Johnson (1955) described many venous-venous anastomoses within the canine thyroid gland. In this investigation, venous-venous anastomoses were observed at the lobular and lobar levels, similar to arterial-arterial anastomoses. There was no conclusive evidence that venous-venous anastomoses resulted prior to this level.

3. Arterial-venous: Modell (1933) reported finding arterial-venous anastomoses in the canine thyroid gland and believed they regulated the amount of thyroid hormone in the blood by controlling the blood flow through the capillary beds. Modell hypothesized that in time of need, these anastomoses are closed and all the blood travels to the follicles with a resultant increase in hormonal absorption. When there is a less demand for the hormone, these arterial-venous shunts are opened and blood does not reach some follicles, with a resultant decrease in hormonal absorption. Williams (1937a) did not agree with this hypothesis of Modell (1933) because Williams

found that the thyroid vessels did not collapse when the blood flow through the gland was decreased. Although, Modell provided convincing evidence for the existence of arterial-venous anastomoses, no one since was able to reproduce his findings. Both Johnson (1953, 1955) and Ichev (1970) provided only indirect evidence for their existence. Both investigators observed the filling of arteries and veins with injection masses without the capillary system being filled. A similar situation existed in this investigation. None of the six procedures used in this study demonstrated conclusively that arterial-venous anastomoses existed. However, indirect evidence, similar to that of Johnson and Ichev, was obtained from the plastic casts of the thyroid vascular system. A red colored paste was added to the liquid plastic and this mass was then injected into the vascular systems of 10 thyroid lobes. Most casts demonstrated uniformly colored vascular systems (including capillary bed), but three casts revealed red arteries and veins with an intervening colorless capillary bed. It was first believed that this was, perhaps, due to the larger size of the dye particles, which failed to pass through the capillary bed, with the liquid plastic. In that case the dye would color only the arteries and not the capillary bed, but this failed to explain how the veins obtained their red color. The procedure was such that the injected material could only enter the gland through the arteries and exit from the

gland by way of the veins (closed system). If the vascular system was such that arteries passed into capillaries which, in turn, continued into veins, with no direct connections between arteries and veins, and if the particles were too large to enter the capillary bed, then the veins should not have contained any dye particles. The fact that they did, supported the possibility that arterial-venous anastomoses did exist, even though they were not actually observed.

Another explanation about their occurrence was considered. Blood vessels are generally believed to constrict for a time at death. It was possible that some dye particles were able to pass through the capillary bed to the veins, but as the vessels constricted, immediately after death only the colorless liquid plastic was able to pass through and thus flushed remaining dye particles from the capillary bed. However, this would not only leave the capillary bed colorless, but also dilute the red color in the veins. The fact that the veins retained the same color intensity as the arteries did not support this possibility.

Since there appeared to be no explanation for the observation that several plastic casts revealed red arteries and veins with an intervening colorless capillary bed, it was alluded that arterial-venous anastomoses, possibly at the lobar and lobular levels existed, although there was no direct evidence supporting this assumption.

Lymphatic drainage

Intrinsic lymph drainage The lymphatic system of the canine thyroid gland in this study began as lymph capillaries which surrounded the individual follicular cells (Figure 19). The lymph capillaries were interconnected and formed a lymphatic plexus around the follicle. In the literature this plexus was called the perifollicular capillary net (Major, 1909; Williamson and Pearse, 1930; Gordon, 1931; Ramsay and Bennett, 1943; Trautmann and Fiebiger, 1957; Smithcors, 1964). The fact that no India ink was found in the arteries or veins which revealed these capillaries concluded them to be lymphatics. The lymphatic plexus appeared to be smaller in diameter and more closely associated with the follicular epithelium than were the blood capillaries, similar to the observations of Ramsay and Bennett (1943). According to Smithcors (1964), the follicles were not in direct contact with lymph capillaries. Smithcors may be correct, though the lymph capillaries in this investigation appeared to outline individual follicular cells, whereas the blood capillaries seemed to run over the surface of the follicle. This suggested that the lymph capillaries were more closely associated with the follicular cells than were the blood capillaries. The secreted hormone would come into contact with the lymphatics before it reached the blood capillaries. This could explain why thyroxin was found in the thyroid lymph vessels. But this did not explain

the general belief that the majority of the hormone entered the blood system instead of the lymphatic system. The findings of Luciano and Koch (1975) may have provided an answer to this concept. Their electron microscopic studies revealed that pores (fenestrations) existed in the blood capillaries and collecting venules of the canine thyroid glands and these pores were closed by diaphragms. They believed that large molecules in the blood could exit through the fenestrations of the arterial end and large molecules in the tissue fluid could enter the blood through the fenestrations of the venous end. Luciano and Koch stated that their morphological findings did not support the documented facts that thyroid hormone is secreted into the lymphatics of the thyroid gland. They concluded that although thyroid hormone can reach the lymph, together with tissue fluid, the major portion of the thyroid hormone is disseminated into the blood.

The lymphatic plexus drained into a larger lymph vessel, which Williamson and Pearse (1930) called the lymph sinusoid. Since the lymph vessels were satellites of the blood vessels, especially the veins, it was considered appropriate to name the lymph vessels to the corresponding blood vascular divisions. Therefore, the lymph vessel which drained the follicle was called the follicular lymph vessel. The follicular lymph vessels converged into the interfollicular lymph vessels, which emerged from the lobule. Within the connective tissue

trabeculae between lobules, the interfollicular lymph vessels drained into lobular lymph vessels, which followed the course of the lobular veins. It was not uncommon to find a vascular triad, with the lymph vessel positioned between an artery and a vein (Figure 21). Only one lymph vessel was observed with each vascular triad, whereas Gordon (1931) observed lymph vessels situated on both sides of the blood vessels.

The lobular lymph vessels converged into the lobar lymph vessels, which drained the lobules, and lobar lymph vessels joined the glandular lymph vessels, draining the functional lobes. The glandular lymph vessels emerged from the thyroid lobes, accompanying the glandular veins.

Extrinsic lymph drainage The extrinsic lymph drainage was not investigated. However, the literature stated that the canine thyroid gland was drained by cranial and caudal lymphatic vessels (Caylor et al., 1927; Schlotthauer, 1927; Chouke et al., 1932). The lymphatics, draining the cranial pole, ended in the mandibular lymph nodes, which then drained into the tracheal lymph trunk. The termination of the lymph vessels draining the caudal pole varied. They were found to enter the deep cervical lymph nodes, or empty directly into the tracheal lymph trunk, or empty directly into the internal jugular vein (Caylor et al., 1927; Schlotthauer, 1927; Chouke et al., 1932).

Angioarchitecture of the Canine Parathyroid Gland

Arteries

Major supply The external parathyroid glands (III), in this study, were supplied by a single parathyroid artery, which arose from one of the glandular branches of the cranial thyroid artery, concordant with those in humans (Halsted and Evans, 1907; Fowler and Hanson, 1929; Curtis, 1930; Hunt et al., 1968). When the external parathyroid gland was situated at the cranial pole of the thyroid lobe, the parathyroid artery arose from the ventral group of glandular branches. When it was situated elsewhere (middle and caudal pole of the thyroid gland) the parathyroid artery arose from the dorsal set of glandular branches.

The parathyroid artery was a relatively large vessel, compared to the size of the parathyroid gland. It entered what appeared to be a hilus in the gland (Halsted and Evans, 1907). Since only one artery supplied the external parathyroid gland and this occurred before the glandular branches entered the thyroid gland, it was concluded that the blood supply to the canine external parathyroid gland (III) was independent of the thyroid vascular supply. This was in agreement with the findings of Halsted and Evans (1907) in humans and that described by Smithcors (1964) in the dog.

