THE LYMPHATICS OF THE LOWER URINARY AND GENITAL TRACTS

THE LYMPHATICS of the LOWER URINARY and GENITAL TRACTS.

An Experimental Study with Special Reference to Renal Infections.

THESIS

by

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INTRODUCTION

A considerable amount of work has been carried out for many years by various investigators on the problem of the relationship of inflammatory lesions in the pelvic organs to coincident bacterial infections in the upper urinary tract. All the possible methods of spread have in turn been held responsible and even in the present day there is no unanimity of opinion. A physician may rightly speak in terms of blood spread, a gynecologist of lymphatic spread, a urologist of one or other or both.

The literature on infections of the kidney is very extensive and as Cabot & Crabtree (1) tersely remark is stupifying both in quantity and complexity. The confusion arises to a great extent in the inaccuracy of terminology. To cite one instance, to a few workers ascending renal infection implies ascension from the renal pelvis into the kidney substance and not the ascent from lower to upper urinary tract as it does to the majority.

The source of infection Necker (2), maintains is the most important consideration. If the source is primary in the urogenital tract it is then designated an urogenous infection; if outside this tract, it is known as endogenous.

The two main routes by which organisms reach the kidneys are a) by blood stream and b) upward through urinary passages, or in other words the descending and ascending routes. A number of years ago the ascending theory predominated and the older writers were unanimous that infections reached the kidney from below, then Albarran's and later Rovsing's work indicated the

blood stream. The consensus of opinion has now swung entirely round with few exceptions to the origin being haematogenous and the study of infections of the kidney is now chiefly, though not wholly, directed toward the question of how organisms gain access to kidney through the blood stream. This however is only part of the problem at issue.

David (3), quoting Senator states, "All that causes an inflammation of the lower part of the genito-urinary tract, before all, a cystitis, has an etiological bearing on pyelitis and pyelonephritis." This once more leads to debatable ground, as to the origin of the primary infection, the cause of its deposition and then its method of spread within the genito-urinary tract.

An infection in any organ in the bony pelvis may be coincident with or precede a renal infection. The difficult task is to explain the relationship as there undoubtedly must be.

The general agreement to-day is that cystitis at least is never primary and that infection comes from some other source either within or outside the genito-urinary system

The origin of bladder and kidney infections and the channels by which organisms reach the urinary tract gives rise to much speculation. The vagina and neighbouring structures have been suspected as the source of B. Coli in ascending infections as well as the bowel from whence the organisms reach the urinary tract by way of blood stream or by direct lymphatic connection between the bowel and kidney (4)

Infection through the blood stream can, naturally, take place from any focus in any part of the body.

There is no doubt that certain factors do favour localization of bacteria in both the pelvic organs and in the upper urinary tract. These may be congenital anomalies, acquired abnormalities, trauma, calculus, etc., together with general conditions e.g., pregnancy, constipation, etc.

Considerable of the experimental work performed on the problem loses value because of the lack of proper controls, which are essential to reasonable deductions. Considering the conflicting theories and experimental findings, the most appropriate approach is along the stepping stones of clinical research progress.

First the theory of direct upward spread by the lymphatics to the kidneys from the pelvic organs is discussed in full.

Preceding the personal investigations, a description of the anatomy of the lymphatics of the lower abdomen and pelvis is given along with the anatomy and physiology of the ureter, since this tube is the gross connecting link between upper and lower tracts.

LYMPHATIC INFECTIONS to KIDNEYS.

Introduction. For many years occasional observers have called attention to the possibility that bacteria might reach the kidney by way of the lymphatics. Though the theory of such an invasion has not received general support, a variety of publications has been produced showing careful anatomic and experimental studies. Some of these have tended to support the theoretical contentions others have rather disproved. Those in favour state that the lymphatics bear an important role in the transportation of infection from the pelvis upwards.

Till recent times the lumen of the ureter was considered the natural pathway for infection to spread from the bladder to the kidneys.

A spread by direct continuity along the mucous membrane of the ureter was next considered the more probable and several investigators have attempted to show a continuous network of lymphatics in the submucosa. This however has never been positively demonstrated but there is in the outer coat of the ureter a definite network of lymphatics, from which vessels drain medially to the lymph nodes in the midline.

Quinby maintained (5) that the lymphatic spread from bladder to kidney had never satisfactorily been proved and held that anatomically the very segmental character of the lymphatic system about the ureter, made direct transportation of bacteria from the bladder to the kidney improbable.

