DEVELOPMENT OF THE UROGENITAL SYSTEM OF THE DOG

by

MAJID AHMED AL-RADHAWY

LICENCE, Higher Teachers' Training College, Baghdad, Iraq, 1954

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Zoology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1958

TABLE OF CONTENTS

TABLE OF CONTENTS

INTRODUCTION AND REVIEW OF LITERATURE

Nephrogenesis has been adequately described in only a few mammals. Buchanan and Fraser (1918), Fraser (1920), and McGrady (1938) studied nephrogenesis in marsupials. Keibel (1903) reported on studies on Echidna; Van der Stricht (1913) on the bat; Torrey (1943) on the rat; and Bonnet (1888) and Davies and Davies (1950) on the sheep. Extensive and numerous reports have appeared on morphogenesis of the urogenital system of the rabbit including those of Renson (1883), Martin (1888), Janosik (1885), Rable (1896), Schreiner (1902), Kerens (1907), and Weinberg (1929). The first, and basic work on human nephrogenesis was published by Felix (1912) followed by reports of lesser magnitude covering specialized phases of the subject by Johnson (1917), Watt (1915), Shikinami (1926), Wen (1928), Heuser (1930), and Torrey (1954). Of these the report of Torrey (1954) is of greatest immediate concern, because of the large number of embryos examined and the consolidation of previous reports in a comprehensive summary of the processes involved.

Because of the small number of mammals that have been studied, and the conflicts in interpretations, and the need for a detailed comprehensive study of nephrogenesis in a mammal other than marsupial, rabbit and human, a study of the processes in the dog was attempted. This study was made possible by the accumulation of a large series of dog embryos and a series of events that provided the author with the opportunity of studying these embryos.

Primarily, the present report is concerned with nephrogenesis, from the first show of pronephric differentiation to the establishment of a functional metanephros. Concurrent development of the genital system has been followed because of the intimate association between the genital and

urinary systems and the ultimate exploitation of certain mesonephric elements by the development of the male gonad.

Terminology of previous works has been selected to most clearly express morphology, primordial origin of potentiality and yet conform with current usage.

The most recent and acceptable interpretation of nephrogenesis in mammals is illustrated by Torrey's report on human nephrogenesis (Torrey, 1954). The anterior part of the nephrotome shows a dorsal ridge-like outgrowth. Nephrostomes develop as invaginations from the coelom in the nephrotome in somite 9-14 inclusive. The primary excretory duct originates from the dorsal surface of the nephrotome along somite 9-13 inclusively. Then it continues to grow caudad by free terminal growth. It reaches the cloaca, and contacts with it in the 26 - 28 somite stage (Shikinami, 1926). The nephric duct becomes fully luminated by the 36 somite stage.

The mesonephric tubules differentiate from the nephrotome along somite 14 to 26 inclusively. They differentiate in a cranio-caudal direction; the original solid masses cavitate then tubulate, and eventually become mesonephric tubules each with a glomerulus, a secretory portion, and a collecting portion. During development the mesonephric tubules join the pronephric duct which becomes the mesonephric duct. After most of the mesonephric tubules have started differentiation, the metanephric diverticulum forms as an evagination from the posterior curvature of the mesonephric duct. The metanephric diverticulum grows dorsad, into the metanephrogenic cord accompanying somite 29-31. The tip of the metanephric diverticulum becomes the renal pelvis, and the connecting part is the ureter. The surrounding nephrotomic material differentiates into metanephric blastema which in turn forms the renal cortex.

MATERIALS AND METHODS

The embryos used in this study were obtained from two sources: laboratory dogs, and wild coyotes.

Three sets of embryos were recovered from coyotes killed by hunters and received as part of the animals used in the study of "Factors Influencing Coyote Population" (Project 280, Kansas Agricultural Experiment Station).

Most of the embryos were obtained from dogs maintained in the laboratory specifically for the study of reproduction problems and dog embryology (Project 321, Kansas Agricultural Experiment Station). These dogs were closely observed, ovulation time determined, and embryos removed by surgery at times calculated to provide the desired embryo stages.

Fixation was accomplished by one of three methods: 1. Bouin's fixative or formalin were used routinely. 2. In some cases the embryo was fixed in situ by perfusion of the fixative through the uterine artery of the excised tract, supplemented by injection of a small amount of 20% formalin directly in the embryonic vesicle. 3. In other cases, the embryonic vesicle, supported by the endometrium, was stripped from the myometrium and fixed by immersion. Part of the last group had the circulatory system injected with lampblack suspended in Locke's solution before they were placed in the fixative. After fixation, the embryos that had been fixed in the uterus were dissected out. Part of the embryos were stained with either dilute acetocarmine or with Harris' haematoxylin diluted 1 to 20. These embryos were then dehydrated, cleared in xylol, and prepared as whole mounts. Other embryos were dehydrated, embedded in paraffin and sectioned at 10 microns. Some were sectioned transversely, others sagittally so as to allow at least one whole mount, one transverse series, and one sagittal series in each

critical group. The sections were stained in modified Harris' haematoxylin (25 ml. Harris' haematoxylin and 8 ml. acetic acid diluted to 500 ml. with water), and counterstained with either eosin or a mixture of orange G and acid fuchsin.

The youngest embryos used in this study were removed late in the sixteenth day or early in the seventeenth day of gestation. The oldest embryos studied in detail were removed from the uterus during the twenty-eighth day of gestation, at which time the metanephros was found to be anatomically advanced enough to suggest functional activity.

Age of the embryos was determined within a two-day period by calculation of gestation time from ovulation. Because there is a variation of approximately eight somites in one day of development and in some cases ovulation time had not been accurately determined, other criteria were used for more accurate staging of embryos. Carefully timed embryos regularly had 6-10 somites at the end of the sixteenth day after ovulation, 25-35 during the twentieth day, and reached the full complement of approximately 50 somites on the twenty-fifty day. Somites were readily counted both on whole mount preparations and on serial sections up to the 30 somite stage, after which the anterior somites became differentiated enough that they were difficult to identify. By this time, however, the spinal ganglia clearly marked the intersomitic grooves. As the full complement of somites neared completion, the range of the mesonephros, development of the Mullerian duct, length of the metanephros, and the extent of branching of the primitive pelvis were used as criteria for specific placement of an embryo in the series.

For convenience of study, the embryos were divided into seven groups (Table 1). Group I contained seven embryos ranging from eight to 16 somites and showed the development of the pronephric elements. Group II, with five

embryos, showed establishment of the mesonephros and progression of the nephric duct to a point near the cloaca. Group III contained six embryos showing the establishment of the connection between the nephric duct and the cloaca. Group IV contained four embryos and showed the initiation of the metanephric diverticulum. Group V contained five embryos which showed the establishment of the primitive ureter, the primitive pelvis, the kidney blastema and the anlagen of the Mullerian ducts and the gonads. Group VI contained two embryos and showed the indifferent gonads and the primary diverticuli of the primitive pelvis. Group VII contained five embryos which were characterized by the differentiable gonads and the establishment of the continuous tubular system in the metanephros.

For the convenience of description, groups V and VII were subdivided as presented under Table 1 and observation.

OBSERVATIONS

Group I
Embryos from 8-16 Somites

1. 8 somites embryo, X-section, 10 micra.
2. 120LC., 9 somites embryo, X-section, 12 micra.
3. 77L., 10 somites embryo, X-section, 10 micra.
4. 120RD., 11 somites embryo, X-section, 12 micra.
5. 113L., 13-14 somites embryo, whole mount.
6. 118L_2., 15-16 somites embryo, sagittal section.

8 Somites Embryo. The youngest embryo used for critical study was an eight somite dog, serially sectioned transversely at 10 micra. In this embryo, the nephrotome showed no differentiation from the first through the seventh somite. Along the posterior part of the eight somite, the nephrotome

Table 1. Embryos studied.

Group	Designation	Somites	Sections: Tran.	Sections: Long.	Thickness in micra
I		8	X		10
	120LC	9	X		12
	77L	10	X		10
	120RD	11	X		12
	115LA	12	X		10
	113L	13-14		X	
	$118L_2$	16			
II	$81L_2$	17		X	
	$81L_1$	18-19		X	10
	81L	19-20	X		
	121L	20	X		10
	45L	25-26	X		
III	65R	26-27	X		
	140R	27-28	X		10
	$41L_1$	27-28	X		
	$42L_2$	28	X		
	83RA	29	X		
	83RA	29	X		
IV	49L	34-35	X		10
	52R	34-35	X		
	81R	35-36	X		15
	130LA	41	X		15
V					
Subgroup (A)					
	48R	36 +	X		15
	$47L_2$	39 +	X		15
	123RD	45	X		15
	761A	46		X	
	241IA	47	X		15
Subgroup (B)					
	145L	45 +	X		25
	145LC	48	X		15
	953	50	X		
	761B	52	X		
	$33L_1$	53	X		
VI	130RD	54	X		15
	114L	54 +	X		15

Table 1. (concl.)

Group	Designation	Somites	Sections: Trans.	Sections: Long.	Thickness in micra
VII					
Subgroup (A)					
	46L	54 +	X		25
	60R	54 +	X		
Subgroup (B)					
	$9L_1$	54 +	X		15
	$9L_2$	54 +	X		20
Subgroup (C)					
	128L	54 +	X		20

had a dorsal knob-like growth which persisted in the preparation through four sections (Plate I, Fig. 1).*

120LC. At the sixth somite in the intersomitic groove between the sixth and the seventh, there was a slight depression from the splanchnocoel toward the nephrotome. At the seventh somite there was a slight nephric growth and a small splanchnocoelic projection toward it. At the eighth somite there was a slight nephric growth, accompanied by the separation of the nephrotome from the somitic mesoderm. There was also a shallow depression from the splanchnocoel toward it. At the ninth somite there was a prominent nephric growth, with the splanchnocoelic depression which was now more prominent than those in the anterior level.

Beyond the ninth somite in the area of the future tenth somite, the nephric growth was present, accompanied with a splanchnocoelic projection. The nephric growth in this area had a clear identity and showed a slight separation from the surrounding mesoderm. Far beyond this level the nephrotome showed a hump-like growth which gradually decreased and then

* All plates in Appendix.

diminished.

77L. At somite 1-5 inclusive, the nephrotome was broken into mesenchyme. At somite 6 there was no nephric growth and the nephrotome was accompanied by a depression from the splanchnocoel. At somite 7 there was a nephric growth accompanied by a splanchnocoelic depression which was deeper than the anterior one. At somite 8 there was a nephric growth which extended dorsad and reached the ectoderm. The splanchnocoelic depression in this level cut through the nephric tissue. The nephric tissue through this was separated from the somitic mesoderm. At somite 9 the nephric growth reached the ectoderm, and it was accompanied by a splanchnocoelic depression which cut through the nephric tissue. The nephric tissue through this range had a clear identity and it was delimited to some degree from the surrounding mesoderm. At somite 10 there was a prominent nephric growth which reached the ectoderm. The splanchnocoelic depression was present. Beyond somite 10 there was a nephric growth accompanied by a splanchnocoelic depression at the area of the future somite 11. Farther back the nephric growth decreased gradually and then diminished.

120RD. The pronephric region extended from somite 7-11 inclusively. At somite 7 the nephric tissue presented the same orientation as in the previous embryo. At somite 8 there was a nephric growth and splanchnocoelic depression as we had seen in the previous embryo. At somite 9 there was a dorsal nephric growth with a splanchnocoelic depression. The coelomic depression cut deeply into the nephric tissue, which at this range showed a dorsal delimitation. At somite 10 the nephric growth reached the ectoderm and made an indentation in it. It showed a dorsal delimitation; whereafter, the distal part separated and then returned to the pròper mass. At somite 11 the nephric mass showed a distal delimitation and then the distal part

separated. It continued backwards as a structure of definite identity, and then disappeared near the ectoderm. The proximal part, the nephric tissue proper, continued caudad and then disappeared in the nephrotomic tissue.

113L. A whole mount showing the extent of the nephric tissue from somite 9-14 inclusive.

$118L_2$. This embryo showed slight nephric outgrowths at intervals, through the distance ranging from somite 3-8 inclusive, which were accompanied by shallow splanchnocoelic depressions. The one at somite 8 was the largest and its depression cut deeply into it. This embryo also had three pronephric tubules which overlapped each other. They had nephrostomes which connected the splanchnocoel, with their nephrocoeles, which were short slit-like cavities. The first tubule originated from the nephrotome through somite 9 and extended dorso-caudad to the anterior level of somite 10 where it overlapped and fused with the succeeding tubule. The second tubule originated from the nephrotome through somite 10, and extended dorso-caudad and then fused with the overlying preceding tubule. The third tubule originated through somite 11 and extended dorso-caudad and fused with the preceding tubule in the range of this somite. Consequently, a common structure was formed from the fusion of the pronephric tubuleswhich was the pronephric duct. The formed duct extended caudad, overlying the nephrotomic tissue, to the range of somite 14, and throughout its extent it was free from the underlying nephrotomic tissue. Through this extent the latter had transverse segmentation, which was more prominent in the anterior level. We shall call the solid segment, formed from this segmentation, the mesonephromeres.