When present, the internal parathyroid gland (IV) received its blood supply from small branches within the thyroid gland.

Intrinsic arterial pattern . The parathyroid artery coursed towards the center of the gland and gave rise to collateral branches, which radiated towards the periphery of the gland. From these branches arose sinusoid-like capillaries which were in close contact with the epithelial cell cords of the gland. The arrangement of the cell cords around the sinusoidal capillaries was reminiscent of that within the liver.

Venous drainage

The sinusoid-like capillaries continued into veins, which followed the course of the arterial branches emerging from the gland. The veins converged into one large vein, which emerged from the gland at the hilus. When the external parathyroid gland (III) existed as multiple nodules, each nodule was drained separately by a vein, which later converged into a single parathyroid vein. The parathyroid vein drained into one of the glandular veins of the thyroid lobe.

Vascular anastomoses

No anastomoses of any of the three kinds, as found in the thyroid gland, were observed.

Lymph drainage

The lymph vessels of the external parathyroid gland (III) did not contain India ink, when the injection was made under

the capsule of the thyroid gland. This did not demonstrate the lymphatics of the gland, it did, however, demonstrate that the lymph drainage of the external parathyroid gland (III) was independent of the thyroid gland.

SUMMARY AND CONCLUSIONS

Gross Anatomy

1. The thyroid glands of the mesaticephalic dogs consist of right and left lobes, along the ventrolateral aspects of the cranial portion of the trachea.
2. The lobes are related to the following:
 - a. Medially - deep cervical fascia surrounding the trachea
 - b. Laterally - the carotid sheath
 - c. Ventrally - the sternothyroideus muscle.
 - d. Dorsally - the esophagus on the left side and the longus capitis muscle on the right.
3. The position of the lobes vary, extending from the caudal border of the cricoid cartilage to the first sixth to eighth tracheal ring.
4. The left lobe is located somewhat cranial to the corresponding right.
5. The left lobe is relatively longer than the right by 1.50 mm and this is independent of sex.
6. A glandular isthmus is occasionally found in mesaticephalic breeds, connecting the caudal poles of the thyroid lobes ventral to the trachea.
8. An external (III) and an internal (IV) parathyroid glands are usually associated with each thyroid lobe. The external parathyroid gland is generally larger than the

corresponding internal one.

9. The external parathyroid gland (III) is usually found near the cranial pole of the lateral surface of the thyroid gland, and it is always outside the thyroid gland capsule. On the other hand, the internal parathyroid gland (IV) lies on the medial surface of the thyroid gland, but inside the thyroid gland capsule. Occasionally, the internal parathyroid gland is embedded within the thyroid parenchyma.

Histology

1. The capsule of the canine thyroid gland is continuous with the deep cervical fascia, which surrounds the gland.
2. The thyroid gland is divided by delicate connective tissue trabeculae into functional lobes, lobules, and follicles. The trabeculae accompany the tunica adventitia of the blood vessels.
3. Individual thyroid follicles are separated from each other by a basement membrane of reticular fibers, which appear to be associated with the blood and lymph capillaries, surrounding the follicles.
4. The thyroid follicles are round to oval in shape and vary in size, which is believed to be due to their physiological state of activity. The different sized follicles are uniformly dispersed throughout the lobes, except towards the periphery, where the larger follicles prevail.

5. The follicular cells with variable heights, probably due to their state of hormone production, contain a rounded, euchromatin nucleus situated toward the base of the cells.
6. The lumina of the follicles usually contain a homogeneous, acidophilic colloid, however, equally present are follicles with partially acidophilic and partially basophilic colloid. This is believed due to the differential penetration of fixatives and their chemical effects on the iodinated colloid as postulated by De Robertis (1941). Fixation artifacts (vacuoles) are frequently found in the colloid.
7. Parafollicular cells (C-cells) are frequently found as single cells within the reticular basement membrane of the follicles and occasionally, occur as clusters (usually 4), surrounded by reticular fibers in the interstitial tissue.
8. A remnant of an ultimobranchial body is found, giving rise to both ultimobranchial and mixed follicles, which could otherwise be mistaken for typical thyroid follicles.
9. The external parathyroid gland (III) is surrounded by a thin connective tissue capsule, which, although separate, is continuous with the thyroid gland capsule.
10. The connective tissue within the parathyroid glands appears to be that of the tunica adventitia of the blood vessels.
11. The arrangement of the epithelial cell cords around the sinusoid-like capillaries is reminiscent of the cellular arrangement within the liver.

12. The histology of the internal parathyroid gland (III) only differs from that of the external parathyroid gland (III) by not possessing a distinct capsule.

Angioarchitecture

1. The mesaticephalic dogs did not possess a "true" caudal thyroid artery, though an artery is present that resembles some characteristics of the caudal thyroid artery as described in the literature. However, based upon the usually accepted criteria for naming other blood vessels which reflect their course and major area of supply, it is believed this artery be appropriately called the tracheo-esophageal.
2. It is suggested that further investigation of the canine caudal thyroid artery be undertaken in the dolicocephalic and brachycephalic breeds because possibility exists that the canine as a species may not possess a caudal thyroid artery.
3. The cranial thyroid artery is the major blood supply to the canine thyroid gland and it arises from the common carotid approximately 1 cm opposite the cranial pole of the thyroid gland. It gives rise to the following:
 - a. Sternocleidomastoid branch - supplies portions of the brachiocephalicus and sternocephalicus muscles.

- b. Dorsal branch - results from bifurcation of cranial thyroid artery. It courses caudally, along the dorsal and medial aspects of the thyroid gland, accompanies the recurrent laryngeal nerve, and anastomoses with the tracheoesophageal artery near the cranial thoracic aperture. It gives rise to the following:
- 1) Pharyngeal branch - supplies cranial portion of esophagus and larynx, and constrictor muscles of the pharynx. Occasionally it arises directly from the cranial thyroid artery near the origin of the sternocleidomastoid branch.
 - 2) Glandular branch (dorsal group) - usually present (but occasionally absent). They enter along the dorsal and medial aspects of the thyroid gland, when present.
 - 3) Tracheal and esophageal branches - supply the cervical portions of trachea and esophagus.
- c. Ventral branch - courses medially towards the larynx, cranial to the cranial pole of the thyroid gland and gives rise to the following:
- 1) Glandular branch (ventral group) - enter lateral and ventral aspects of thyroid gland near cranial pole.
 - 2) Cricothyroid branch - supplies sternohyoideus, sternothyroideus, thyrohyoideus, and cricothyroideus

muscles, and gives rise to the caudal laryngeal, which enters the larynx via the cricothyroid membrane.

- 3) Anastomotic branch - joins the corresponding branch from the opposite side across the cricotracheal membrane.
- 4) Terminates by supplying glandular branches (also belonging to the ventral group) to the ventro-lateral aspect of the thyroid lobe. The level of its termination is dependent upon the branching of the dorsal branch as well as the presence of a glandular isthmus. When the dorsal branch supplies glandular branches to the caudal half of the thyroid lobe, the ventral branch terminates within the cranial half of the lobe. In the absence of dorsal glandular branches, the ventral branch vascularizes the caudal pole of the thyroid lobe. In addition, the ventral branch supplies the glandular isthmus, when present, and occasionally supplies the opposite lobe via this route.
5. The intrinsic arterial pattern of the canine thyroid gland follows the internal divisions of the gland. Therefore, it is appropriate to name the arterial branches corresponding to its functional divisions. The arterial pattern is as follows:

- a. Glandular branches - enter the thyroid gland parenchyma before dividing into lobar branches, on the other hand these branches, in humans course and divide on the surface of the thyroid gland.
- b. Lobar branches - course within the connective tissue trabeculae between functional lobes and released lobular branches into the functional lobes.
- c. Lobular branches - travel within the interlobular septa giving rise to interfollicular branches. The number of lobular branches supplied to the functional lobes and the number of lobar branches supplying lobular branches depend upon the size of the functional lobe, the larger functional lobes being supplied by a greater number of lobular branches from a greater number of lobar branches.
- d. Interfollicular branches - course between follicles of the lobule and give rise to follicular branches. The number of interfollicular branches supplied to the lobule and the number of lobular branches giving rise to the interfollicular branches depend upon the same criteria as described in (c) above for vascularizing the functional lobes. The interfollicular branches usually terminate into two follicular branches. Occasionally, in large lobules, the interfollicular branch divides into several equal sized branches, which, in turn, give rise to follicular branches.