Ascending lymphatic infection according to Sweet & Stewart (6) took place by one of two methods.

1). By way of lymphatics around the prostate and bladder neck and thence to blood stream to kidney.

2). Direct lymphatic infection along lymphatics of ureter.

Historical Anatomy. The lymphatics of the urinary tract have received careful study from a number of competent investigators.

Mascagni (7), in 1797, demonstrated the lymphatics of the upper ureter draining into the lymphatic system in the region of the kidney pelvis and suggested the possibility of organisms reaching the kidney along those paths. He also showed that the lymphatics of the lower ureter drained into the lymph nodes in the bony pelvis.

Teichman (8), in 1861, and Krause (9), in 1876, both suggested the presence of lymphatics in the mucosa of the ureter. But Sappey, in 1874, stated the structures could only be demonstrated in the muscularis.

Gerota (10), in 1897, using Prussian Blue for injection made a careful study of the bladder lymphatics. He showed well-defined lymphatics of the muscularis which connected with those of the muscularis of the ureter and which drained into the hypogastric glands along the iliac artery.

Stahr (11), in 1900, demonstrated the anastomosis of the lymphatics of the ureter with those of the kidney pelvis and thence with the kidney substance. He also indicated the presence of deep and superficial lymphatics in the kidney parenchyma and that they connected with those in the fatty capsule. Both

of these drained into glands along the vena cava.

Sakata (12), in 1903, came to the following conclusions from his experience.

1). No network of lymph vessels was demonstrable in the mucosa and submucosa of the ureter.

2). In muscle sheath and on external surface of the ureter, there were well-developed lymph vessels, which for the most part lay parallel with the blood vessels.

3). The afferent lymph vessels were present chiefly in the central or middle portion of the ureter and went to the lumbar glands, which lay both beside and anterior to the aorta and vena cava and internal to the common iliac artery.

4). The lymph vessels of the lower section of the ureter went either directly into the hypogastric glands or else they united with the lymph vessels of the bladder.

5). In the upper section, the lymph vessels which went directly into glands were not constantly demonstrable, but where they were they went to the glands which lay far above, beside and over the ureter. Otherwise they passed into the lymph vessels of the kidney.

6). The lymphatic unions between the bladder and kidney were not direct, but existed either by the interposition of the regional glands of the bladder and kidney or by means of the lymph vessels of the ureter.

The vessels of the ureter communicated with the vessels of the kidney and bladder. There were two ways of indirect communication.

1). By way of hypogastric lymph glands (drainage from the kidney to the lumbar glands and from the bladder to hypogastric glands while the lumbar and hypogastric glands communicated.)

2). The lymph vessels of the ureter communicated at the upper and lower parts of the ureter with the vessels of the kidney and bladder.

The vessels of the lower ureter went to regional glands; the bladder lymphatics to regional glands; but these vessels might anastomose before reaching the hypogastric glands.

From the lower ureter the lymph vessels of the lower portion of the ureter could be filled. The single lymph vessels that ran lengthwise along the ureter united with the lymphatics of the kidney and the pelvis of the kidney.

The lymph vessels were so situated and connected that they offered a favourable means of transmitting infection from the bladder to the kidney, especially since they were capable not only of transmitting infection through the walls of the ureter, but also through the regional glands, which acted as connecting links between the lymphatics of the bladder, ureter and kidney.

To sum up this work a careful study of ureteral lymphatics was made but no demonstrable lymphatics in the mucosa or submucosa were seen. The anastomosis of the muscularis and peri-ureteral lymphatics with those of the bladder and kidney were demonstrated and also the drainage of the lower ureter into the hypogastric

glands and the middle and upper ureteral lymphatics to the lumbar glands. On occasion an anastomosis between the two sides could be injected. Sakata also showed that the chain of lymphatics between the ureter and bladder was not continuous but highly interrupted. Organisms therefore to reach the kidney would have to pass through several systems of lymph nodes, a contingency decreasing the probability of such a happening.