Group II
Embryos from 17-26 Somites

1. 81L_2., 17 somites L. S. in uterus.
2. 81L_1., 18-19 somites, L. S. in uterus.
3. 81L., 19-20 somites, X-Section in uterus.
4. 121L., 20 somites, S-Section.
5. 45L., 25-26 somites, X-Section.

81L_2. The pronephric region extended from somite 8-11 inclusively. The incomplete pronephric outgrowth through somite 8 was still present. The first tubule was well developed and extended from somite 9 backwards where it overlapped the succeeding tubule and fused with it at somite 10. The second tubule originated from somite 10 and extended caudalwards and fused with preceding tubules. The third tubule originated through somite 11 and extended dorso-caudad and fused with the preceding tubule. All the pronephric tubules were accompanied by splanchnocoelic depressions which represented vestigial nephrostomes. By this fusion a common structure, the pronephric duct, was initiated which extended caudalwards to the level of somite 16. In the meantime, the underlying nephrotomic tissue had been segmented into small units, the mesonephromeres. The anterior units were luminated and we shall call them coelomephromeres, and their cavities nephrocoeles. (Plate IV, Fig. 1).

81L_1. The pronephros. The three pronephric tubules were present and showed the same orientation as in the previous embryo. The pronephric duct showed the same relation to the pronephric tubules, and extended more caudad to the segmental plate, where its posterior tip lay against the ectoderm. The mesonephros showed that anterior mesonephric units were in the coelonephric stage while the rest were in the mesonephromeric stage. (Plate IV,

Fig. 2).

811. The pronephros. The three pronephric tubules were present and the third tubule was not an intact structure and was represented by two separated masses (Plate IV, Fig. 3). The pronephric duct extended from somite 11 to the segmental plate and had the same orientation as in the previous embryo. Its cross section was round at the anterior level, and became oblong at the posterior level. The mesonephrons in this specimen were 22 coelonephromeres on the left side and 20 on the right side. The remaining nephrotomic tissue was still as a solid continuous mass connected to the surrounding mesodermal tissue.

451. The pronephros in this specimen showed the first and the second tubules had degenerated, and the third tubule was the only one which remained intact (Plate IV, Fig. 4). The pronephric duct had extended more caudad and it reached the cloacal region of the hind gut. It was still as a solid structure without a lumen all the way through. At that stage there was an outgrowth from the lateral wall of the cloaca towards the pronephric duct. The mesonephrons extended from somite 11 to the segmental plate. All of them were in the coelonephric stage and the anterior ones (1-7) were connected to the pronephric duct by solid outgrowths (Plate IV, Fig. 4). Most of the authors called the pronephric duct, after it was connected with the mesonephric units, the mesonephric duct. In order to eliminate the confusion created by calling the same structure by different names in different stages, we called it the nephric duct in all its stages of development.

Group III
Embryos from 27-29 Somites

1. 65., 26-27 somites, X-section.
2. 140R., 27-28 somites, X-section.
3. $41L_1$., 27-28 somites, X-section.
4. $42L_2$., 28 somites, X-section.
5. 83RA., 29 somites, X-section.
6. 83RB., 29 somites, X-section.

65R. The pronephros was only a small mass of nephric tissue at somite 10 which represented a remnant of the degenerated pronephros. The mesonephros extended from somite 11 to the segmental plate. All the mesonephric units were in the coelonephric stage. There were 27 of them at the left side, and 29 on the right side. The anterior thirteen coelonephromeres on the left side, and the anterior fourteen on the right side were joined to the pronephric duct by solid dorso-lateral outgrowths. The posterior 14 coelonephromeres which were on the left side and the posterior 15 on the right side were not yet connected. These coelonephromeres were rounded bodies, enclosing cavities which were the nephrocoels. In the anterior level, they were in a ventral medial position to the nephric duct, while in the posterior level, they took a medial position. The cells of these coelonephromeres were of the columnar type (Plate III, Fig. 4). In the area of the segmental plate, the nephrotome was still connected to the mesoderm where the nephric duct took a dorsal position to it. The nephric duct extended from somite 10 to the cloacal area where it overlapped the lateral growth from the cloaca.

140R., 41L. The mesonephros of these two embryos showed the same arrangement as did the previous embryo. A series of coelonephromeres

extended from somite 11 to the segmental plate. Those which were in an anterior level were connected to the nephric duct, while those in a posterior level were still unconnected. The pronephric duct showed the same orientation and relation to the cloaca as did the previous.

42L2. The mesonephric units extended from somite 11 to the segmental plate. The nephric duct extended from somite 11 to the segmental plate. The mesonephric units were followed by the nephrotomic plate which was still in connection with the mesodermal tissue. There were 37 mesonephric units on both sides of this embryo. The anterior 12 mesonephric units on the left side and the anterior 13 on the right side were in the coelonephric stage and were joined to the nephric duct. These units had dorsal invaginations which initiated the formation of the mesonephric capsules (Plate V, Fig. 3). We called these coelonephromeres which had dorsal invaginations, and small solid untwisted connecting stems, coelonephromeres type C, those which were joined and without invaginations, coelonephromeres type B (Plate III, Fig. 4), and those which were unjoined, coelonephromeres type A. The succeeding 5 mesonephrons on the left side (13-17) and the three on the right side (14-16) were coelonephromeres type B. The remainder, 20 on the left side (18-37) and the 25 on the right side (17-41) were coelonephromeres type A. The nephric duct was still a solid cord-like structure, and extended from somite 10 to the urogenital sinus.

83RA., 83RB. The mesonephros extended from somite 11 to the segmental plate. It was more advanced in development than in the previous embryo. In 83RA there were 54 mesonephrons on the right side, 25 of them were joined, 27 coelonephromeres type A, and 2 mesonephromeres. The anterior 11 of the 25 joined mesonephrons had S-shaped forms, because of the flexions in their connecting portions. The outer, or external layer of the mesonephric capsule

of the latter type was composed of flattened squamous cells, while the inner layer was composed of columnar cells (Plate V, Fig. 4). There were about 11 mesonephrons of the S-shaped type on the right side while the rest of the 25 joined mesonephrons varied from coelonephric type C to the coelonephric type A. The joined mesonephrons extended through somite 11-21, inclusive. On the left side there were 55 mesonephrons, 25 of them were joined including the anterior 7 of the S-shaped type, 23 coelonephric type A and 2 mesonephromeres. The succeeding nephrotomic tissue, which extended through the segmental plate had not yet separated from the surrounding mesodermal tissue. In 83RB there were 51 mesonephrons on the right side, 21 of them were joined, 21 coelonephromeres type A, and 9 mesonephromeres. The anterior 15 mesonephrons of the 21 joined were in the S-shaped stage. On the left side, there were 50 mesonephrons, 20 joined, 12 of these were in S-shaped stage, 21 coelonephric type A and 9 mesonephromeres. The nephric duct extended from somite 11 to the urogenital sinus with which it connected at the area of the segmental plate. The allantois connected with the hind gut at the level of the 29th somite. Behind the connection of the nephric duct with the urogenital sinus there was an area where the endoderm of the hind gut fused with the ectoderm. The structure formed from this fusion was called the cloacal membrane. In 83RA and 83RB the capsules of the mesonephrons were formed of outer squamous layers and inner cuboidal layers. The inner layers were composed of a basal lamina composed of one cell layer of cuboidal cells upon which rested 2 or 3 loosely attached layers. Some of the cells were detached from this layer and were free in the cup-like depression.

Group IV
Embryos from 34-41 Somites

1. 49L., 34-35 somites, X-section, 10 micra.
2. 52R., 34-35 somites, X-section.
3. 81R., 35-36 somites, X-section, 15 micra.
4. 130LA., 41 somites, X-section, 15 micra.

49L., 52R. The mesonephros began at somite 11, and extended to the level of somite 29. All the mesonephrons were connected to the nephric duct. They showed successive stages of development from the anterior level backwards, ranging from the sigmoid type B, to the coelonephric type B. The sigmoid forms type B occupied the anterior level from somite 11-17, inclusive. Those which followed were ranging from the sigmoid form type A to the coelonephric form type C, to the coelonephric type B, respectively. The sigmoid mesonephrons which formed the first group had not been seen in the previous embryos. They were in a more advanced stage of development than the sigmoid type A. In this sigmoid form, the sigmoid flexion was more pronounced in that portion which connected the mesonephric capsules to the nephric duct. This connecting portion was not luminated in all its length except at the distal part nearest to the capsule. In this form the capsule was directed dorsad with little turn to the medial side (Plate VII, Fig. 1). The nephric duct had a little lower position than in the sigmoid form type A.

Cranially the nephric duct was lateral to the mesonephros, and caudalwards, the duct assumed a lower position and became ventral to the mesonephros. In this stage the nephric duct had a lumen at its posterior part, from the level of somite 21 to the cloaca. The nephric duct connected with the latter, at the same area where the allantois joined the hind gut. The nephric duct connected with a definite part of the hind gut, which was called

the urogenital sinus, which extended to somite 31, inclusive.

In the previous group of embryos examined, the nephrotomic plate had not detached from the adjacent mesoderm. In these two embryos (49L and 81R) at the middle range of somite 29, where the mesonephric tissue terminated, the unorganized nephrotomic tissue began and continued as an uninterrupted cord-like mass, to the posterior level of somite 31. This cord-like structure was the metanephrogenic cord. It did not have the same thickness all the way through. It was thicker at the posterior level of somite 30, and at the range of somite 31. In its extent it followed the nephric duct (Plate VII, Fig. 4). At somite 29 to the middle of somite 30 it had a position medial to the nephric duct. Caudad, where it became thicker, it took a dorsal medial position, and then changed its position from the medial and extended to the lateral side. In the latter place it was in more contact with the nephric duct. After that the metanephrogenic cord took a medial position and disappeared at the posterior range of somite 31 (Plate IX, Fig. 2). At that level the duct made a turn to reach the lateral side of the cloaca. At the place of contact, the nephric duct showed a thickened area of enlarged cells. The cloacal membrane extended from the posterior range of somite 32-33.

The mesonephros began at somite 12 and extended caudalwards to somite 29. The mesonephros showed the same orientation in relation to the nephric duct as in the previous group. In these two embryos the mesonephros was protruded from the dorsal body wall, due to the growth of the mesonephrons and the enlarging posterior cardinal veins. The mesonephrons showed a more advanced stage of development. In the anterior level, in the connecting portion of the mesonephron, three minor portions could be distinguished. The distal portion, nearest to the capsule which was composed of columnar

cells, was the secretory portion, tubulus secretorious, according to Mihalkovics (1885) or the tubulus postglomerulus according to Nicolas (1891). The proximal portion nearest to the nephric duct was of less caliber than the secretory portion and was composed of cuboidal cells. This portion was called the tubulus collectivus (Plate VIII, Fig. 2). The middle portion, which had a wide lumen, showed two or three ampulla-like swellings, and was located between the collecting and the secretory portions (Plate VIII, Fig. 1). This portion was called the tubulus intermedius, or tubulus ampullare. We shall call this kind of mesonephron the tripartite form. The capsule was large, it had a medial position in the mesonephros, and its glomerulus was larger than before. The tubulus secretorious extended from the capsule laterad and then turned dorso-mesiad to connect with the tubulus intermedius above the capsule. The tubulus collectivus extended medially under the postcardinal vein to reach the tubulus intermedius.

The nephric duct at this stage showed a lumen all the way through. It connected with the urogenital sinus before the union of the rectum and sinus. The urorectal notch was projecting internally as a ridge which extended as a septum, the urorectal septum. The extension of this septum backwards had increased the separation of the rectum from the sinus.

In the place of contact between the metanephrogenic tissue and the nephric duct, the latter showed a thickening of large epithelial cells. In 130LA, at the same place, there was a small dorsal evagination towards the metanephrogenic tissue. This evagination was the metanephric diverticulum.

Group V
Embryos from 41-53 Somites

Subgroup A.	No.	Somite	Anterior level of the mesonephros	Age in days
	1. 48R	36 +	Ant. 8th ganglion	23
	2. $47L_2$	39 +	Ant. 9th "	
	3. 123RD	45	Ant. 9th "	
	4. 761A	46	Middle 9th "	
	5. 241IA	47	Post. of 9th "	
Subgroup B.	1. 145L	45 +	10th ganglion	
	2. 145LC	48	Post. 10th "	26
	3. 953	50	11th "	
	4. 761B	52	" "	
	5. $33L_1$	53	" "	26

In this group, with its successive embryos, was observed the initiation and establishment of the ureter, and the pelvis in the primitive stage. The embryos were arranged to give complete linked developmental series where the primitive fundamentals of the metanephros, the primitive ureter, the pelvis and the kidney blastema covered one somite range, the 31st somite.