- e. Follicular branches - are short which gain the surface of the follicles and ramify into a follicular capillary. Although, different follicles within the same lobule are frequently supplied by different interfollicular branches, the general rule of one follicular branch per follicle prevails.
 - f. Follicular capillaries - branch into a capillary bed over the surfaces of larger follicles, but remain unbranched over the surface of smaller follicles.
6. Only one type of arterial ramification is considered to occur (as described in 5 above).
 7. The external parathyroid gland is supplied by the parathyroid artery, arising from a glandular branch of the cranial thyroid artery before the latter enters the thyroid gland. The internal parathyroid, on the other hand, receives its blood supply directly from thyroid branches within the gland.
 8. The parathyroid artery enters the hilus of the gland and travels towards the center of the parathyroid gland. It radiates branches towards the periphery, which gives rise to sinusoid-like capillaries.
 9. The veins of the thyroid gland originate from the follicular capillaries and follow the course of the arterial branches. Therefore, the venous drainage pattern is the same as the arterial pattern, except in the reverse order, i.e.:

- a. Venous capillaries - form beds in larger follicles, venous channels in smaller follicles. They converge forming the follicular vein which leaves the surface of the follicle approximately opposite the point where the follicular arterial branch gains the follicular surface.
- b. Follicular veins - which drain the follicle and converge forming the interfollicular veins.
- c. Interfollicular veins - emerge from the lobule and join adjacent interfollicular veins forming lobular veins which drain the lobules.
- d. Lobular veins - follow the trabeculae between lobules and converge forming lobar veins.
- e. Lobar veins - drain the functional lobes. They drain into glandular veins, which emerge from the thyroid gland.
- f. Glandular veins - form cranial and caudal thyroid veins near the corresponding poles of the thyroid lobe.
- g. Cranial and caudal thyroid veins - usually enter the internal jugular vein near the cranial and caudal poles of the corresponding thyroid lobes. Occasionally the caudal thyroid vein accompanies the dorsal branch of the cranial thyroid artery and empties in the brachiocephalic vein slightly cranial to the beginning of the cranial vena cava.

10. The veins of the parathyroid gland also follow the course of the arterial branches; they emerge from the gland at the hilus as a parathyroid vein, and drains into one of the glandular veins of the thyroid lobe.
11. Only 2 and occasionally 3 extrinsic thyroid anastomoses are found, however, they are major communications which may function as collateral blood supplies under pathological conditions, viz.:
 - a. Dorsal branch of cranial thyroid artery anastomoses with tracheoesophageal artery near the cranial thoracic aperture.
 - b. Collateral cranial thyroid arteries anastomose by a small twig from collateral ventral branches across the cricotracheal membrane.
 - c. Collateral ventral branches anastomose across glandular isthmus, when present.
12. Only arterial-arterial anastomoses, which function to insure a blood supply to the thyroid follicles in pathological conditions, and venous-venous anastomoses, which function to drain hormone carrying blood quickly from the gland, are distinctly evident. However, it is believed that arterial-venous anastomoses, which may act to regulate thyroid hormone absorption in the blood (Modell, 1933), exist, possibly at the lobar and lobular levels, within the canine thyroid gland.

13. The lymph vessels of the thyroid gland follow the course of the blood vessels (vascular triads) and thus closely resemble the pattern of venous drainage.
14. The lymph capillaries appear to be more closely associated to the follicular cells than are the follicular blood capillaries, and this would explain the occurrence of thyroid hormone in the lymph draining the gland, however, the observations of Luciano and Koch (1975) may explain why the bulk of the hormone is transported by the blood, instead of the lymph.
15. The lymphatics of the parathyroid glands are independent of the thyroid gland.
16. Although the canine thyroid gland differs from the human gland in several aspects regarding morphology and angio-architecture, both are basically the same as to function. A knowledge of these differences in thyroid glands allows the canine thyroid gland to be used as an animal model for human experiments.

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APPENDIX

Legend for Figures

1. Common carotid a.
2. Cranial thyroid a.
3. Sternocleidomastoid br. of 2
4. Dorsal br. of 2
5. Glandular br. of 4
6. Ventral br. of 2
7. Glandular br. of 6
8. Cricothyroid br.
9. Anastomotic twig of 6
10. Lobar br.
11. Lobular br.
12. Interfollicular br.
13. Follicular br.
14. Unbranched follicular capillary
15. Follicular capillary bed
16. Venous follicular capillary bed
17. Follicular vein
18. Interfollicular vein
19. Lobular vein
20. Lobar vein
21. Glandular vein
22. Cranial thyroid vein
23. Caudal thyroid vein
24. External parathyroid vein
25. Internal jugular vein
26. Tracheal and esophageal brs. of 4
27. Bronchoesophageal a.
28. Tracheoesophageal a. (caudal thyroid a. of the literature)
29. Anastomosis between 4 and 27, near the cranial thoracic aperture
30. Lymph capillaries
31. Interfollicular lymph vessel
32. Lobular lymph vessel
33. Pharyngeal br.
- A. Thyroid lobe
 - a. Longus capitis m.
 - B. Trachea
 - C. Esophagus
 - D. Glandular isthmus of A
 - E. Cricoid cartilage
 - F. External parathyroid gland (III)
 - G. Thyroid follicle
 - H. Follicular epithelium
 - I. Basement membrane

- J. Parafollicular or C-cell
- K. Ultimobranchial tube containing a homogenous colloid-like substance with cellular debris
- L. Ultimobranchial duct
- M. Mixed follicle
- N. Nucleus of endothelial cell
- O. Venous semilunar cusps



Figure 1. The arterial supply to the left thyroid lobe—slightly displaced (ventrolateral view)

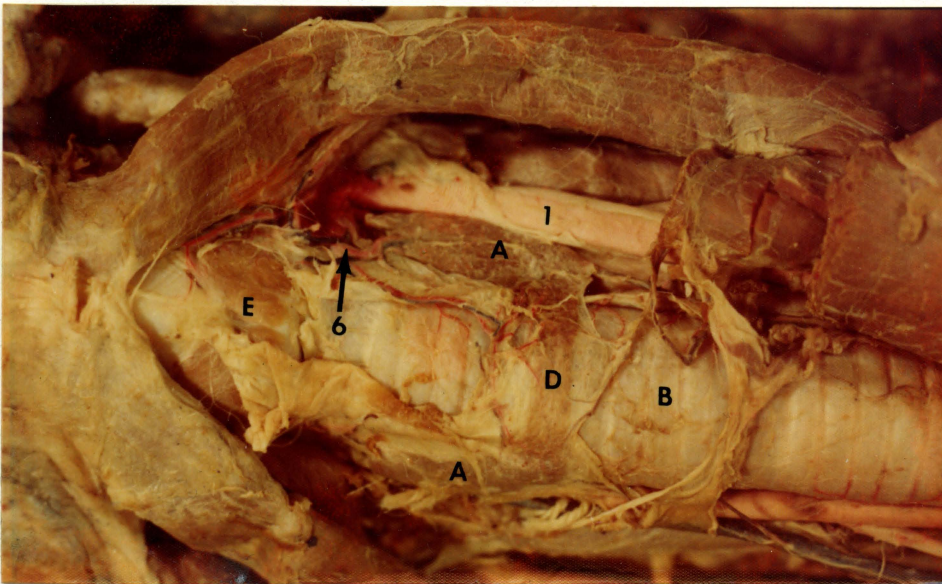


Figure 2. A glandular isthmus connecting the caudal poles of the thyroid lobes (ventral view)