Bauereisen (13), in 1910, using fresh ureters of stillborn infants demonstrated lymphatics in the submucosa of the ureters by the use of silver nitrate and by Gerota's technique. He also indicated the anastomosis of lymphatics between the different coats of the ureter - the submucosal, the muscularis and peri-ureteral. The lymph flow appeared to be in addition, from mucous toward the fibrous coat of both bladder and ureter. The opinion was advanced that in spread of infection from bladder to kidney the choice of routes would be by way of the lymphatics of the ureter. In Bauereisen's own words: "The kidneys and bladder therefore stand in much closer relation to one another through the lymphatics of the ureter, than one has heretofore supposed. I think I may declare that the kidney can be reached from the bladder by pathogenic organisms more easily by way of the lymphatics than intra-ureterally." Also, "We are far removed from the view that every pyelitis and pyelo-nephritis is of lymphatic origin, but we do believe from the final demonstration that the mucosa, submucosa, muscularis and adventitia of the human ureter are provided with a great connected lymphatic network, that we have placed in the right light a previously hardly even mentioned path for the infection of the kidney, ureter and bladder." Certain

cases of disease of the urinary tract the author held could only be explained by the extension by way of the lymphatics and even the haematogenous path had to be excluded in its favour in some instances.

In his experimental work, Bauereisen (13) showed that in tuberculous cystitis the infection was carried first into the wall (the adventitia, muscularis, submucosa and mucosa) of the lower segment of the ureter and wandered gradually in the external layer toward the kidney. In other words infection of the ureter took place from without inwards.

The intimate relation between lymphatics of the internal genitalia in the female and those of the bladder and ureter was pointed out. A free anastomoses between the lymphatics of the broad ligament and those of the ureter was suggested, which accounted for the path of upward spread. From his work Bauereisen made the following deductions:

1(. There was an anastomosing network of lymphatics in the wall of the bladder and ureter communicating with a similar network in the renal pelvis and parenchyma, while at the lower end communicating with the lymphatics of the pelvic structures in both male and female.

2). Infection of bladder and lower ureter might reach the renal pelvis or kidney by the lumen or mural lymphatics.

3). Introduction of bacteria to the bladder might cause ascending interstitial lymph spread.

4). The degree of spread depended on the virulence of the organism and susceptibility of host.

5). If the kidney tissue was involved, the path of infection was from the subepithelial tissues of the pelvis to the kidney by way of inter-tubular and peri-vascular lymphatics.

6). From the kidney the peri-renal tissues might become involved through the capsular lymphatics which anastomosed with those of the cortex.

Kumita (14) demonstrated superficial and deep lymphatics in the adipose capsule. The superficial lymphatics formed a capillary network which drained into a lymph node lying above the renal vein of the corresponding side.

The deep lymphatics formed a similiar network and terminated on the right side in a node lying below the exit of the renal vein and to the left of the vena cava. On the left side they emptied into a node lying below the renal vein and to the left of the aorta.

These deep lymphatics communicated with the superficial lymphatics and those of the fibrous capsule. The external layer of the fibrous capsule had a capillary network of lymphatics communicating with the deep lymphatics of the adipose capsule and the lymphatics of the internal layer of the capsule. The latter had a capillary network of lymph vessels, which communicated with those of the external layer of the capsule and emptied into the lymphatics of the cortex of the kidney. In the human being a similar communication took place between the lymphatics of the adipose capsule and those of the kidney. Lymph spaces which communicated with the capsule of the kidney were found under the

capsule. The lymphatics passed from the cortex to Bowman's capsule formed a capillary network in the glomeruli and from there passed along the loops of Henle and the collecting tubules, surrounding them as they went. They made their exit at the hilum, going to the regional glands. The lymphatics of the ovary emptied directly into the lymph nodes at the kidney. Kumita substantiated Bauereisen's findings that the lymphatics of the bladder, posturethra and lower ureter passed to the hypogastric nodes, of the mid-ureter to the lumbar nodes and those of the kidney hilus, upper ureter and fatty capsule drained into the aortic nodes above and below the renal vessels.

This work was also confirmed by Muller (15).

Sugimura (16), in 1911, from a study of 21 autopsies concluded:-

1). The ureters especially the lower third were almost constantly involved in acute cystitis by way of the ureteral lymphatics.

2). Only traces of inflammation were present in the ureteral mucosa and no ascent of infection on the mucosa from the ureteral openings could be seen.

3). Many areas of infiltration in the lower segment of the ureter could be picked out in lymph tracts of the muscularis and adventitia and also of the submucosa. These were most marked in the intramural portion of the ureter and were continuous with the affected lymphatics of the corresponding bladder layers.

The conclusion from these findings was that infection ascended through the ureteral lymphatics. Further -

4). The ascent of acute inflammation of the bladder through the lymphatics of the ureter toward the kidneys seemed to differ according to the kind and virulence of the organism producing the inflammation, duration of disease and the anatomical change of the bladder wall. Ascent went about parallel to the anatomical change of the inflamed bladder wall.