The group was subdivided into two subgroups, subgroup A and subgroup B.

Subgroup A

Embryos from 41-47 Somites. This group showed that the metanephric diverticulum, which was initiated at the place of the active contact, became prominent where it pushed its way into the metanephrogenic cord (Embryo 48R, Plate VIII, Fig. 2). In the embryo ($47L_2$), this diverticulum became more

enlarged and had pushed a greater distance into the metanephrogenic tissue. At the same time this diverticulum showed a kind of differentiation in which the distal portion was more distended and more enlarged than the proximal portion (Plate VIII, Fig. 4).

In the next embryo (123RD) this differentiation became more pronounced where the distal bulb-like portion became more distinguished from the tubular proximal portion. This bulb-like distal portion was the primitive pelvis because it was the antecedent to the mature pelvis. The proximal portion was the primitive ureter, and the metanephrogenic tissue which surrounded the primitive pelvis was the kidney blastema (Plate IX, Fig. 2).

In the succeeding embryos (761A and 241LA) the primitive pelvis showed a distinct elongation in the cranio-caudal direction.

Besides the establishment of the primitive fundamentals of the metanephros, this subgroup showed different relations between the nephric duct, the urogenital sinus and the rectum. The connection of the rectum with the urogenital sinus was retreated to a posterior level, beyond the level where the nephric duct connects with the sinus. This phenomenon increased gradually through successive embryos. The phenomenon indicated that the cloacal septum was apparently pushing back between the rectum and the urogenital sinus.

Another striking and noticeable phenomenon showed by subgroup A and also by subgroup B was that the anterior level of the mesonephros had retreated backwards, which indicated that the degenerative factor was going side by side with the developmental factor. The mesonephrons in this group were in the tripartite stage. They had not dispersed all along the mesonephros, as in the previous group, but were in a compact group, showing some intermingling. Those which were in the anterior level showed more

complexity in the tripartite state. There were two secondary flexions added to the tripartite form. This led to the formation of a double sigmoid form. One of the two new flexions was at the tubulus intermedius, and the second at the tubulus secretorius (Plate VIII, Fig. 3). This was the convoluted form. The three primary portions of the convoluted form, the tubulus collectivus, tubulus intermedius, and tubulus secretorius, were not in one level but were arranged in three levels. The glomerulus appeared in all three levels, while the tubulus intermedius appeared in the first two levels. The tubulus secretorius appeared in the second level, while the tubulus collectivus appeared in the third level. This indicated that the mesonephron had a differential growth in its various portions. The tubulus intermedius was the fastest in its development. In this stage the tubulus intermedius had a third ampulla (Plate VIII, Fig. 3).

In embryo $47L_2$, at the anterior tip of the mesonephros and at the range of the 9th spinal ganglion, there appeared in the coelomic epithelium, which surrounded the mesonephros ventrally, a thickening which did not extend beyond the range of this ganglion. In the succeeding embryo, this thickening became more prominent and covered more area. At its posterior range it showed a small invagination which pushed into the mesonephros. This invaginated thickened epithelium represented the anlage of the anterior part of the Mullerian duct (Plate IX, Fig. 3).

Subgroup B

Embryos from 47-53 Somites. The anterior level of the mesonephros was at ganglion 11. Progressing caudally, the width of the mesonephros increased and then decreased gradually. The posterior level was at the range of ganglion 26. The mesonephrons showed more complexity in their

convoluted forms and the mesonephric capsule was larger than before. The glomerulus had increased in size and was very large compared to the other parts of the mesonephron. The mesonephric capsule was ventral to the other constituents of the mesonephros. This was very well demonstrated in the serial longitudinal sections which progressed dorsally, from where the glomeruli were the first to appear. Every aortal branch which goes to the mesonephros, fed more than one glomerulus (Plate X, Fig. 3).

The metanephros in this group showed the same primitive fundamental stage which was composed of the primitive pelvis, which was invested by the metanephric blastema, and the primitive ureter. In this stage, they exhibited more growth and a migration to the anterior level where the metanephros covered an area ranged from 28-27 ganglia. The longitudinal axis of the metanephros in this stage was .39 mm. while the longitudinal axis of the primitive pelvis was .28 mm. (embryo 76lB). The primitive ureter was connected with the middle part of the primitive pelvis in a ventral medial position (Plate X, Fig. 2).

The Mullerian anlage, which was observed in the previous subgroup, was very pronounced in this subgroup where it extends to ganglion 10. At that range there was a deep depression of the thickened coelomic epithelium in the anterior part of the mesonephros. This invagination precedes the formation of a duct (Plate X, Fig. 1). The Mullerian anlage at that range had changed its position from ventral to ventro-lateral to the mesonephros. It was more prominent in the embryo 145C. than in embryo 145L, and became more prominent and extended farther backwards in each succeeding embryo of this group. At the anterior level, ganglion 9, it was a plate-like structure of thickened epithelial cells in front of the mesonephros.

The genital ridge was first evident at the level of ganglion 12, on

the medial side of the mesonephros, where there appeared an area of thickened cells of the coelomic epithelium. This ridge-like thickened coelomic epithelium was the genital ridge and was the antecedent to the gonad. In the last embryo of this group (33L) this ridge reached the range of ganglion 24.

Group VI
Embryos Showing Indifferent Gonad

No.	Somite No.	Length of Met.	Ganglion Range of Mull. Anlage	Gonad	Ganglion Range of Mets.
130RD	54	.65 mm.	10 — Ant. 11	indifferent	25 - 27
114L	54 +	.75 mm.	10 — Post.11	"	25 - 27

In this group the anterior level of the mesonephros was retarded to the posterior level of ganglion 11 (114L). The mesonephrons showed more convolution. The glomeruli were tremendously large, and they were well seen in (114L) which was injected with carbon particles (Plate XI, Fig. 1).

The metanephros extended more craniad where its anterior level reached ganglion 25, in 130RD. The longitudinal axis of the metanephros became longer than before and covered 3 ganglia, 25-27, inclusive, (.75 mm. long). The primitive pelvis in this group had two arms. The anterior arm began anterior to the connection of the ureter and the posterior arm was posterior to the connection. The anterior arm was longer than the posterior arm (Plate XI, Fig. 2).

Reconstruction of the primitive pelvis demonstrated three diverticula. One of the diverticula was at the anterior portion of the pelvis, the second at the middle, and the third at the posterior portion. This diverticulation was more prominent in 114L than in 130RD. They were the antecedents to the

major calyces of the mature permanent kidney. In the metanephric blastema around the primitive pelvis, two zones were distinguished, the inner zone, which was nearest to the pelvis was compact and stained darker than the outer zone, which was less compact (Plate X, Fig. 2).

The metanephros in this stage overlapped the posterior part of the mesonephros due to the metanephros extending anteriorly. The ureter was longer than before due to its growth from one side and due to the extension of the metanephros to the anterior level.

The Mullerian duct anlage extended from the level of ganglion 10 to 11. In 114L it was more extended posteriorly than at 130RD where it reached the posterior level of ganglion 11. This anlage was opened at the anterior level of ganglion 10, and formed an invagination at the posterior range of this ganglion. Caudally this invagination closed and detached from the surface, where it continued posteriorly as a duct in few sections and then disappeared at the posterior level of ganglion 11 (Plate XI, Fig. 3).

The gonad anlage, the genital ridge, extended from ganglion 12 and continued backwards to the range of ganglion 23 in 130RD and to the range of ganglion 24 in 114L. The anterior level of this anlage was less prominent and caudally it became more defined and more delimited from the mesonephros. It was in a medial position to the mesonephros, laterad to the mesentery, and hung from the dorsal body wall. In the middle of the genital ridge, at the area of the gonad proper, could be distinguished an outer layer, the germinal epithelium, and an inner mass, the inner epithelial mass (Plate XI, Fig. 4). The tissue, by which the gonad was attached to the coelom lateral to the mesentery and which connected it to the mesonephros, was the forerunner of mesorchium or the mesovarium. This stage, in which the inner epithelial mass showed no distinguished organization,

Group VII
Embryos with Differentiable Gonads

	No.	Ganglion range of the Mesonephros	Gonad and their ganglion range	Metanephros and its ganglion range	Mullerian duct and its ganglion range
Subgroup A	46L	15-24	16-24 ovary, showed the sex cords (Pfluggers' cords)	20-24 The pelvis showed secondary branching	15-18
Subgroup B	60R	16-24	16-24 Testis, showing testis cords and rudiments of rete testes	20-24 secondary branching	16-21
	$9l_1$	21-24	22-24 Testes showed the cords and the rete testes	20-24 The connection of the secretory elements with the collecting tubules	21 - genital hillock
	$9l_2$	21-24	21-24 Testis' cords and rete testes	20-24	21 - genital hillock
Subgroup C	128L	21-24	21-24 Testes with septuli	20-24	21 - genital hillock

was the indifferent stage and in that stage could not be differentiated as testis or ovary.

Group VII
Subgroup A

Embryos with Secondarily Diverticulated Pelvis. In this stage the anterior level of the mesonephros retreated backwards (at 15 ganglion in 46L and at 16 ganglion in 60R). The metanephros maintained its place which it had reached in the previous group. The primitive pelvis had diverticulated, forming primary branches which in turn gave rise to secondary branches (Plate XII, Fig. 2). The metanephric blastema was not a continuous mass as before, as it had divided into several masses each of which surrounded one of the secondary branches of the primitive pelvis. The Mullerian duct, extended further back in this group, where it reached ganglion 21 and disappeared near the surface of the coelomic epithelium. The gonad extended from ganglion 16 to 23 inclusively. It was divided into an anterior progonal area, which was the rudiment of the suspensory ligament, followed by the gonad proper area, and the posterior epigonal area, which was a peritoneal support attached to the mesonephros.

In 46L. the gonad was an ovary, showing the sex cords (Pfluggers' cords). These cords appeared as invaginations from the germinal epithelium. The ovary was attached to the mesonephros and to the dorsal body wall by a fold of peritoneum which was the mesovarium.

In 60R. the gonad was a testis, showing the testicular cords which were the rudiments of the seminiferous tubules. These cords were surrounded by a layer of connective tissue, which was the tunica albuginea. The testes were attached to the mesonephros and to the dorsal body wall by the mesorchium.

In the mesorchium, toward the mesonephric capsules, there were condensed cords which were the rudiments of the rete testes.

Subgroup B

Embryos with the Anlagen of the Uriniferous Tubules. The mesonephros had retreated backwards until its anterior level reached ganglion 21.

The secondary branches in this stage had branched into smaller and smaller branches, and eventually became the collecting tubules of the metanephros. The metanephric blastema had divided into smaller masses and these masses had been differentiated into capsules and into small ducts which were connected to the ends of the collecting tubules. The metanephric or Bowman's capsule showed, as did the mesonephric capsule, an outer layer of squamous epithelium and an inner layer of columnar epithelium (Plate XIII, Fig. 2). The glomeruli were present and the blood vessels, which have invaded the metanephros, fed them. The level of the metanephros was the same as in the previous group. The right metanephros was in a more advanced level, by one ganglion range, than the left mesonephros.

The gonad in this group was a testis that showed the same fundamental elements as in the previous groups, except that the rete testes are now more prominent and more extended than in the previous groups (Plate XIII, Fig. 4).

The Mullerian duct reached the urogenital sinus, and terminated in a protuberance from the dorsal side of the sinus. This protuberance was the genital hillock (colliculus seminalis), and the Mullerian duct, which terminated in the uterus masculinus in the adult male dog (Plate XII, Fig. 4). The nephric duct opened into the urogenital sinus at the side of the genital hillock. In the mature male dog, this duct was the vas deferens, which

opened at the side of the genital hillock. Anterior to the genital hillock, the ureter connected with the neck of the allantois at its dorsal side in a definite area which was the place of the trigone in the mature dog.

The urogenital sinus opened to the exterior on an elevated area which was the genital tubercle. This area was flanked by two folds which were the genital folds. At the sides of these folds there were two swellings which were the genital swellings. (Plate XII, Fig. 3).

Subgroup C

Embryos with Advanced Gonad. The gonad in this embryo was a testis which was more differentiated than in the previous groups.

At this stage partitions were dividing the testes into lobules. The partitions were the rudiments of the septuli. They were continuous with the tunica albuginea from one side and with the area which contained the rete testes centrally. The latter area was the mediastinum. The rudiments of the rete testes were larger than in the previous group and were connected to the mesonephric capsules.