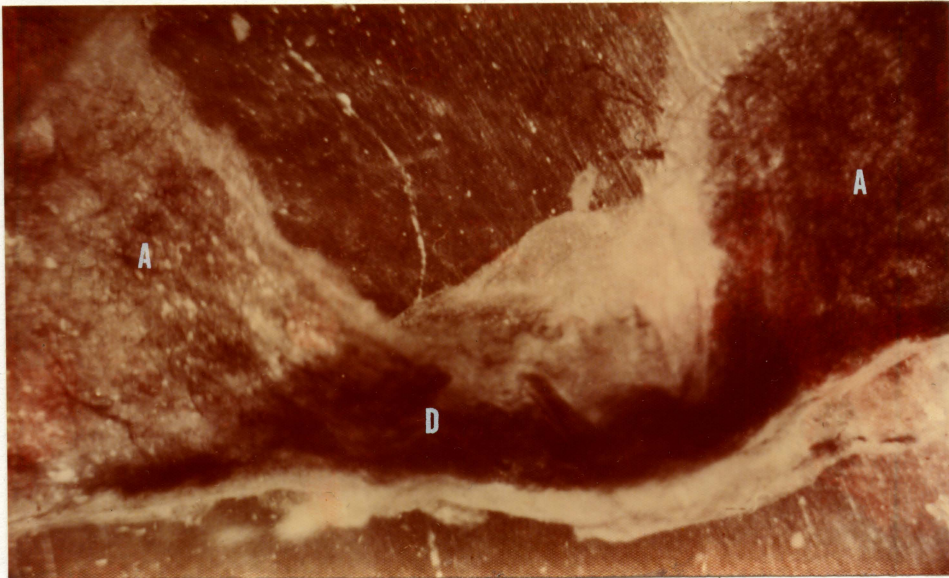


Figure 3. An India ink injected glandular isthmus, treated with clearing agent. Mag. 14 times

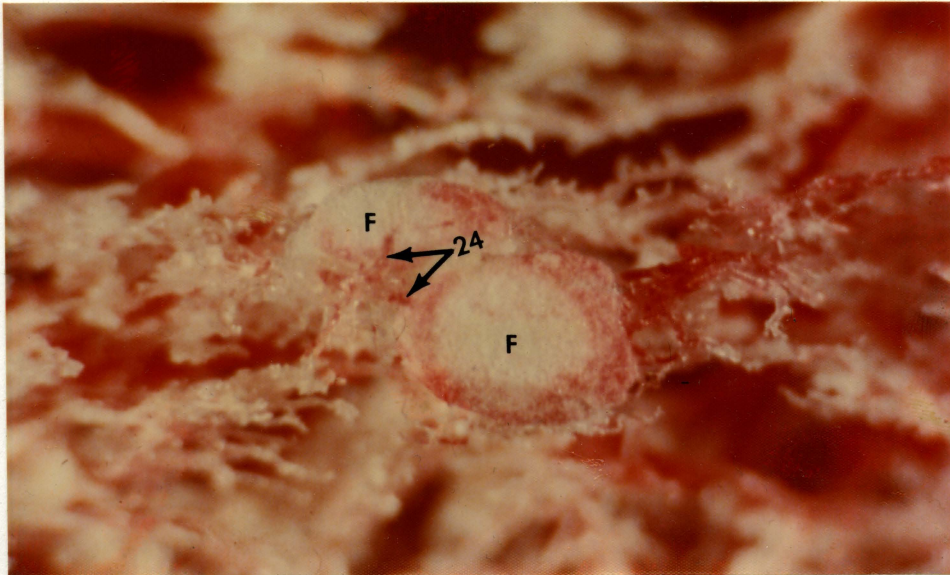


Figure 4. Two parathyroid nodules (plastic injection technique). Mag. 25 times

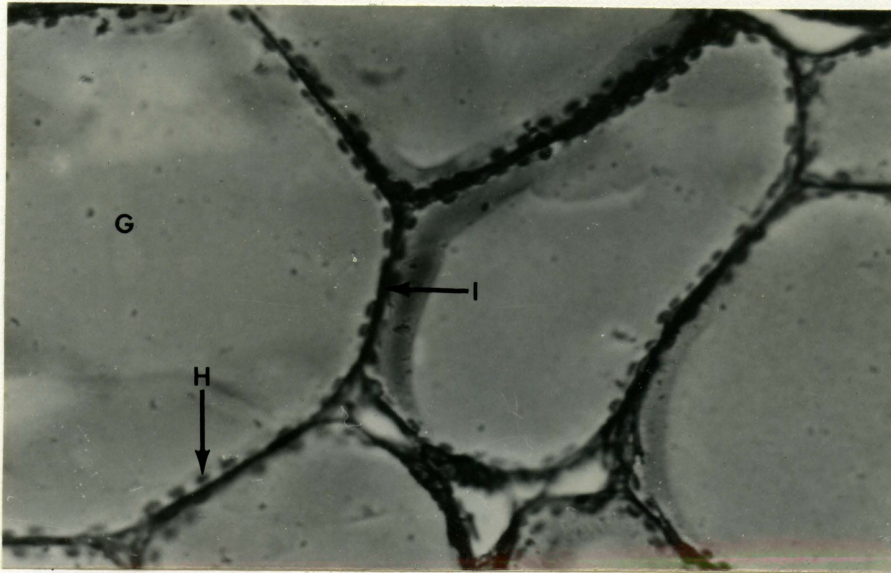


Figure 5. Reticular fibers in the basement membrane of the follicles (Silver stain). Mag. 360 times

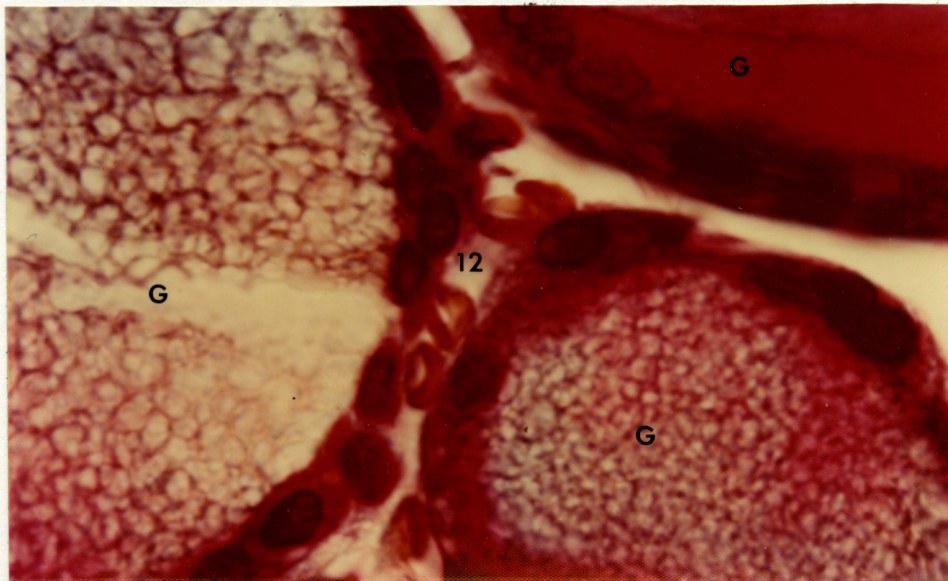


Figure 6. An interfollicular vessel (Crossmon's Modification of Mallory's Triple). Mag. 1430 times