5). In chronic non-specific inflammation of the bladder, with or without retention of urine and also in so-called simple descending infection of the upper urinary tract, the involvement of the lymphatics of the ureters could be clearly demonstrated. Although the mucosa of the ureter seemed more extensively involved in the acute descending infections the suspicion nevertheless lay close at hand that the lymph tracts of the ureter played an important role in the extension of acute inflammation of the bladder and kidneys.

6). The inflammation could further, with intact ureter, spring from the bladder to the kidney pelvis intra-ureterally as had been described before.

In 1910, Stewart (17) reported following his experiments that "Ascending infections of the kidney quite often take place

through either the lymph or blood vessels of the ureter. When infection takes place in this way, it seems almost positive that the lymph vessels of the ureter are the carriers of the infection. The lumen of the ureter is less often a factor in ascending infection of the kidney than has previously been supposed."

Sweet & Stewart (6), in 1914, following a series of experiments on transplantations of the ureters into the intestinal tract and the substitution of rubber tubing for a segment of the ureter, studied the cases as to the routes of ascending infection. They suggested that once infection was established in the genito-urinary tract, it spread entirely by the lymphatics.

From anatomical, pathological and experimental evidence they concluded that:

1). The network of ureteral lymphatics anastomosed freely with the lymphatics of the bladder inferiorly and those of the kidney superiorly.

2). That an ascending infection travelled up the peri-ureteral lymphatics and not up the ureteral blood vessels nor through the ureteral lumen. In support of this -

a) - the lumen could be excluded because the veins of the bladder and the veins of the ureter, for the greater part opened into the general venous system, not into the venous system of the kidney.

b) - the lumen of the ureter could be excluded because if the lumen was open to

infection, the infectious process was traceable in the lymphatic system, not along the mucosa of the ureter. If the lumen was closed to infection, the process extended to the kidney in the usual way: if the lumen was open to infection, as when the ureter was passed through the pancreatic duct, there was no ascending infection; if the lumen was open, but the continuity of the lymphatics was interrupted, infection did not ascend; and finally if the kidney pelvis was directly connected with the gut, the general infection characteristics of an ascending infection of the kidney did not occur.

Eisendrath & Kahn (18) were one of the first to stress the important role of the lymphatics in the peri-ureteral sheath in ascending renal infections. They concluded as did Sampson & Bauereisen before, that infection could travel to the kidney from the female genitalia and other abdominal viscera which lay in close relation to the ureter. They tried to simulate conditions as they occurred in life by injecting cultures of organisms into the urinary bladder of animals without injuring either the bladder or ureter. Along with Eisendrath & Schultz (19), in 1915, 1916 & 1917, they carried out a number of experiments and described, following bladder injections, a round cell infiltration of the

submucosa of the bladder extending into the ureter, where it was present in the submucosa or peri-ureteral lymphatics, involving the subpelvic tissue and kidney.

Summarizing their findings inflammatory infiltrations seemed to follow in a most accurate manner the course of the lymphatics, as determined by Kumita & Bauereisen.

In the early stages of infection the infiltration was found in the submucous layer of the bladder and was especially dense around the smaller vessels in this layer. The infiltration could then be followed up into the ureter. It was most marked in the submucous coat in the lowermost portion of the ureter. The peri-ureteral sheath played the chief part in transmitting the infection upward. By the experiments the authors were convinced that the lymph current was inan upward direction. The connecting link between the lymphatics of the ureter and those within the kidney was thought to be along the lymphatics of the subpelvic areolar tissue which surrounded the blood vessels as they entered the kidney tissue.

Hess (20) confirmed these findings.

Helmholz & Beeler (21), in 1918, injected cultures of a virulent organism found in a rabbit kidney into the bladder of a series of rabbits. They concluded from the results that in some instances the infection ascended by way of the ureteral lymphatics and in others through the lumen of the ureters. In 1922, Helmholz produced additional evidence to show that changes produced by intravenous injections tended to localize in the parenchyma, papillae, and adjacent lining of the pelvis, while those produced by intra-vesical injection, or ascending infections,

tended to localize in the peri-pelvic tissue about the vessels which entered the kidney.