DISCUSSION AND GENERAL CONSIDERATION

Formation of the Kidney

One of the current concepts about nephrogenesis, which was prevailing in all general treatises, textbooks, and the literature was the idea that during the development of the excretory system of the amniota, there was a succession of three types of kidney, the pronephros, the mesonephros, and the metanephros, in a chronological and spatial order.

It is a matter of controversy between the nephrogenetists about the

development and the relationship of the three types of kidneys. Were they different kinds of kidneys of different design, or three manifestations of a homogenous nature to one primordium of nephrogenic potentiality, showing differential development in time and space? Were there actually three types of kidneys in the ontogeny of the amniota, or was there only one continuous kidney? These questions split the investigators in this field into schools holding different views and concepts about the nephrogenesis of the amniotes. To organize the different views and concepts stated by most of the nephrogeneticists into definite clear-viewed schools for the convenience of the comparative study was the object of the following discussion.

1. The trinephric (tripartite) theory which was advocated by the earlier German embryologists Felix (1912), Gengenbaur (1901) and Kolliker (1879) stated that the amniotic nephric system consisted of three types of organs, the pronephros, the mesonephros, and the metanephros, which during the ontogenetic development succeeded each other chronologically and spatially. It was the third type, the last to appear, which was retained as the permanent mature kidney. This school emphasized the distinction between the three types, and considered them as non-homologous organs. Their order of occurrence in ontogeny, resembled their order in phylogeny. Most of the evidence derived from the morphology and the physiology of these types denied the presence of such distinction. The similarity in structure and the similarity of the functional performance between these three types refuted such consideration. The three terms, pronephros, mesonephros, and metanephros, used by the trinephrists were still used in most of the textbooks for the convenience of description and did not infer the presence of three such different kinds of kidneys.

2. The holonephric theory was advocated by Balfour (1885) and Sedgwick (1905) and other recent embryologists. The holonephrists stated that there was only one kidney, which they called the holonephros, of a polymorphous manifestation, which may develop more or less spatially and temporally.

3. The continuum concept, stated by Torrey (1943, 1954). Torrey in his work on the rat nephrogenesis (1943) and the development of the human nephric tissue (1954) postulated and emphasized the fact that what was found was no more than one continuous kidney which was inseparable into three types. Many evidences through the study of the development of nephric tissue in different vertebrates demanded the presence of such concept.

(a) One of the facts, which was in favor of this view, was the lack of differentiating criteria between the three organs designated by the trinephric theory. The trinephrist Felix has mentioned three criteria to distinguish between the three kinds of kidney, "1, by their appearance before or after the excretory duct; 2, by the presence or absence of an external glomerulus, and 3, by the point of origin of the principal tubule from the stalk of the primitive segments."

The first criterion indicated the role of the pronephric tubules in formation of the excretory duct and their pre-existence in relation to it. The mesonephric units appeared later. In the case of the gymnophionan, Hypogeophis, Brauer (1902), the nephric tubules, which were in the area of the pronephros, had a different relationship to the excretory duct. In this case there were 12 tubules; eight of them complete their development. The three anteriormost grew and fused to initiate the excretory duct which extended backwards independently to the cloacal area. The remaining tubules

connected with the duct secondarily and so differed from the anterior pronephric tubules which participated in the origination of the excretory duct. This condition illustrated the inadequacy and inaccuracy of the first differentiating criterion. According to the second criterion, the presence of the external glomeruli determined the pronephric tubule. There were many cases, especially in the lower vertebrates, where the pronephric tubules had internal glomeruli. Davies and Davies (1950), have shown the presence of a large glomus (external glomerulus) associated with the mesonephros of the sheep embryos.

(b) The graduation of complexity of the whole kidney. This gradual increase, in complexity of structure of the tubules, appeared in the ontogeny in a cranio-caudal direction. When the anterior tubules accompanied an ontogenic period which required their physiological performance, as in the case of the amniotes having larval stages, they were organized into a definite organ, the pronephros. This also illustrated the fact that this organ was rudimentary in the unamniotes of no larval stage exemplified by the elasmobranchs.

The posterior tubules which followed showed a gradient of a steeper kind, as in the case of the selachian kidney where the posterior part was more complex than the anterior. Another example was in the teleosts (Audige, 1910) where there were different graded forms of kidney, fluctuating from the whole mesonephric type, to a more complex one in which the posterior part was metanephric, and had its own ureter and blood supply. Another example was the avian nephric tubules where the mesonephric tubules had graded complexity and changed gradually to the metanephric kind. In such a case the term opisthonephros (Kerr, 1919) was used for the holonephros in such a situation.

4. The hologeneity concept postulated that the nephric system, in its areas, was a homologous system morphologically and physiologically. This view was expressed by the experimental embryologists from their work on the avian and amphibian embryos.

(a) Homogeneity in origin considered the nephric tissue through its extent originally from the same primordium, namely, the nephrotome. The evidence of this fact was obtained from the descriptive study and by experimental testimony obtained from avian and amphibian materials.

(b) The physiological homogeneity regarded the end product of the nitrogen metabolism which was in the form of uric acid in the adult and the embryo, Boyden (1926-7) and Gerard and Cordier (1934).

(c) Homogeneity in the potentiality of the nephrogenic blastema. The evidences from experimentation on chick embryos (Greunwald, 1937 and 1942), on the anura, Rana helmatica and Alytes obstetricus (Camber, 1948) and on the urodele, Triton alpestris, Machemer, 1929 (Fraser, 1950), showed that the nephric blastema was potentially similar throughout its extent. For the interpretation of the dog nephrogenesis, and for the convenience of the descriptive procedure, the same routine was used as most of the text-books do, by considering it under the three types of kidneys.

The Pronephros

Considering the pronephros created two problems. One of the problems was formation of the pronephric units. The other was the formation of the pronephric duct, the mechanism of its initiation, and the factors involved.

In the work done by many investigators, on the nephric development in different animals, three interpretations of the origin were mentioned.

1. The first method which the majority of the works favored can be

summarized as follows:

(a) The appearance of definite pronephrons from the anterior level of the nephrotome---the pronephric area.

(b) The pronephrons grew dorsally and then turned caudad.

(c) The fusion of their distal parts then followed.

(d) A continuous structure (tube or cord), which is the pronephric duct, was formed.

(e) Once the pronephric duct was formed, it continued to grow caudalwards by an independent terminal growth until it reached and connected with the cloaca.

This method determined the pre-existence of definite pronephrons from one side, and the participation of these pronephrons in the formation of the pronephric duct. These pronephrons in some animals had tubular structures and were spoken of as pronephric tubules. When they have cavities, nephrocoels, and connected with the splanchnocoel, by the pertoneal funnels or the nephrostomes, and they were called the pronephric duct, or the segmental duct, due to the participation of many elements in its formation.

One of the routine examples of this method was described in the myxinoids by Bdellostoma (Price, 1896, 1904). In the embryos of this animal, a series of tubules arose from the nephrotome from somites 11-82 inclusive. The fusion of the distal ends of these tubules initiated the excretory duct. The anterior tubules established a connection with the splanchnocoel, and they were devoid of glomeruli. The posterior group had no such connection with the splanchnocoel and differed from the anterior group by having glomeruli.

Another good example of this method was shown by the gymnophionan Hypogeophis described (Brauer, 1902). In the embryos of this animal there

were 12 tubules. The first three tubules participated actively in the formation of the excretory duct, and the rest, which complete their growth (5-8th, inclusive), connected to the duct secondarily. A similar description in the human was mentioned by Felix (1912), Johnson (1917), and Watt (1915). The same method was described by Hamburger and Hamilton (1951) in the chick where the pronephric tubules, which occupy 11-15 somites inclusive, participated in the initiation of the pronephric duct.

2. The splitting and delamination method. In such a method there were no definite discrete pronephrons as in the previous case. The nephrotome plate, in the pronephric area, showed a continuous dorsal ridge-like growth.

(a) This ridge-like growth was called the nephric ridge.

(b) After the ridge was established, there followed a distal splitting by which the dorsal part was delaminated from the mass proper.

(c) Beyond this area the posterior tip of the delaminated structure continued to grow caudalwards independently. This method was described in the lower vertebrates as in the anura.

Fraser (1920), in his work on the nephrogenesis of the cat's embryos reported that the nephric ridge extended from somite 9-14 inclusive. The pronephric duct developed secondarily by a splitting of the dorsal part, and then continued caudalwards by independent growth. This method was described in the human embryos by Wen (1928), Atwell (1930), and Heuser (1930), where they reported that the pronephric duct was originated by differentiation in situ. Torrey (1954) in his work on the human nephric development confirmed this method when he observed that the nephric duct (the pronephric duct) originated in situ differentiation and delamination from the nephrogenic cord in the range of somite 9-13 or 14 inclusive.

Posterior to this range the developing pronephric duct continued caudad by terminal independent growth. The pronephros in the dogs extended from somite 3-11 inclusive. The anterior part, which extended from somite 2-8 inclusively, was vestigial and was represented by slight rudimentary dorsal ridge-like outgrowths accompanied by shallow depressions from the splanchnocoel. The splanchnocoelic depressions represented vestigial nephrostomes. The pronephric outgrowth through somite 8, was the largest, and its nephrostome was deeper. The pronephric outgrowths could be considered as vestigial pronephrons which failed to complete their development. The posterior part of the pronephros which extended from somite 9-11 inclusive, was represented by three tubules. The first tubule, originated from the nephrotome, through somite 9, and extended dorsad toward the ectoderm and then turned caudad to the range of somite 10, where it connected with the succeeding tubule. The first tubule had a small, short nephrocoel, and opened to the splanchnocoel through the nephrostome. The second tubule, originated from the nephrotome at the level of somite 10, and grew dorso-caudad to fuse with and overlap the preceding tubule at the middle of this somite. The formed structure extended backwards where it connected with the succeeding tubule at the level of somite 11. The second tubule had a nephrocoel and a nephrostome (Plate III, Fig. 1). The third tubule originated at the level of somite 11 and extended dorso-caudad to connect with the overlapping common structure, formed from the fusion of the first and second tubule.

A common structure, the pronephric duct, was originated by this mechanism. This indicated that the first method was expressed in the canine nephrogenesis by the participation of the last three tubules. After it was formed, the pronephric duct continued caudalwards over the underlying nephrotomic tissue.

The nephric duct reached the cloacal region when the embryo was in the 25-28 somite stage. At the same time an evagination grew from the lateral side of the cloaca. In the 28-29 somite stage, the nephric duct had established its connection with an evaginating growth from the cloaca. The nephric duct up to that stage was a solid cord-like structure extending from the pronephric area and overlying the nephrogenic tissue. At the hind gut the duct made a curvature to reach the urogenital sinus, in the segmental plate area. It began to show a lumen at its posterior part in the 33-35 somite stage. At that stage the duct had a lumen from somite 21-31 inclusive, and became fully luminated all the way through at the 40-41 somite stage.

The Mesonephros

The mesonephrogenic tissue extended from somites 11-29 inclusive. The nephrotomic tissue started to differentiate when the nephric duct started growing caudad. This indicated some kind of interaction of an inductive nature between these tissues and suggested that the duct was behaving as an organizing factor in the development of the mesonephros. This observation needs experimental data in order to be confirmed. The data obtained from experiments on the amphibian and the avian embryo suggested such interaction. The removal of the nephric duct led to the failure of the mesonephric units to develop.

The works of Gruenwald (1937, 1942), Gambar (1948), Burns (1938), Boyden (1927), Waddington (1938), and others, confirmed the role of the nephric duct in the initiation and development of the mesonephros. These workers showed that the destruction of the nephric duct by using electrolytes or any cauterizing agent, retarded the development of the nephrogenic

tissue into mesonephros.