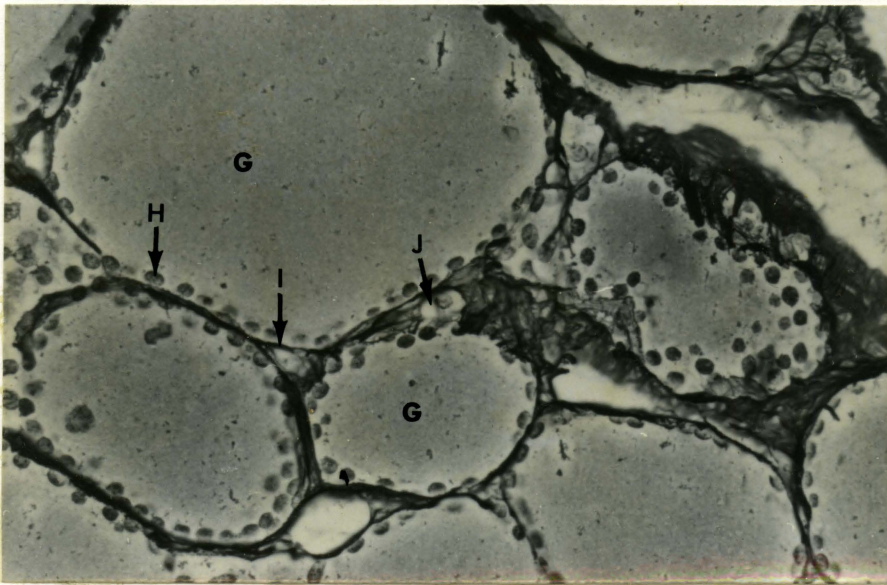


Figure 7. A parafollicular or C-cell (Silver stain). Mag. 360 times

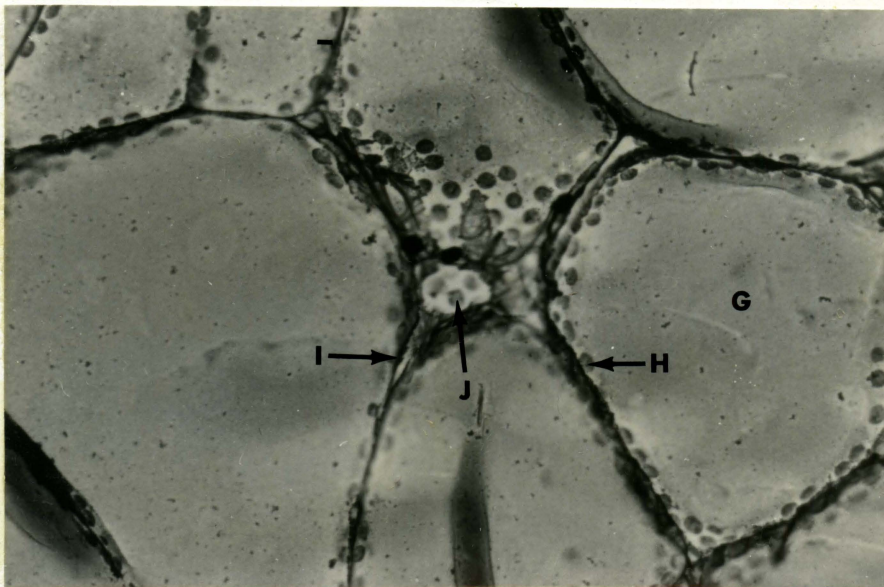


Figure 8. A cluster of parafollicular or C-cells (Silver stain). Mag. 360 times

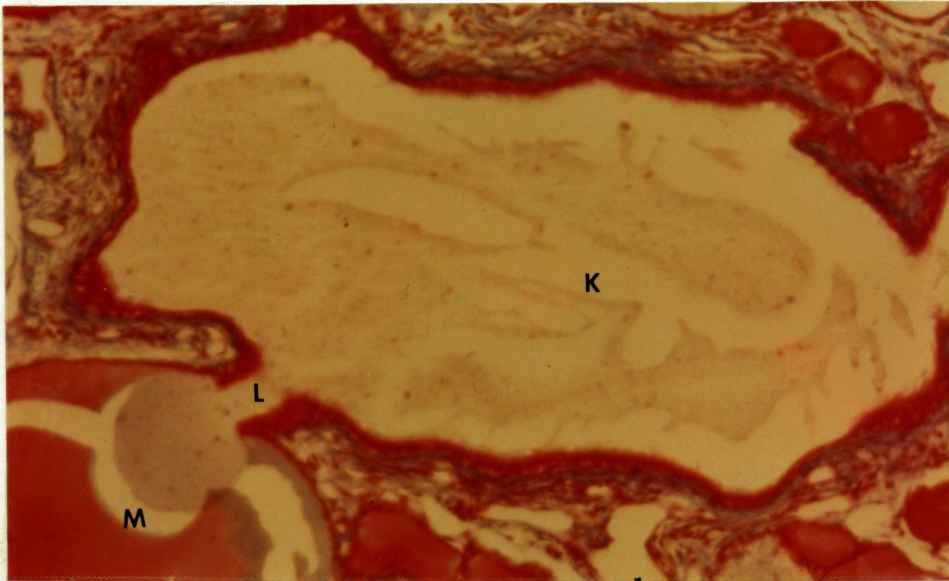


Figure 9. A remnant of an ultimobranchial body (Crossmon's Modification of Mallory's Triple). Mag. 143 times