In addition to direct upward spread along the course of the ureter, there was the possibility of invasion of the kidney from the adjacent lymph glands which had become infected. These could be seen as calcified areas in roentgenograms in some cases. There was frequently a history of chronic pelvic inflammation. Working from this fact Winsbury White (22) injected pigment into the cervix of female guinea pigs and followed it in lymph channels to the base of the broad ligament then to the glands in the hollow of the sacrum, the common iliac glands, then up to the glands at the level of the renal hila. Pigment was actually seen in the areolar tissue of the hilum of the kidney.

Microscopical examination of the ureters at successive levels failed to show any indication of an ascent in the walls themselves but, in the surrounding areolar tissue or peri-ureteral tissue, the main lymphatic pathway lay,.

K.M. Walker (23) inoculated the urethra of animals with carmine granules and finely powdered ferrous carbonate. The results were such as to favour the idea that the particles travelled to the upper extremity of the ureter by way of the surrounding plexus of lymphatics. A disposition of granules was discovered in the kidneys of the capsule. They then travelled along the planes of connective tissue which ran into the parenchyma of the kidney from the capsule. Organisms were also used and these travelled up the peri-ureteral lymphatics to the renal capsule.

Carson (24), in 1925 and 1927, demonstrated cancer cells in the peri-vascular lymphatics of the ureter secondary to primary

carcinoma of the bladder, prostate and cervix uteri and in the peri-vascular lymphatics of the renal pelvis from primary carcinoma of the prostate. In his experimental work infection was produced at the lower end of the ureter and was demonstrated to pass upward through the peri-ureteral lymphatics to the kidneys.

The lymph current of both the bladder and the ureter was shown to be from the mucous toward the fibrous coat. The peri-ureteral lymphatics communicated with each other in a transverse as well as a longitudinal direction by means of vertical and oblique branches. The lymphatics of the upper portion of the ureter communicated with the lymphatics of the kidney which accompanied the blood vessels forming a capillary network in the cortex, surrounding all the tubules like the blood capillaries; the lymphatics of the cortex communicated with those of the capsule.

Muller (15) wrote on the method of spread of infection within the kidney and attempted to show that in autopsy specimens it passed along the lymphatic channels from the renal pelvis upwards. From the boundary zone between the medulla and cortex, it passed upward towards the cortex along with the inter-tubular vessels and their branches and it followed the lymphatics, the finest divisions of which accompanied the blood vessels into all parts of the kidney.

The work already quoted would tend to indicate that both motile and non-motile organisms were easily transported from the bladder to the kidneys by the lymphatic vessels in the peri-ureteral sheath. This ascent does not appear to be dependent on obstruction in the lower urinary tract and occurs even with an intact uretero-vesical orifice. From the lymphatics of the

ureter the infection would seem to pass to the lymphatic vessels of the renal pelvis then by continuity, to the network of intra-renal lymphatics and even to the peri-nephric tissue through the communicating of lymphatics of the cortex with those of the true and fatty capsule of the kidney.

All workers do not agree with the previous findings. David & Matill (25) discussing the subject of ureteral lymphatics as a pathway for infection within the urinary tract stated that without doubt there was a rather rich lymphatic system in the submucosa and muscularis of the bladder and ureter as well as in the peri-ureteral fat, in the kidney pelvis, in the parenchyma of the kidney and its fatty capsule. The lymphatics of the bladder, ureter and kidney had distinct communicating branches, but it was equally important to emphasize the fact that the drainage of the bladder, ureter and kidney was segmental into the lumbar and hypogastric nodes and into the nodes along the renal vessels. The ready flow of lymph was not from the bladder through the ureter to the kidney or vice versa. They also demonstrated that the occurrence of a cellular exudate in the lymphatics of the ureter and pelvis of the kidney did not necessarily indicate an infection of the urinary stream.

Writing on the question of the ureteral lymphatics as a route for extra urinary infections, the same authors stated that it was theoretically possible in cases of pyosalpinx, pelvic peritonitis, acute appendicitis or appendiceal abscess that an inflammatory exudate coming in contact with a ureter might involve the peri-ureteral lymphatics of the ureter and eventually spread along them

and involve the pelvis of the kidney and kidney itself. This view has been strongly urged by certain authors to explain the frequency of pyelitis in girl babies whose vaginal secretions had been found to contain B. Coli soon after birth.