The differentiation of the mesonephrotomic tissue started in a cranio-caudal direction. The first step of the differentiation was the segmentation of the nephrotome into solid rounded units, the mesonephromeres. The second step of the differentiation showed the mesonephromeres began to organize their cells so that at the end of this organization a cavity appeared, the nephrocoel, which was surrounded by a layer of columnar cells. The luminated mesonephromeres were what were called the coelonephromeres. During the third step the coelonephromere started to establish a connection with the nephric duct by a dorso-lateral outgrowth. In the meantime, they started to show a dorsal depression which continued to deepen gradually until at the end there was a cup-shaped structure which was the anlage of the mesonephric capsule. The coelonephromeres ranged from the unconnected type A, to the connected type B, and to the connected with a dorsal depression type C (Plate XIV, Fig. 4). In the fourth step, the connecting portion started to show a flexion which initiated the S-shaped mesonephron, the sigmoid form. (Plate V, Fig. 5). Early in the sigmoid stage, the two layers of the mesonephric capsule began to differentiate. The inner layer proliferated and thickened while the cells of the outer layer flattened. At the same time, some cells detached from the inner proliferated layer and could be seen in the cavity of the vesicle. The vascularization of the mesonephric capsule started with the formation of the sigmoid form. A tuft of blood vessels, the glomerulus, inside the vesicle, was present in this stage. The proliferation of the inner layer of the mesonephric capsule, and the delamination of cells from it before the invasion of the aortal branch, led to the suggestion that the mesonephric elements participated in the formation of the glomeruli, and that the delaminated cells were of angioblastic potentiality and participated

in the formation of the glomeruli. Observations of such kind have been reported by some workers (See Horizon, Streeter, Volume 11, Group XII). During the fifth step, the connecting sigmoid portion continued to differentiate and cavitate and became a tubule of three distinguishable portions. These were the tubulus secretorious, the tubulus intermedius, or ampullare, and the tubulus collectivus. The tubulus secretorius was formed of columnar cells, while the tubulus collectivus was formed of cuboidal cells. The tubulus intermedius was a transitional area from the columnar type to the cuboidal type. It showed two ampulla-like swellings and was thus called ampullare. This stage of the mesonephron was called the tripartite stage. Kollikier (1879), Mihalkovics (1885), Meyer (1890, 1902), Minot (1903), and Schreiner (1902) were the earlier workers who described this form of mesonephron. Mihalkovics (1885) was the first to distinguish and to call the tubular collectivus and the tubulus secretorius while Nicolas called the latter tubulus postglomerulus.

The relation of the nephric duct to this form was different from what it was in the previous form. The nephric duct had a position lateral to the mesonephron after it had had a dorso-lateral position in the previous forms. The direction of the glomerulus became dorso-medial.

In the sixth step, the tripartite form, began to show a second sigmoid flexion and the tubulus secretorious, and the tubulus intermedius were involved in this secondary sigmoid flexion. At the same time the tubulus intermedius developed a third ampulla. Such a form was more complicated than the tripartite form, and it was called the convoluted form (Plate VIII, Fig. 3). The glomerulus continued to grow and enlarge until it became a very large structure in the mesonephron. The glomeruli were supplied with blood carried by several mesonephric arteries from the dorsal aorta. Each

of these arteries supplied more than one glomerulus (Plate X, Fig. 4). The mesonephros bulged into the coelom due to the development of the mesonephrons and to the presence of the post cardinal veins.

All the morphological and histological data indicated that the mesonephros was functional in the dog embryo and played an important excretory role in the embryonal life.

The Metanephros

The metanephrogenic tissue extended from the middle of somite 29 to 31 inclusive. In the 34-35 somite stage it was a cone-shaped cord (Plate VII, Fig. 4). At the anterior level it was narrow and had a position medial to the nephric duct. Through the 30th somite it took a dorso-medial position. In the range of the 31st somite it extended in its width from the medial to the lateral side of the nephric duct, where it was in contact with the latter. At the posterior range of this somite the metanephrogenic cord returned again to take a position medial to the nephric duct. Later on, at the place of contact, an evagination grew dorsad and started to push its way into the metanephrogenic tissue. This indicated that there was some kind of interaction between the metanephrogenic tissue and the nephric duct which led to the origination of the metanephric diverticulum. During the second step, this diverticulum began to differentiate into two parts — a distal bulb-like portion, which was the forerunner of the pelvis and a proximal tubular portion, which was the forerunner of the ureter (Plate IX, Fig. 2). In this stage the metanephrogenic tissue which was now called the kidney blastema and was a cap-like structure around the primitive pelvis. The primitive pelvis then began to diverticulate sending primary diverticula which were the antecedents to the major calyces and secondary ones which were the

antecedents of minor calyces. The process of diverticulation continued until the final tubules, which are the collecting tubules (Plate XIII, Fig. 2) were formed. The blastema, developing with the diverticulating pelvis, divided into small masses which were the metanephromeres. These metanephromeres went through the same essential steps through which the mesonephromeres had gone. They cavitated and formed the metanephric capsules (Bowman's capsules) and connected with the tips of the collecting tubules by means of secondary outgrowths. In this way the uriniferous tubules were established. The metanephric capsule had the same histological characteristics as the mesonephric capsule. Nephrogenetically, the metanephros or the permanent kidney of the mature dog was of dual origin. The secretory elements were derived from the metanephrogenic tissue while the collecting elements were derived from the nephric duct.

During its development, the metanephros migrated from its original place to a more anterior level. Later on the anterior level of the right kidney was at the posterior range of the 20th spinal ganglia as in the mature dog. The left kidney was more caudad by one vertbra-range.

The Ureter

The ureter developed by elongating and establishing a new connection with the neck of the allantois. The neck of the allantois eventually enlarged and became the urinary bladder. The ureter acquired its new independent connection after it had a common connection with the nephric duct by the incorporation and absorption of the posterior part of the nephric duct, by the growing urinary bladder. The ureter opened to the dorsal wall of the allantois neck. This area was the antecedent of the trigonal area in the mature urinary bladder. Posterior to this level was the place where the

nephric duct connected with the urogenital sinus, lateral to an elevation which was the forerunner of the genital hillock (colliculus seminalis).

The Urogenital Sinus

The urogenital sinus is that part of the hind gut where the allantois and the nephric duct joined. It was an important area which showed the relation between the urogenital system, the allantois and the hind gut. With the development of the embryo, this sinus began to separate from the hind gut (the rectum) due to the growth of the urorectal septum posteriorly. This septum originated from the ridge which was between the ventral floor of the gut and the allantois. The urogenital sinus opened to the exterior on an elevated area, the genital tubercle, which was flanked by two folds, the genital folds. At the side of the genital tubercle there were two swellings, the genital swellings, which were the antecedents of the scrotum in the male dog, and the labia majora in the female. The genital tubercle and the genital folds formed the penis and the prepuce in the male while in the female they formed the clitorus and the labia minora.

The Mullerian Duct

In the 40-42 somite stage the Mullerian duct appeared as a thickened flat area in the coelomic epithelium in front of the mesonephros. This area was located at the range of the 10th spinal ganglion (Plate X, Fig. 1). Later on, this area extended caudalwards as the embryo advanced in its stages. Caudally, this thickened area invaginated into the mesonephros and then detached as a duct inside the latter. This duct continued to grow caudad lateral to the nephric duct, until it reached and joined the urogenital sinus. The anterior end was the antecedent of the oviductal funnel,

while the remainder was the primordium of the uterus and the vagina.

The Gonad

The first appearance of the gonad was at the 47-48 somite stage as a thickened area in the coelomic epithelium, at the medial side of the mesonephros.

The Genital Ridge Stage

The genital ridge was at the anterior level of the thickened coelomic epithelium when it first appeared at the 12 ganglion range, and then retreated backwards as the mesonephros retreated, until eventually it extended from somite 21-24 inclusive. In this stage, the gonad was little more than a thickened layer of epithelial cells which was called the genital ridge (Plate X, Fig. 6).

The Indifferent Stage

The indifferent stage was the 54 somite stage. Later on the genital ridge differentiated into three areas. The anterior area was the progonal area which was the forerunner of the suspensory ligament. The middle area, which is the gonad proper, was enlarged and delimited from the mesonephros as an independent body (Plate XI, Fig. 4). It was now composed of an outer layer, the germinal epithelium, which surrounded a core of less compact cells, the inner epithelial mass (Plate XI, Fig. 4). In this stage the testes cannot be differentiated from the ovary due to the fact that they show the same structures and orientation. Posterior to the gonal area was the epigonal area which was no more than a peritoneal support attached to the mesonephros.

The Determining Stage, The Testes

In this stage the testes showed cord-like condensations in the inner epithelial mass. The condensations were surrounded by a connective tissue, the tunica albuginea (Plate XIII, Fig. 3). The cords were the antecedents of the seminiferous tubules (Plate XIII, Fig. 3). The testes hung from the coelom by a peritoneal fold which also connected to the mesonephros. This fold was the mesorchium. The rudiments of the rete testes appeared in the mesorchium, toward the mesonephric capsules, as cord-like condensations (Plate XIII, Fig. 4). The septuli appeared as partitions which divided the testes into lobules. The rete testes continued to develop until it connected the testes cords with the mesonephric capsules. The distal parts of the sex cords were more twisted, the rudiments of the tubuli contorti, than the proximal parts which were straight, the tubuli recti. The testes cords were separated from each other by the interstitial cells.

The Ovary

The ovary was attached to the dorsal body wall by the mesovarium. There were invaginations of the germinal epithelium in the form of cord-like structures, the sex cords (Pfluggers' cords), which then detached from the epithelium and became located in the cortex. The rudiments of the rete ovarii developed in the mesovarium as cord-like condensations toward the mesonephros.

SUMMARY

(1) Ontogenetically, the nephric tissue with its duct originated

from the intermediate cell mass, the nephrotome.

(2) The nephrotome, from somite 7-11 inclusive, was involved in the formation of the pronephros.

(3) The pronephric units, the pronephrons, originated by dorsal outgrowths from the nephrotome.

(4) There were three tubular pronephrons which were involved in the formation of the nephric duct by the fusion of their distal portions.

(5) Once the nephric duct was initiated, it continued caudalwards by terminal growth, until it reached the cloaca at the 25-26 somite stage.

(6) At the 28-29 somite stage it established connection with the hind gut.

(7) The caudal part of the nephric duct luminated at the 35-36 somite stage and became fully luminated throughout its length, at the 40-41 somite stage.

(8) The mesonephros utilized the nephrotome from somite 11-29 inclusive. The differentiation of it started at somite 11 and continued caudad.

(9) The mesonephrotome segmented into units called mesonephromeres, which cavitated (coelonephromeres), and then connected with the nephric duct.

(10) The connecting part began to develop a sigmoid flexion, which led to the formation of the sigmoid form.

(11) The full grown mesonephron consisted of a large glomerulus and a connecting part with three portions, the tubulus secretorious, the tubulus intermedius, and the tubulus collectivus.

(12) The mesonephron continued to develop more flexions and transformed to the convoluted form.

(13) The metanephros utilized the nephrotome through somite 29-31 inclusive. This nephrotome was a cone-shaped cord and was called the metanephrogenic cord.

(14) A dorsal evagination from the nephric duct, the metanephric diverticulum, grew into the metanephrogenic cord.

(15) The metanephric diverticulum differentiated into a distal bulb-like portion, the primitive pelvis, and a proximal tubular portion, the primitive ureter.

(16) The primitive pelvis diverticulated repeatedly until the final branches were the antecedents to the collecting tubules.

(17) The metanephrogenic tissue differentiated into small units, the metanephromeres, which were the primordia of the metanephrons.

(18) The metanephromeres differentiated into the secretory elements of the uriniferous tubule, and during their development established connection with the collecting tubules. In the meantime, the metanephros migrated cranially until it reached its final location.

(19) The Mullerian duct originated first as a thickening in the coelomic epithelium, ventral to the mesonephros. Eventually, it invaginated and detached into the mesonephros as a duct. The anterior part did not invaginate and remained as a flat plate. It continued in its growth caudalwards until it reached and connected with the urogenital sinus.

(20) The gonad appeared first as a ridge-like thickening from the coelomic epithelium medial to the mesonephros (the genital ridge).

(21) The genital ridge differentiated into three areas which were: the progonal area (the suspensory ligament's anlage), the gonal area (the anlage of the gonad) and the epigonal area, which was a peritoneal support connected to the mesonephros.

(22) The anlage of the gonad passed through the indifferent stage in which the testes and the ovary were undifferentiable from each other. In this stage the two consisted of an outer germinal epithelium and inner epithelial mass.

(23) The gonad then passed through the determining stage in which the two kinds of gonads were differentiable from each other.

(24) The seminiferous cords differentiated in the inner epithelial mass as condensations. The tunica albuginea developed as a connective tissue around these cords.

(25) The rete testes differentiated in the mesorchium as cord-like condensations toward the mesonephric capsules.

(26) The septuli differentiated as partitions dividing the developing seminiferous cords into groups called lobules.

(27) The germinal epithelium of the ovary proliferated and invaginated into the gonad as cord-like structures (Pfluggers' cords) which eventually detached into the newly differentiated cortex.

(28) The hind gut separated from the urogenital sinus by the growing urorectal septum which developed between the sinus and the rectum.

(29) The ureter developed an independent connection to the neck of the allantois which eventually developed into the urinary bladder.

(30) The urogenital sinus opened to the exterior in an elevated area, the genital tubercle, which was flanked by two folds, the genital folds. The genital swellings appeared at the sides of the genital tubercle.

ACKNOWLEDGMENTS

Indebtedness and sincere thanks are acknowledged to Dr. H. T. Gier for his instruction, positive criticism and patience during this study.