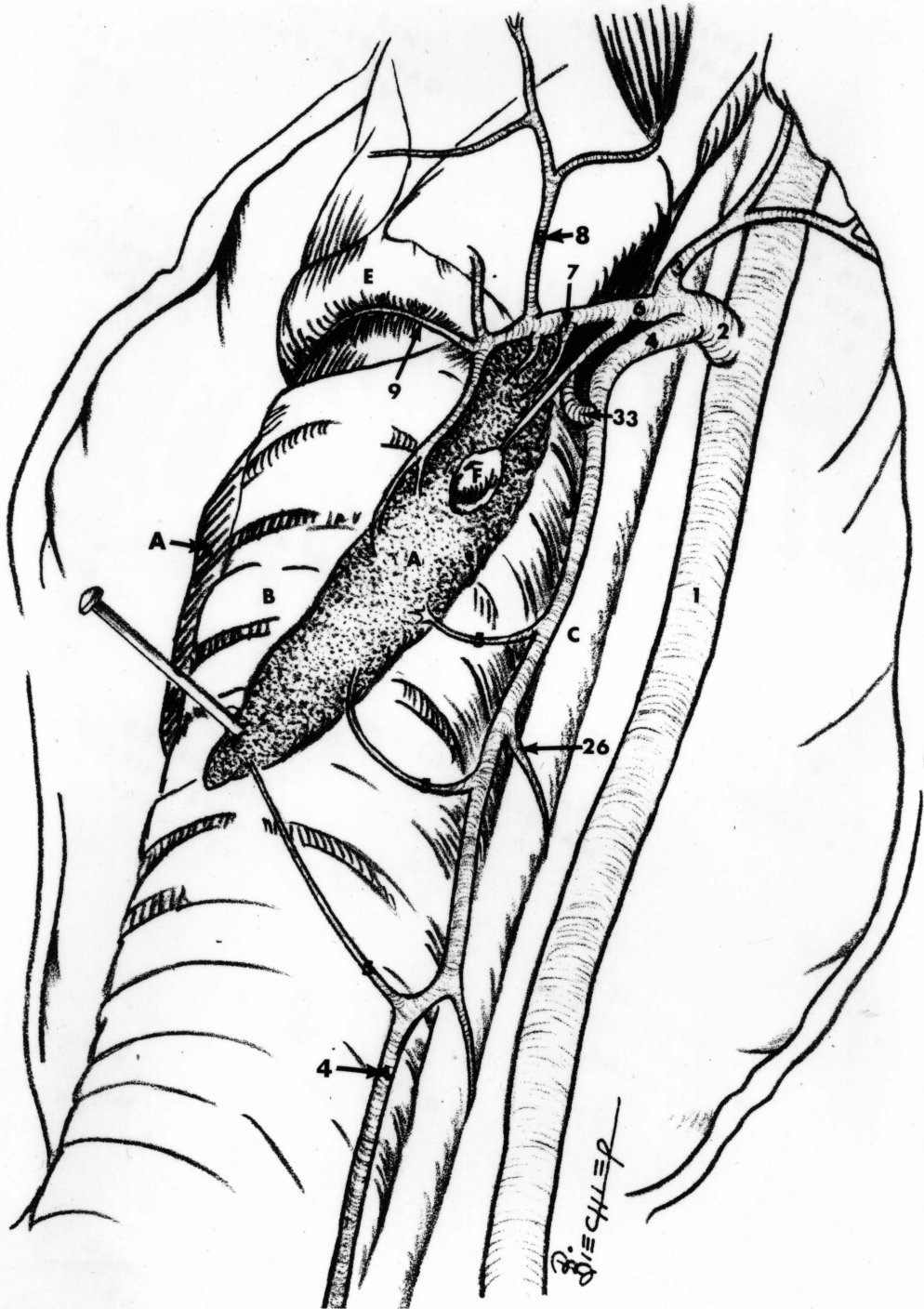


Figure 10. The extrinsic vasculature of the left thyroid lobe--slightly displaced

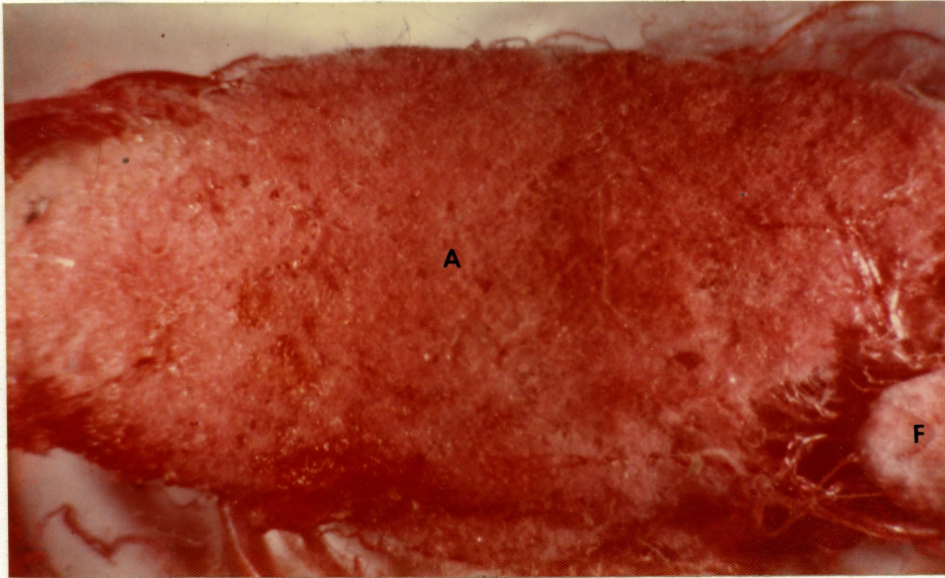


Figure 11. A plastic cast of the thyroid and external parathyroid (III) vasculature. Mag. 14 times

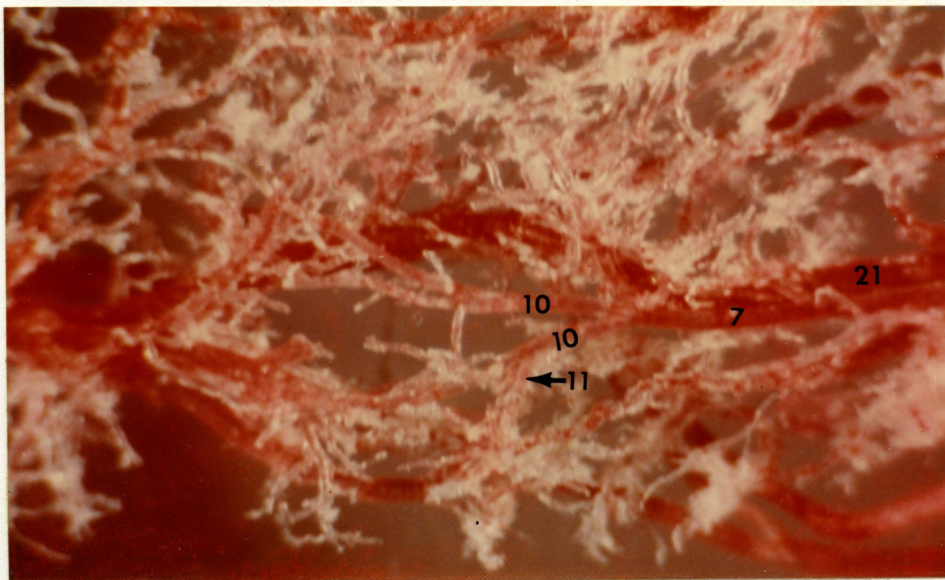


Figure 12. A plastic cast of the intrinsic thyroid vasculature - Capillary network partially removed. Mag. 14 times

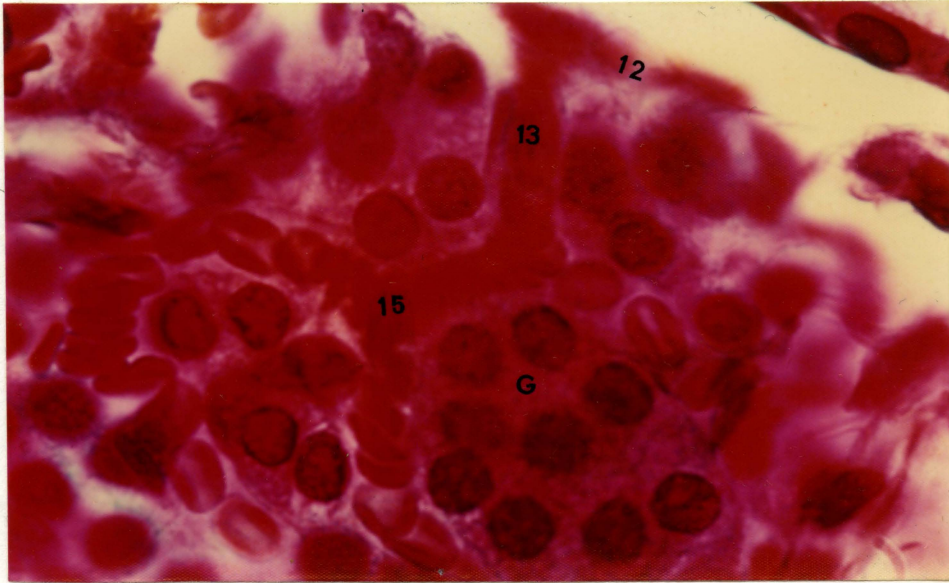


Figure 13. The follicular capillary bed of a large follicle (Crossmon's Modification of Mallory's Triple). Mag. 1430 times