Summing up their experimental work the authors concluded that:-

1) Neither round nor polymorph cellular infiltration of the ureteral or subpelvic kidney lymphatics was synonymous with urinary tract infection.
2) The lymphatics of bladder and ureter played an unimportant role in the conduction of acute infections from the bladder to the kidney.
3) Infectious material brought into intimate contact with the peri-ureteral lymphatics did not affect them to any considerable extent and infection of the urinary stream did not result.
4) An involvement of the peri-ureteral lymphatics might occur when the cut end of a divided ureter, which had been ligated, came in contact with infectious material, but it was improbable that infection of the kidney pelvis by this route occurred.

Cabot & Crabtree (1) also failed to follow the investigators who held to have demonstrated ascension of bacteria by lymphatics from bladder to kidney with production of renal infection and offered a fair and honest criticism built on a framework of anatomical observations. It was generally believed and upon sufficient evidence that the lymphatic currents throughout the body, followed the flow of blood in the blood vessels. Unless one was prepared to disregard this doctrine, difficulty arose in tracing lymphatic processes over areas which were totally

lacking in continuous vascular channels. There were no blood vessels running an uninterrupted course from the bladder to the kidney. The blood supply of the ureter was distinctly segmental, and the only vessels which ran in this general direction were the spermatic vessels in the male and the ovarian vessels in the female. Furthermore, assuming the probable fact that organisms reached the lymphatics about the bladder and over the lower segment of the ureter, the probability of their reaching the blood stream rather than continuing in devious lymphatic channels seemed to the authors overwhelming. That organisms passed from the bladder into the peri-vesical lymphatics, reached the blood stream and ultimately the kidney, the authors not only believed but were prepared to show. Reasoning from lesions produced elsewhere in body by lymphatic infections progress by this method was comparatively slow and on account of the interrupting lymph nodes was more likely to produce highly localised lesions than lesions spreading rapidly over long distances and flooding a distant area with organisms.

Arbeiter has shown that when organisms left the intestine by the lymphatics they rapidly appeared in the blood and this tendency was amply confirmed.

Graves & Davidoff (26) discussing extension of infection upward along the ureteral wall through the lymph vessels stated that there was little evidence of anatomical grounds for such an occurrence, the lymphatics of the ureter being arranged segmentally instead of continuously from bladder to kidney; but even if anastomosis between the segments, permitted a continuous lymph stream, the considerable amount of experimental work done on

the subject had failed to prove satisfactorily, that infection ascended along this channel.

The most frequent path of renal infection is probably through the blood stream, but the lymphatics cannot be dismissed without consideration. From the important role that lymphatics play in infection in other parts of the body, it would seem reasonable that they must take on occasion an active part in transportation of urinary infection.

The object of this paper is to study the path of this transportation by the lymphatics and the position of the kidneys in relation to this path. Before any personal work the ureter must be considered in detail as it is the natural connection between upper and lower tracts though presumably all the processes concerned with its functions occur from above downwards or towards the mid-line. Then the lymphatics of the lower abdomen and pelvis will be described.

ANATOMY & PHYSIOLOGY OF THE URETER

Microscopically the ureter has 3 distinct layers.

a) An outer coat or adventitia consisting of connective tissue with some elastic fibres, vessels and nerves, a variable amount of fat, and a fibrous capsule which is continuous with the fibrous coat of the bladder.

b) A middle layer or tunica muscularis. This coat consists of three more or less distinct layers, the middle is circular, the inner longitudinal and less well-defined, the external layer even more poorly developed, and also longitudinal. The layers become more distinct near the bladder. The ureteral sheath of Waldeyer is a layer of longitudinal muscle bundles situated in the adventitia of the distal few centimeters near the bladder. This sheath is divided from the rest of the muscle by connective tissue which also serves to join it from underlying structures.

c) The mucosa of the ureter presents a stratified epithelium. Capillaries and connective tissue strands enter the epithelium from the submucosa raising it into papillae like the corium of the skin. The submucosa is formed of elastic fibres and connective tissue and blends with the inner longitudinal muscle bundles. It is absent in the distal ureter where the muscle layer reaches the epithelium itself.

The ureteral blood supply is from the renal, spermatic or ovarian, internal iliac and inferior vesical arteries. The first two supply the pelvis and the abdominal portion and the second two the pelvic portion. These vessels reaching the ureter at different levels send out branches along its wall. Smaller arterioles penetrate the substance of the organ at right angles to the surface, again to split into longitudinal branches in the propria. Out of this arises a capillary network. Sampson demonstrated that the blood supply may also come from the aorta and uterine arteries. The veins begin in the propria and carry their blood to larger vessels at the inner boundary of the muscularis. These form the venous plexus of the mucosa which is longitudinal but enmeshed by right angled and oblique communicating branches. It drains in turn into a larger plexus visible grossly in the adventitia.