Gratitude and appreciation are deeply expressed to Dr. D. J. Ameel and Dr. D. M. Trotter for their supervision, assistance and guidance throughout the study.

The author is also deeply indebted to and wishes to thank the Department of Zoology and the Department of Anatomy for laboratory space, equipment and other facilities.

LITERATURE CITED

Atwell, W. J.
A human embryo with seventeen pairs of somites; Carnegie Inst. Wash. Pub. 407, Contrib. to Embryo. 21:1-24. 1930.

Audige, J.
Contribution a l'elude des reins des poison teleosteens. Arch. de Zool. Esper. et. gen. 4(5):245-624. 1910.

Balfour, F. M.
A treatise on the comparative embryology. Vol 2. 2nd ed. 792 p. London. 1885.

Bonnet, R.
Preparate und Zeichnungen zur Entwickelungsgeschichte des schafes. Anat. Anz. 3:714-717. 1888.

Boyden, E. A.
Experimental obstruction of the mesonephric duct. Proc. Soc. Exp. Biol. & Med. 24(6):572-576. 1927.

Brauer, A.
Beitrage zur Kenntniss der Entwicklung und Anatomie der Gymnokhion. III. Die Entwicklung der Excretionsorganse. Zool. Jahrbweher, Abt. Anatomie und Ontogenie. 16:1. 1902.

Buchanan, G. and E. A. Fraser
The development of the urogenital system in the Marsupialia with special references to Trichosurus vulpecula. Part I. J. Anat. 53:11-26. 1918.

Burns, R. K.
Development of mesonephros in Amblystoma after early extirpation of the duct. Proc. Soc. Exp. Biol. & Med. 39(1):111-113. 1938.

Camber, R.
Recherches experimental sur les facteurs de la morphogenese du mesonephros chez les amphibiens anoures. Bull. biol. 82:214-285. 1948.

Davies, J. and D. V. Davies
The development of the mesonephros of the sheep. Proc. Zool. Soc. London. 120:73-93. 1950.

Felix, W.
"Die erste Anlage des Excretions-Systems des Huhnchens." Festschr. Nägeli v. Kolliker Zurich. 1891. "The development of the urogenital organs." Manual of human embryology. Keikel and Mall. Vol. 11. 1912.

Fraser, E. A.
The pronephros and early development of the mesonephros in the cat. J. Anat. 54:287-305. 1920.

_____
The development of the vertebrate excretory system. Biol. Rev. 25:159-187. 1950.

Gegenbaur, C.
Vergleichende Anatomie der Werbeltthier mit Berucksichtingung der Wirbellosen. Vol. 2, 696 p. Leipzig. 1901.

Gerad, P., and R. Cordier
Esquisse d' une histophyologie comparee due rein des vertebres. Biol. Rev. 9:110-131. 1934.

Gruenwald, P.
Zur Entwickelungsmeckanik des Urogenitalsystems beim Huhn. Arch. F. Entwickelungmech. d. organ. 1937.

_____
Experiments on distribution and activation of the nephrogenic potency in the embryonic mesenchyme. Physiol. Zool. 15:396-409. 1942.

Hamburger, V. and H. L. Hamilton
A series of normal stages in the development of the chick embryo. J. Morph. 88:49. 1951.

Heuser, C. H.
A human embryo with 14 pairs of somites. Carnegie Inst. of Wash. Pub. 414, Contri. to embryo. 22:135-153. 1930.

Janosik, J.
Histologisch-embryologishe Ubersuchungen uber Urogenitalsystem. Sits. Ber. Akad. WissWien, Natch. Nat. Kl. 91. 1885.

Johnson, F. P.
A human embryo of 24 pairs of somites. Carnegie Inst. Wash. Pub. 226, Contrib. to embryo. 6:125-168. 1917.

Keibel, F.
Uber entwickenlung des urogenitalapparates von Echidna. Anat. Anz., Erganzungshaft. 23:14-17. 1903.

Kerens, B.
Recherches sur les premeieres phases du development de l'appreil excrecteur des Amniotes. Arch de Biol. 22:493-648. 1907.

Kerr, J. G.
Textbook of embryology, Vol. 11, Vertebrata with the exception of mammalia. London: MacMillan. 1919.

Kolliker, A.
Handb. d Geweblhre. entwick. Gesch. 1879. 535 p.

Martin, E.
Uber die Anlage der Uriniere beim Kanich Arch Mikr. Anat. 32:109-123. 1888.

McCrady, E.
The embryology of the opossum. The Am. Anat. Mem. 16:233. 1938.

Meyer, H.
Die Entwicklung der Urinieren beim Menschen. Arch F. Mikr. Anat. 36:138-172. 1890.

Mihalkovics, V.
Untersuchungen uber die Entwickelung des Harn und Geschlecht-sapparates der Amnionten. Inter. Monatsschr. Anat. N. phys. 2:435-485. 1885.

Minot, C. S.
Laboratory textbook of embryology. Philadelphia: Saunders, 1903.

Nicolas, A.
Contribution à l'étude des cellules glandulare. 1. Les éléments des Canalicules du rein primitif chez les mammifères. Extrait du Journ. Internat. d'Anat. et de physiol., T. 8:94. 1891.

Price, G. C.
Development of the excretory organs of the myxinoid, Bdellostoma, stouti. Lockington. Zool. Jahrb. Anat. v. ontogenic. 10:205. 1896.

A further study of the development of the excretory organ in Bdellostoma stouti. Amer. Jour. Anat. 4:117-138. 1904.

Rable, C.
"Uber die Entwicklung des Urogenitalsystems der Selachier." Morph. Jahrb. Bd. XXIV. 1896.

Renson, G.
"Recherches sur le rein cephalique et le corps de Wolff chez les oiseaux et les mammiferes (extrait). Arch. f. Mikr. Anat. Bd. XXII. 1883.

Schreiner, K. E.
"Uber die Entwicklung der Amnioteniere." Zeitschr. F. Wissensch. Zool. Bd. LXXI. 1902.

Sedgwick, A.
A student textbook of zoology. New York: MacMillan, 1905. 705 p.

Shikinami, J.
Detail form of Wolffian body in human embryos of the first eight weeks, Carnegie Inst. Wash. Pub. 363, Contrib. to Embryo. 18:46-61. 1926.

Torrey, T. W.
The development of the urogenital system of the albino rat. I. The kidney and its ducts. Amer. J. Anat. 72(1). 1943.

_____
The early development of the human nephros. Carnegie Inst. Wash. Pub. 693, Contrib. to embryo. 35:175-197. 1954.

Van der Stricht, O.
Le Mesonephros chez la Chauvesois Comt. rend. Assoc. des Anat. 60-65.

Waddington, C. H.
The morphogenetic function of a vestigial organ in the chick. Jour. Exp. Biol. 15(3):371-376. 1938.

Watt, J. C.
Description of two young twin human embryos with 17 to 19 paired somites. Carnegie Inst. Wash. Pub. 222, Contrib. to embryo. 2:5-44. 1915.

Weinberg, E.
A note on the origin and histogenesis of the mesonephric duct in mammals. Anat. Rec. 41:373-386. 1929.

Wen, I. C.
The anatomy of human embryo with 17 to 23 pairs of somites. Jour. Comp. Neurol. 45:306-376. 1928.

APPENDIX

EXPLANATION OF PLATE ABBREVIATIONS

Photomicrographs in Plates I, III, V, VII, VIII, IX, X, XI, XII and XIII were taken of sectioned stained materials. Plates II, IV, VI and XIV are photographs of pictoral diagrams. The following abbreviations are used throughout:

Al.---Allantois
Am.---Ampulla
Bl.---Metanephric blastema
Bl_1.---Inner zone of the metanephric blastema
Bl_2.---Outer zone of the metanephric blastema
Cl.M.---Cloacal membrane
Cnm.---Coelonephromere
Coel.---Coelome
C.T.---Collecting tubule
D.A.---Dorsal aorta
G.E.---Germinal epithelium
G.H.---Genital hillock
G.F.---Genital fold
G.I. Inner epithelial mass
Gl.---Glomerulus
G.R.---Genital ridge
G.S.---Genital swelling
G.T.---Genital tubercle
L.M.---Lateral mesoderm
M.A.---Mesonephric artery
M.D.---Mullerian duct
M.D.A.---Mullerian duct anlage
Mn.C.---Mesonephric capsule
$Mn.C_1$.---Outer layer of Mn.C.
$Mn.C_2$.---Inner layer of Mn.C.
Mnm.---Mesonephromere
Mns.---Mesonephros
Mo.---Mesorchium
N.---Nephric duct
Nn.C.---Metanephric capsule
$Nn.C_1$.---Outer layer of Nn.C.
$Nn.C_2$.---Inner layer of Nn.C.
N.D.---Metanephric diverticulum
N.Co.---Metanephric cord
Ncoe.---Nephrocoel
Nn.---Metanephron
Nns.---Metanephros
Ns.---Nephrostome
Nt.---Nephrotome
Nt.P.---Nephrotomic plate
$P.B_1$.---Primary branch of the primitive pelvis
$P.B_2$.---Secondary branch of the primitive pelvis
$P.B_3$.---Tertiary branch of the primitive pelvis
Pc.V.---Postcardinal vein
P.G.---Pronephric growth
Pa.G.---Postanal gut
Pe.U.---Penile urethra
Pn.D.---Pronephric duct
Pnn.---Pronephron
Pns.---Pronephros
P.P.---Primitive pelvis
P.T.---Pronephric tubule
P.U.---Primitive ureter
R.T.---rete testis
S.---Sigmoid form
S.C.---Seminiferous cord
So.---Somite
St.---Stomach
T.---Testis
T.A.---Tunica albuginea
T.C.---Tubulus collectivus
T.I.---Tubulus intermedius
T.S.---Tubulus secretorius
Ug.S.---Urogenital sinus
Ur.S.---Urorectal septum

EXPLANATION OF PLATE I

Fig. 1. Transverse section of an 8-somite embryo, through the 8th somite showing the three kinds of mesoderm. (X 150).

Fig. 2. The right side of Fig. 1 with more magnification, the nephrotome with a dorsal growth. (X 400).

Fig. 3. Transverse section of an 11-somite embryo through somite 9, showing the relation of the pronephric outgrowth to the other mesodermal tissue. 120HD. (X 150).

Fig. 4. The left side of Fig. 3 more magnified, to show the pronephric outgrowth, and the delimited distal part from the outgrowth proper. (X 400).

PLATE I

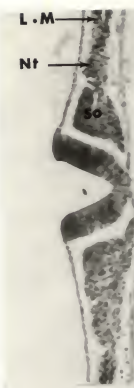


Fig. 1.

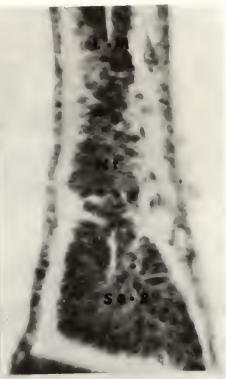


Fig. 2.

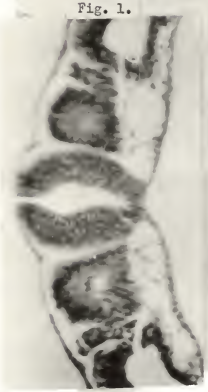


Fig. 3.

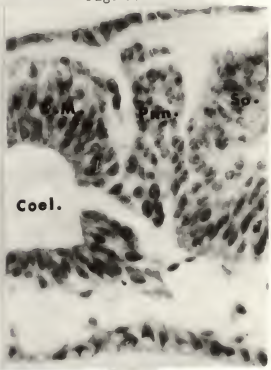


Fig.4.

EXPLANATION OF PLATE II

Fig. 1. Pictoral diagram showing the nephrotome of a 12-somite embryo in range of somites 7-13 inclusive. Notice the dorsal growth through the pronephric area (7-11 somites inclusive) and its relation to other mesodermal tissue.

Fig. 2. A transverse section through somite 7 at level A.

Fig. 3. A transverse section through the anterior of somite 8 at level B.

Fig. 4. A transverse section through somite 8 at level C.

Fig. 5. A transverse section through somite 9 at level D.

Fig. 6. A transverse section through somite 10 at level E.

Fig. 7. A transverse section through somite 11 at level F. Notice the presence of the nephrostome, the slit-like nephrocoele and the degree of the outgrowth in the different pronephric areas.

PLATE II

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

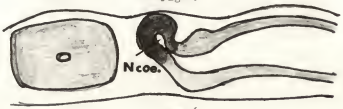


Fig. 6.