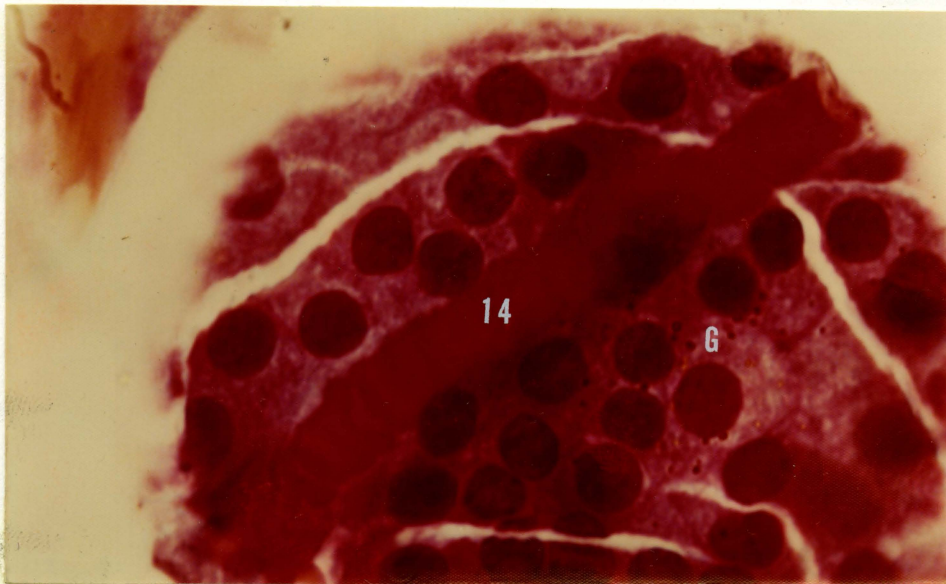


Figure 14. The follicular capillary of a small follicle (Crossmon's Modification of Mallory's Triple). Mag. 1430 times

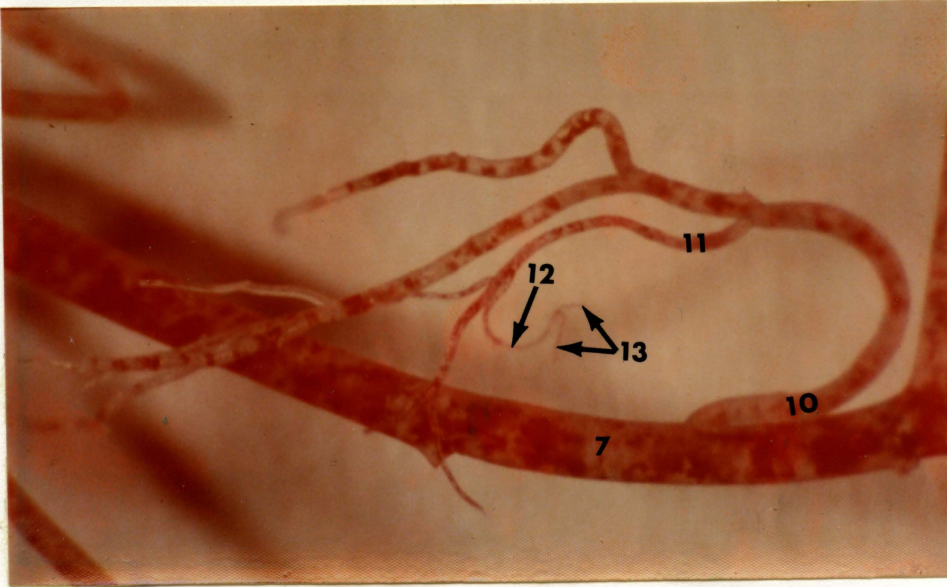


Figure 15. A plastic cast of the intrinsic thyroid vasculature - capillary network completely removed. Mag. 29 times

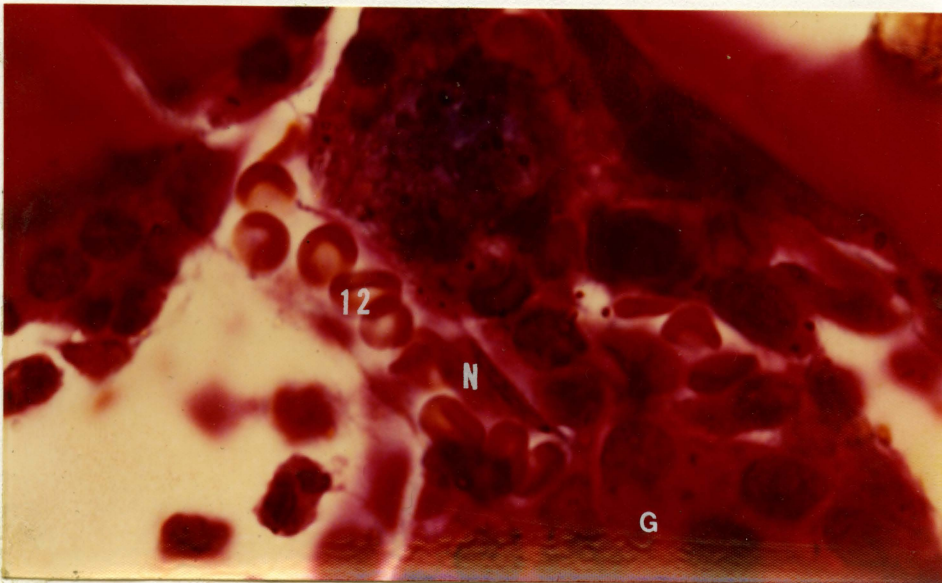


Figure 16. The wide lumen of an interfollicular branch (Crossmon's Modification of Mallory's Triple). Mag. 1430 times