The ureter receives its nerve supply from three sources - the renal, the spermatic and the hypogastric plexuses. The renal plexus supplies the pelvis and upper half of the abdominal portion; the spermatic supplies the lower half of the abdominal portion; and the hypogastric plexus, the pelvic segment. Both myelinated and non-myelinated fibres enter with the blood vessels to form a ground plexus in the adventitia.

Disse (27) describing the uretero-vesical junction stated that the ureter remained a separate structure with only its mucosa blending with the bladder at the level of the orifice. Since it met and passed through the vesical wall obliquely, the ureter ended as though out off obliquely with a shorter anterior and a longer

posterior wall. The upper wall formed a fold, embracing the orifice and called the ureteral valve. The intra-mural portion of the ureter had muscle bundles beginning at and even penetrating the propria.

Lymphatic Vessels of Abdomen and Pelvis, (28). The lymphatic vessels of the abdomen and pelvis might be divided into.

1) Parietal & 2) Visceral

1. The Parietal lymphatic vessels consisted of two sets, superficial and deep.

   The superficial lymphatic vessels followed the course of the superficial blood vessels, and converged to the axillary and the superficial inguinal lymph glands.

   The deep lymphatic vessels ran alongside the principal blood vessels.

2. The Visceral lymphatic vessels consisted of -
   a) those of subdiaphragmatic portion of the digestive tube and its associated glands, the liver and pancreas.
   b) those of spleen and suprarenal glands.
   c) Those of the urinary organs.
   d) those of the reproductive organs.

LYMPHATIC VESSELS OF GENITAL TRACT.

Poirier stated that all lymphatics of the vagina emptied into the pelvic glands and that when an injection of the vaginal lymphatics was made, even just within the hymen, no injection

material passed to the inguinal glands except through some anastomosing channels. The lymphatics of the middle third of the vagina emptied into the hypogastric glands, those from the upper third joined with the lymphatics of the cervix uteri and passed to the iliac glands.

The lymphatics of all the coats of the uterus (29) emptied into large lymphatic vessels in the external muscular stratum and those in turn emptied into efferent trunks at the sides of the uterus. The lymphatics of the uterus might be divided into two groups, the lymphatics of the cervix and the lymphatics of the body of the uterus. The lymphatics of the cervix uteri joined with those of the upper part of the vagina and emptied into the sacral and hypogastric and superior iliac glands. The lymphatics from the corpus uteri joined with those of the tube and ovary and emptied into the lumbar glands. A few lymphatics from the uterine cornua passed along the round ligaments and emptied into the inguinal glands.

Winsbury White (22) demonstrated the upward lymphatics from the uterine cervix. Clinically there was proof that they were lying first of all on the floor of the pelvis in the base of the broad ligament, next on the posterior wall of the true pelvis to be continued upwards on the posterior abdominal wall by way of the main lymphatic trunks lying in the vicinity of the midline. The further upward route was often indicated by radiographic evidence which showed phleboliths on the pelvic floor and calcified glands in the hollow of the sacrum or along the posterior abdominal wall up to the level of the renal hila.

The lymph vessels of the ovary ascended with the ovarian artery to the lateral and pre-aortic lymph glands.

The lymphatic vessels of the prostate terminated chiefly in the hypogastric and sacral lymph glands, but one trunk from the posterior surface ended in the external iliac lymph glands, and another from the anterior surface joined the vessels which drained the membranous part of the urethra.

Those of the seminal vesicles went partly to the hypogastric and partly to the external iliac lymph glands.

The lymphatic vessels of the testes consisted of two sets, superficial and deep, the former commencing on the surface of the tunica vaginalis, the latter in the epididiymis and body of the testes. They formed from four to eight collecting trunks which ascended with the testicular veins in the spermatic cord and along the front of the psoas major, to end in the lateral and pre-aortic groups of lumbar lymph glands (30).

LYMPHATIC VESSELS OF THE URINARY ORGANS.

The lymphatic vessels of the kidney formed three plexuses -

a) in substance of the kidney

b) beneath its fibrous capsule

& c) in the peri-nephric fat. b & c communicated freely with each other.

The vessels from the plexus in the substance of the kidney converged to form four or five trunks which issued at the hilum. Here they were joined by vessels from the plexus under the capsule, and following the course of the renal vein, ended in the

lateral aortic lymphs glands. The peri-nephric plexus was drained directly into the upper lateral aortic lymph glands.