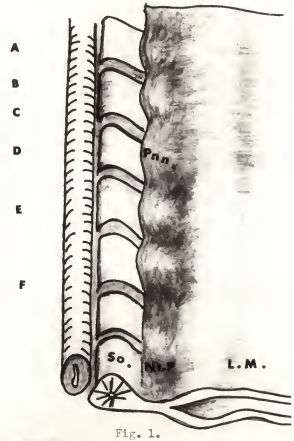


Fig. 1.

Fig. 7.

EXPLANATION OF PLATE III

Fig. 1. Sagittal section of 81L_1 showing the first pronephron in the range of somite 9. (X 225).

Fig. 2. Sagittal section of 81L showing the second pronephron and the nephric duct. (X 150).

Fig. 3. Sagittal section of 81L_1 showing the nephrostome of the third pronephron. (X 525).

Fig. 4. Sagittal section of 45L showing the nephric duct with the anterior-most mesonephrons (coelonephromeres). (X 300).

Fig. 5. Sagittal section of 45L in a posterior level showing the relation between the nephric duct and the mesonephrons (coelonephromeres). (X 375).

Fig. 6. Transverse section (left side) of 81L, in anterior level in the mesonephric area, showing the relation between the mesonephros (coelonephromere) and the nephric duct and the splanchnocoel. (X 375).

PLATE III

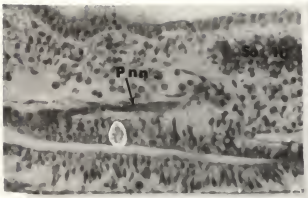


Fig.1.

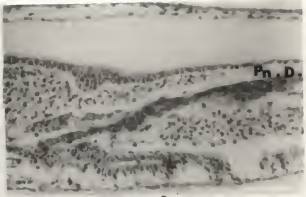


Fig.2.

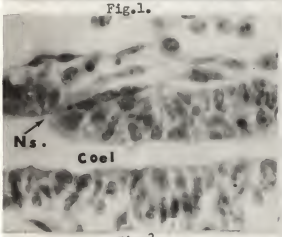


Fig.3.

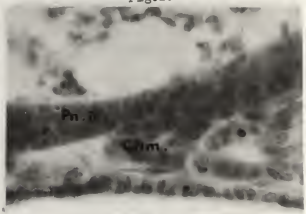


Fig.4.

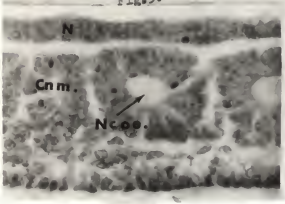


Fig.5.

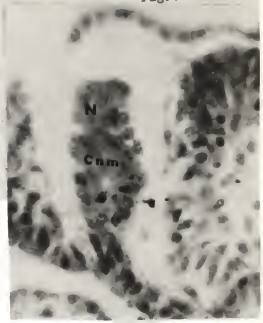


Fig.6.

EXPLANATION OF PLATE IV

Fig. 1. A pictoral diagram showing the pronephros, the nephric duct, and anterior part of the mesonephros. Notice the three tubular pronephrons and the mesonephrons in their mesonephromeric stage. 81L_2.

Fig. 2. Showing the same area in an advanced stage. Notice the mesonephrons which had started to cavitate. 81L_1.

Fig. 3. Showing the same area in more advanced stage. Notice the mesonephrons which acquired cavities (nephrocoeles) and became coelonephromeres. The pronephros was advanced in its degeneration. 81L.

Fig. 4. The same area in more advanced stage. Notice the mesonephrons which have connected to the nephric duct. The pronephros have degenerated more and the last pronephron was the only one which remained intact. 45L.

PLATE IV

Fig.1.

Fig.2.

Fig.3.

Fig.4.

EXPLANATION OF PLATE V

Fig. 1. Transverse section of $42L_2$ in a posterior level of the mesonephric area, showing the relation between the mesonephrons (mesonephromeres) and the nephric duct. (X 150).

Fig. 2. Transverse section of $42L_2$ in the region of the segmental plate showing the posterior tip of the nephric duct and the cloacal diverticulum. (X 150).

Fig. 3. The mesonephron in the coelonephric stage with its relation to the nephric duct. 83RB. (X 700).

Fig. 4. The mesonephron in later coelonephric stage (type C). See the outer layer of the anlage of mesonephric capsule becoming thinner. 83RA (X 700).

Fig. 5. The mesonephron in the sigmoid stage (type A). See the thickening inner layer of the mesonephric capsule, the delaminated cell detached from it, and the thin outer layer. 83RB. (X 700).

PLATE V

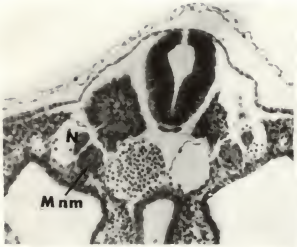


Fig.1.

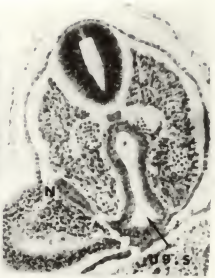


Fig.2.

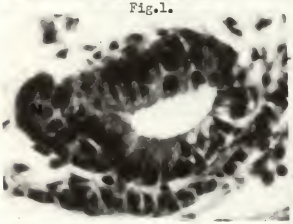


Fig.3.

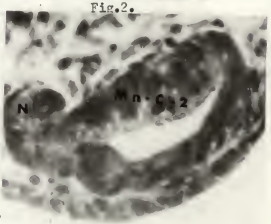


Fig.4.

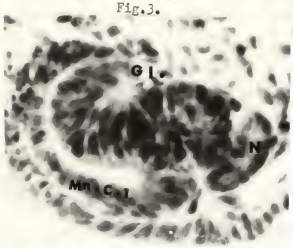


Fig.5.

EXPLANATION OF PLATE VI

Fig. 1. A pictoral diagram showing the relation of the mesonephrons to the nephric duct, and the relation of the latter to the hind gut and the allantois, where it was not connected with the cloaca. A, B, C, D, E, F, G, showing the mesonephrons in different levels with their relation to the nephric duct. 65R. and $42L_2$.

Fig. 2. The previous area in more advanced stage. The nephric duct joined the cloaca. 83RA. and 83RB.

Fig. 3. A pictoral diagram showing the mesonephros and the metanephrogenic tissue, with their relation to the nephric duct. A, B, and C are three sections through the metanephrogenic tissue at level A, B, and C, chosen to show the relation of the latter with the nephric duct. 52R. and 49L.

PLATE VI

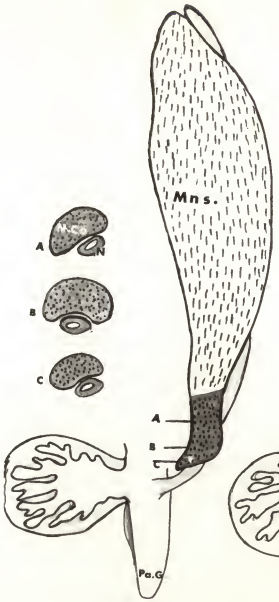


Fig. 1

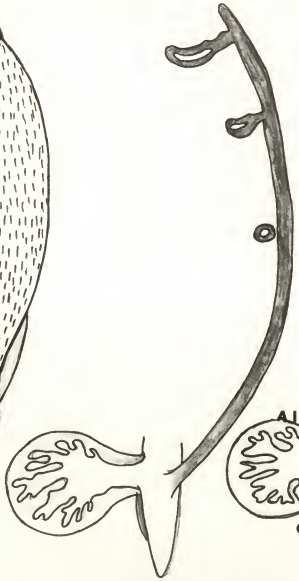


Fig. 2

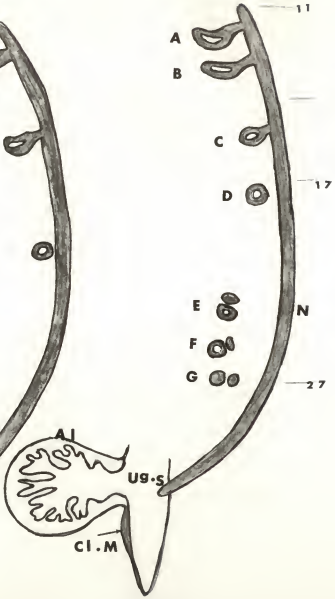


Fig. 3

EXPLANATION OF PLATE VII

Fig. 1. Mesonephron in later sigmoid stage (type B). See the outer layer of the mesonephric capsule which is composed of squamous cells. 52R. (X 180).

Fig. 2. Transverse section of 52R. at the level of 31st somite, showing the relation between the metanephrogenic tissue and the nephric duct. (X 180).

Fig. 3. Transverse section of 52R. at the level of 32nd somite showing the connection of the nephric duct with the urogenital sinus. (X 180).

Fig. 4. Diagonal section of 49L. showing the whole length of the metanephrogenic cord and its relation to the nephric duct. See the place of active contact between the two tissues. (X 180).

PLATE VII

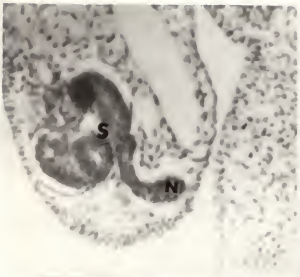


Fig.1.

Fig.2.

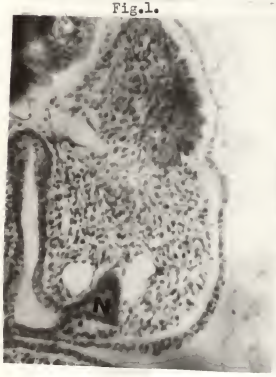


Fig.3.

Fig.4.

EXPLANATION OF PLATE VIII

Fig. 1. A transverse section of the mesonephros in 48R., showing the tripartite mesonephron and its orientation in the mesonephros. (X 225).

Fig. 2. A transverse section of 48R., showing the metanephric diverticulum with the kidney blastema. (X 225).

Fig. 3. A transverse section of the mesonephros in $47L_2$., showing the early convoluted mesonephron. (X 225).

Fig. 4. A transverse section in $47L_2$., in the metanephric region, showing the metanephric diverticulum and the metanephrogenic tissue. (X 225).

PLATE VIII

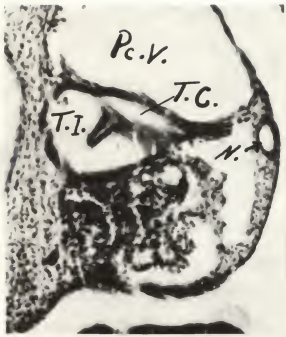


Fig.1.

Fig.2.

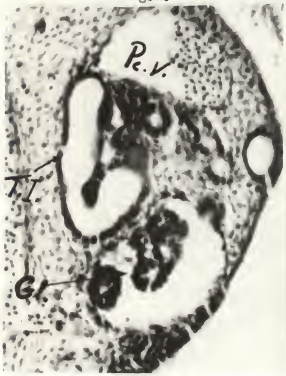


Fig.3.

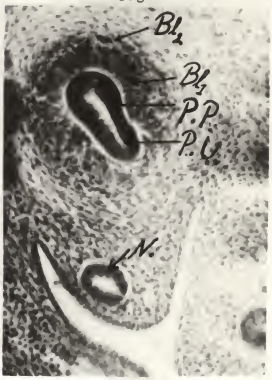


Fig.4.

EXPLANATION OF PLATE IX

Fig. 1. A transverse section of the mesonephros in 123RD., showing the convoluted mesonephron and the mesonephric artery to the glomeruli. Note the level of the nephric duct. (X 225).

Fig. 2. Transverse section of 123RD., showing the metanephric diverticulum and the kidney blastema. (X 225).

Fig. 3. Transverse section of $47L_2$ in the region of the 10th spinal ganglion showing the Mullerian anlage in an anterior level. (X 225).

PLATE IX

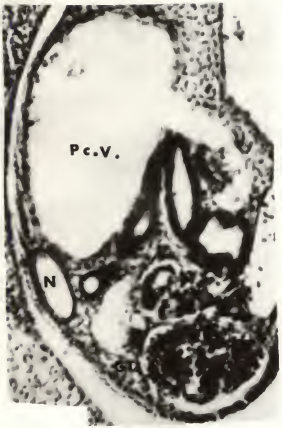


Fig.1.

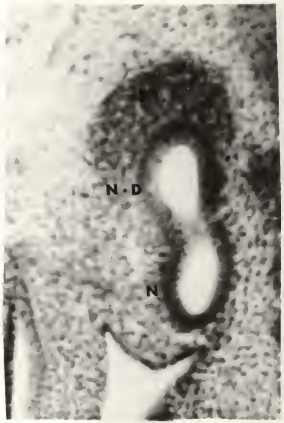


Fig.2.