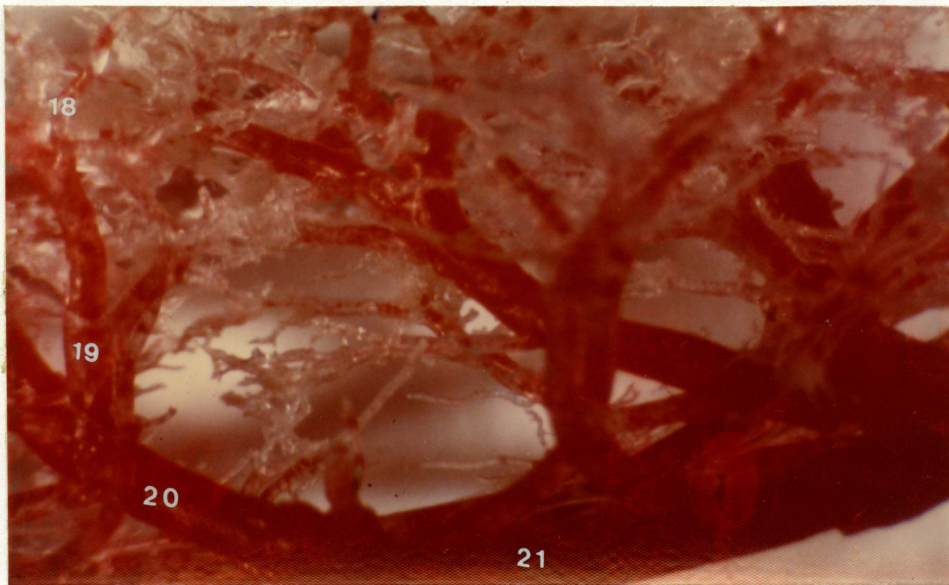


Figure 17. A plastic cast of the intrinsic thyroid veins. Mag. 17 times

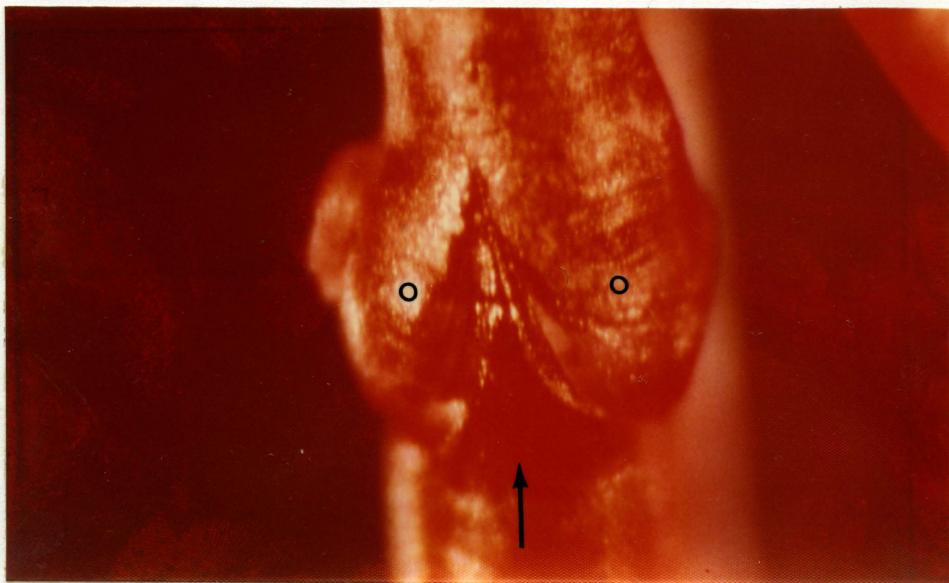


Figure 18. A plastic cast of a thyroid venous valve (Arrow indicates blood flow). Mag. 70 times

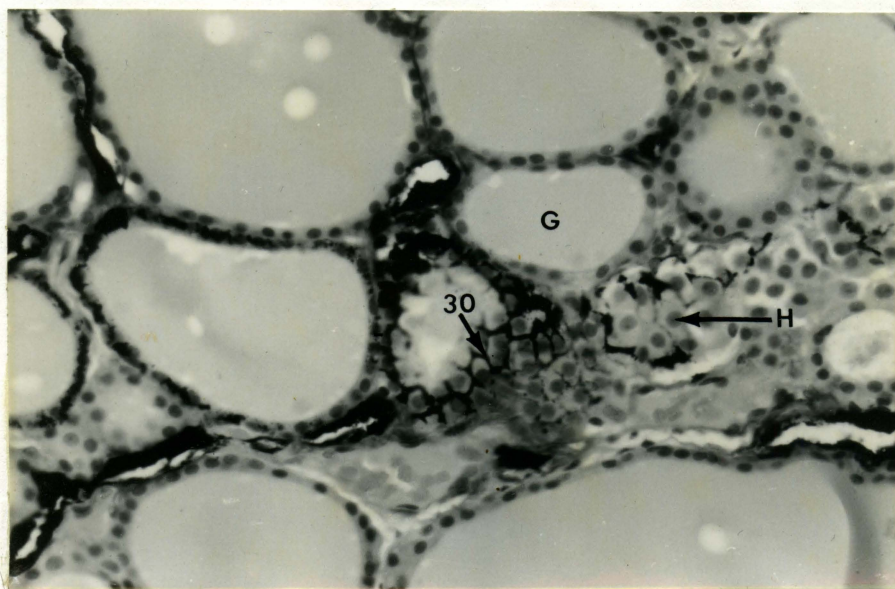


Figure 19. India ink injected lymph capillaries, closely associated with follicular cells (Hematoxylin). Mag. 360 times

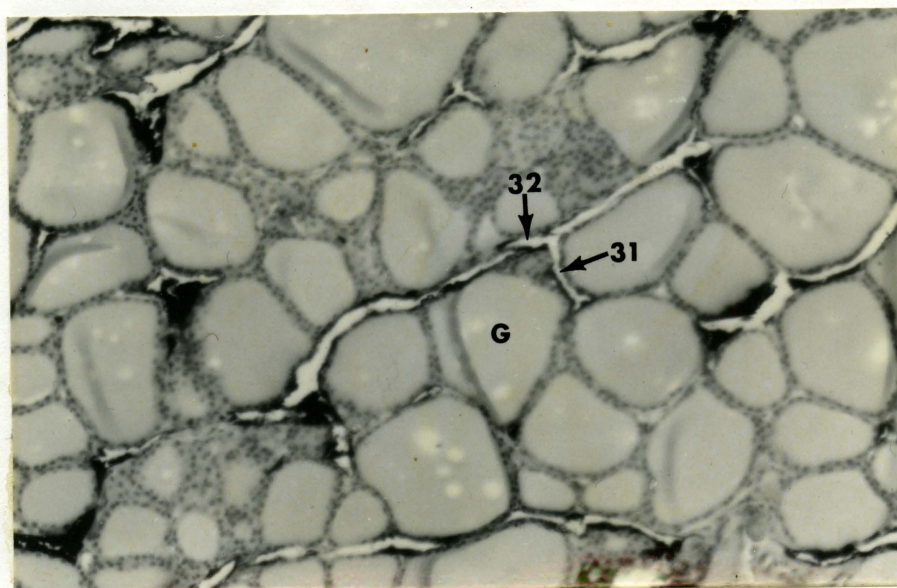


Figure 20. India ink injected lymph vessels of the thyroid gland (Hematoxylin). Mag. 143 times

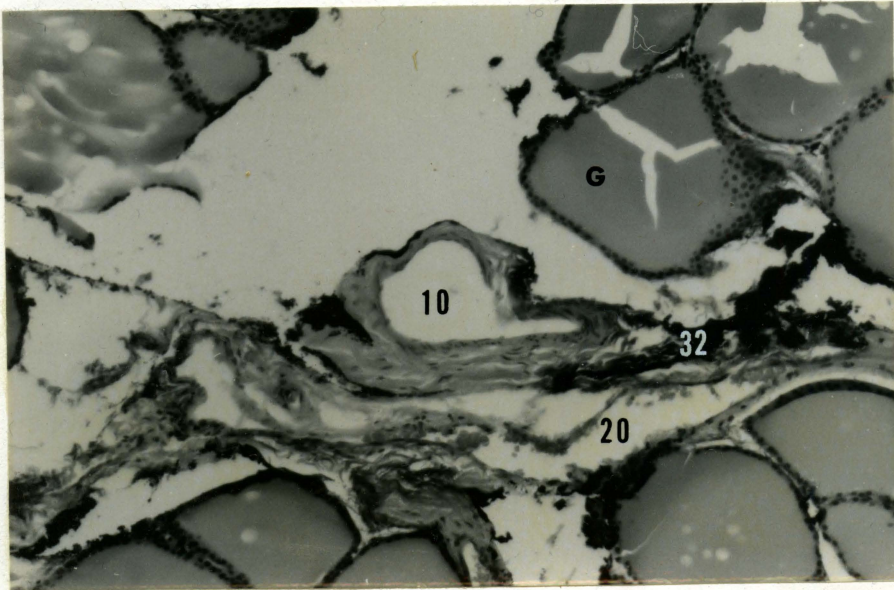


Figure 21. A vascular triad of the thyroid gland, comprising an artery, vein, and lymphatic (Hematoxylin).
Mag. 143 times