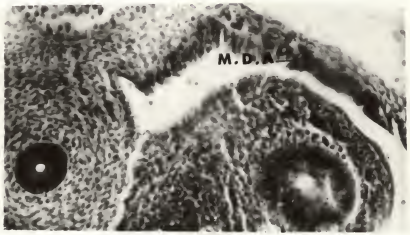


Fig.3.

EXPLANATION OF PLATE X

Fig. 1. Mullerian anlage and its relation to the mesonephros in 145LC. This anlage is an invagination of the thickened coelomic epithelium into the mesonephros. (X 166).

Fig. 2. The right and left metanephros in 145LC., in the primitive stage. Note the kidney blastema has differentiated into an inner compact zone and an outer loose zone. (X 132).

Fig. 3. Part of a longitudinal section of the mesonephros in 953, showing the distribution of the mesonephric artery into more than one glomerulus. (X 110).

Fig. 4. The primitive pelvis, the kidney blastema and the ureter. 953. (X 110).

Fig. 5. The Mullerian duct anlage in an anterior level. $33L_1$. (X 132).

Fig. 6. Part of a longitudinal section of the mesonephros with the genital ridge. $33L_1$. (X 166).

PLATE X

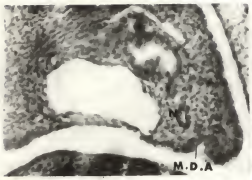


Fig.1.

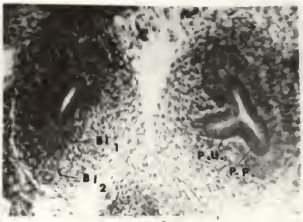


Fig.2.

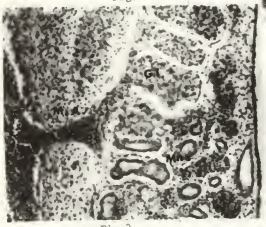


Fig.3.

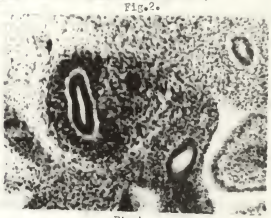
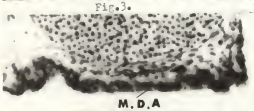


Fig.4.



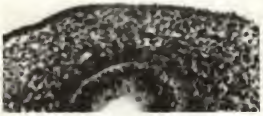


Fig.5.

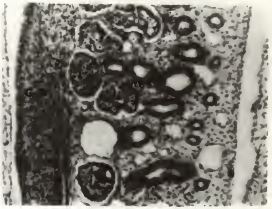


Fig.6.

EXPLANATION OF PLATE XI

Fig. 1. Longitudinal section of mesonephros of 114L., which was injected with carbon particles, showing the glomeruli and the genital ridge. (X 80).

Fig. 2. A longitudinal section of the metanephros in 114L., showing the two arms of the primitive pelvis. (X 150).

Fig. 3. The Mullerian duct in 114L. in more advanced stage. (X 225).

Fig. 4. Transverse section of 130RD., showing the indifferent gonad and its relation to the mesonephros and the mesentery. (X 150).

PLATE XI

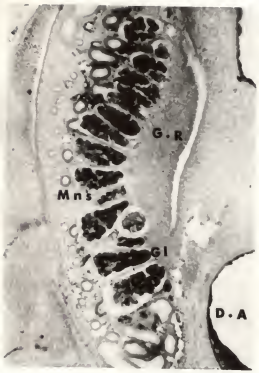


Fig.1.

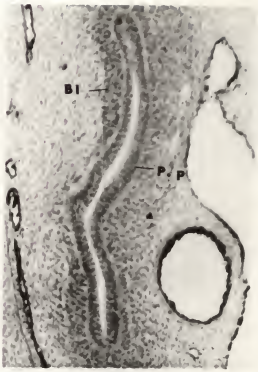


Fig.2.

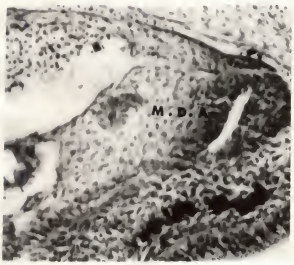


Fig.3.

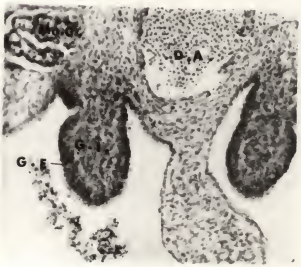


Fig.4.

EXPLANATION OF PLATE XII

Fig. 1. A longitudinal section of the metanephros in 60R., showing the diverticulation of the primitive pelvis into tertiary branches. Note the subdivision of the kidney blastema into masses around each branch. (X 120).

Fig. 2. A longitudinal section of the metanephros in 46L., showing the secondary diverticulation of the primitive pelvis. (X 120).

Fig. 3. A transverse section in $9L_2$., showing the genital tubercle, the genital fold, and the genital swelling. (X 80).

Fig. 4. The urogenital sinus and the genital hillock with the relation to the nephric duct. (X 150).

PLATE XII

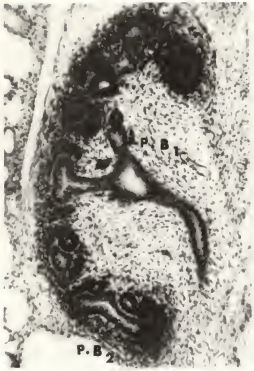


Fig.1.

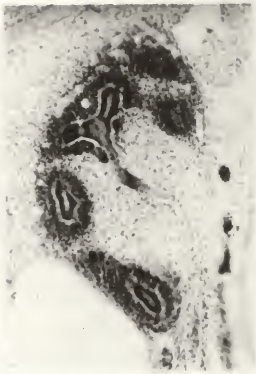


Fig.2.

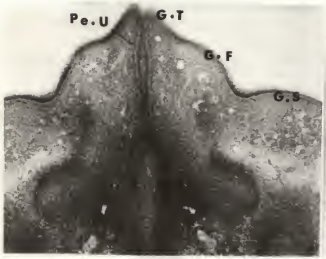


Fig.3.

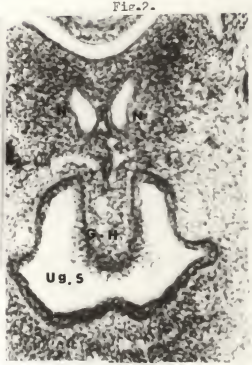


Fig.4.

EXPLANATION OF PLATE XIII

Fig. 1. A proper section in $9L_2$., showing the mesonephros, metanephros, and the testes with their relation to each other. (X 60).

Fig. 2. A part of the metanephros in $9L_2$., more magnified to show the collecting tubule and the secretory elements of the metanephron. Notice the two layers of the metanephric capsule (Bowman's capsule). (X 150).

Fig. 3. A part of the testes in $9L_2$., more magnified to show the testes cords, the genital epithelium, and the tunica albuginea. (X 750).

Fig. 4. The mesorchium in $9L_2$., magnified to show the rudiments of the rete testes. Notice the relation of the rete to the mesonephric capsules. (X 150).

PLATE XIII

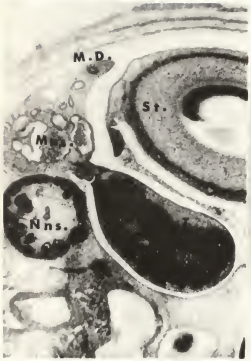


Fig.1.

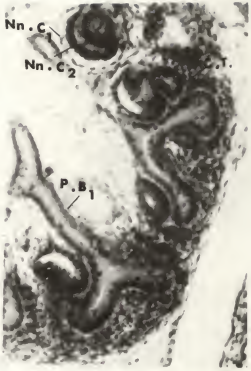


Fig.2.

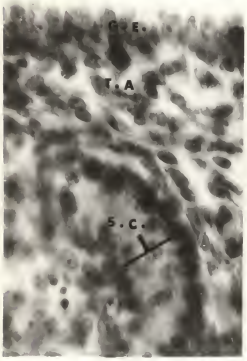


Fig.3.

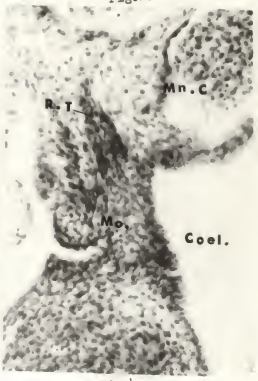


Fig.4.

EXPLANATION OF PLATE XIV

The mesonephron through its different stages, with its relation to the nephric duct and other concerned structures.

Fig. 1. The mesonephron in the mesonephromeric stage.

Fig. 2. The mesonephron in the coelonephric stage. Notice the arrangement of the cells around the nephrocoel.

Fig. 3. The coelonephromere with a dorsal concavity due to the invagination of the dorsal wall. Notice the dorso-lateral outgrowth toward the nephric duct.

Fig. 4. A joined coelonephromere, where the outgrowth reached the nephric duct and fused with it.

Fig. 5. The sigmoid form in its early stage of development. Note the initiated sigmoid flexure in the connecting portion and the transformation of the distal portion into the mesonephric capsule. See the inner thick proliferating delaminating layer and the thin outer layer.

Figs. 6 and 7. The sigmoid form in more advanced stage, where the sigmoid flexure became more pronounced. Notice the initiated glomerulus in the cup-shaped concavity of the mesonephric capsule.

Fig. 8. The tripartite form. Notice the three portions of this form, the tubulus secretorious, the tubulus intermedius, and the tubulus collectivus. See the location of the newly luminated nephric duct, the two ampullae of the tubulus intermedius (T. Ampullare) and the direction of the glomerulus.

Fig. 9. The early convoluted form. Notice the secondary sigmoid flexure contributed by the T. Intermedius and the T. Secretorius. See the new third ampulla in the T. Ampullare.

PLATE XIV

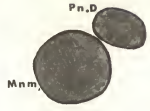


Fig.1

Fig.2.


Fig.3.

Fig.4.


Fig.5.

Fig.6.


Fig.7.

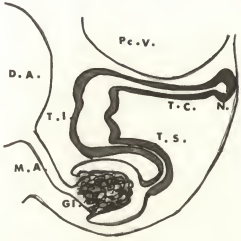


Fig.8.

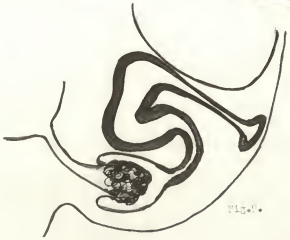


Fig.9.

DEVELOPMENT OF THE UROGENITAL SYSTEM OF THE DOG

by

MAJID AHMED AL-RADHAWY

LICENCE, Higher Teachers' Training College, Baghdad, Iraq, 1954

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Zoology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1958

The histogenesis of the urogenital system had been studied in few animals and most of the works which had been done were incomplete and covered limited stages. A study was attempted to give a complete story of the development of this system and especially the nephrogenesis in the dog.

Seven groups of canine embryos, representing progressive development stages, were obtained from wild coyotes and laboratory dogs. These specimens were fixed, embedded, sectioned and stained for study.

Nephrogenetically, the pronephros, the mesonephros and the metanephros developed from the nephrotome and succeeded each other in a chronological and spatial order. The pronephros was nonfunctional, and was represented by an anterior vestigial area which was succeeded by three complete tubular pronephrons (somite 9-11, inclusive). The pronephric duct was formed by the terminal fusion of the three tubular pronephrons. When the duct was initiated it started to grow caudad by free terminal growth until it reached and fused with the cloaca at the 28-29 somites stage. The mesonephros developed from the nephrotome through somite 11-29, inclusive. The mesonephrons connected to the pronephric duct secondarily and the duct became the mesonephric duct. The mesonephrons had large glomeruli, secretory and collecting elements, and all the morphological data indicated its functioning. The metanephros utilized the metanephrogenic cord through somite 29-31, inclusive. The pelvis, the ureter, the calyces and the collecting elements of the uriniferous tubules were differentiated from an evagination from the mesonephric duct, the metanephric diverticulum. The secretory elements were originated from the metanephrogenic cord.

The Mullerian duct originated from the coelomic epithelium as an invagination into the mesonephros at its ventro-lateral side.

The gonads were originated from the coelomic epithelium medial to the mesonephros and they passed through the genital ridge stage, the indifferent stage, and the determining stage in the latter of which the gonads were differentiated into the testes and the ovaries. At the genital ridge stage the gonads were composed of thickened epithelial cells, while at the indifferent stage they were composed of an outer germinal epithelial layer and an inner epithelial mass. At the determining stage the seminiferous tubules' anlage were developed as condensations in the inner epithelial mass, the rete testes as condensations in the mesorchium. The tunica albuginea was differentiated as connective tissue around the seminiferous cords and was continuous with the septuli. In the ovary, the Pfluggers' cords were developed as invaginations from the germinal epithelium and the rete ovarii as condensations in the mesorchium.