In addition Poirier & Cuneo (31) stated that the parenchymal lymphatics of the kidney emerged at the hilum and followed the blood vessels, usually the vein, in 4-8 trunks. These finally terminated in the juxta aortic lymph nodes.

The Lymphatics of the Ureter are incompletely studied. According to Sakata (12) the lymph capillaries in the propria drained into a larger network lying close to the muscle layer. Efferent vessels pierced the muscle and continued in the adventitia. Sakata by injection showed these efferent vessels to be divided into deep and superficial groups. Each group from approximately each third of the ureter drained into corresponding lymph nodes along the iliac vessels, the aorta, and the vena cava. There was no direct lymph channel between the bladder and kidneys, and lymphatic communication if it existed must be either through anastomoses between the lymph capillaries in the different levels of the ureter or through anastomoses between the lymph nodes draining these areas.

There seemed to be abundant communication between the lymphatics of the pelvic organs and the ureters. Despite this fact, clinically, metastatic growths of the ureter from tumours of the uterus, bladder or prostate were very uncommon findings. On the other hand metastases from growths of these pelvic organs were frequently met with in lungs, liver, kidneys, bones, etc. (32)

Robinson claimed (33) that the lymph drainage of the lower portion of the ureter was downwards. That might help to explain the rarity of ureteral metastases.

Kirschbaum (34) also remarked upon the infrequency of metastases to the ureters from the surrounding organs and suggested similar explanations.

Lymphatics of the Bladder (35). It was now generally agreed that there were no lymph vessels within the mucosa of the bladder. There were however definite lymphatics in the submucosa. These were in intimate relationship with a very rich plexus in the muscularis. The muscle bundles were closely enmeshed in the vessels of this plexus. The many efferent channels from the muscularis and submucosa drained into a larger network of lymphatics in the cellular peri-vesical or sub-peritoneal tissue of the bladder wall. This peri-vesical plexus was in relation inferiorly with the lymph vessels of the ureters, vesicles, vasa and prostate (uterus and vagina.) Its anterior channels descended on the anterior surface of the bladder to glands which lay in the areolar tissue back of the symphysis. These were small and few in number but they might be points of origin of peri-vesical infections. They drained into nodes which were placed on each side, along the external iliac vein, a little above the crural ring. The lateral trunks of the peri-vesical plexus led obliquely downward and backward to glands which were found along the lateral umbilical arteries or lateral umbilical ligaments. The efferent channels from these glands went to glands of the external iliac and hypogastric groups. The posterior lymphatics drained the base of the bladder and its posterior surface. They might be divided into two groups, one of which led outward and upward to the hypogastric nodes. The remaining posterior vessels passed backward along the sides of the rectum to the anterior surface

of the sacrum, where they ascended to end in glands at the bifurcation of the abdominal aorta.

Lymphatic Vessels of the Urethra. The lymphatics of the cavernous portion of the urethra accompanied those of the glans penis and ended with them in the superficial and deep sub-inguinal and external iliac lymph glands. Those of the membranous and prostate portions and those of the whole urethra in the female, passed to the hypogastric lymph glands.

PERSONAL WORK.

In this study the role of the lymphatics in renal infections was the problem. Even after discussing the literature there seems little unanimity of opinion.

Having completed a long but necessary picture of the problem as it stands, the questions remain: To what extent are renal infections due to lymphatic ascent, and do the lymphatics form a direct connection between the bladder and the kidneys?

In the first place, the mass of evidence which tends to show that the peri-ureteral lymphatic ascent will account for a considerable number of the cases of upper urinary tract infections, is a striking feature. The explanation seems almost too simple.

From a developmental point of view it is contrary to what one would expect. The ureteric bud appears in embryos of about 5 mms., and grows first dorsad and then cephalad. By six weeks the pelvis has advanced opposite the second lumbar segment in the retroperitoneal tissue. The drainage would therefore be expected to take place either medially or downwards. There may be an apparent anatomic communicating network, but a physiologic continuity is improbable.

The original plan in experimental work was an attempt to obtain absorption from the bladder and to follow the route of absorption. Thence the study would be taken to other areas and the results compared, especially in relation to the presence or absence of spread toward the kidneys.

Rabbits were used throughout and the anesthetic employed was either intramuscular urethane or intravenous nembutal.

Owing to the difficulty of controlling bacterial experiments in animals and forming reasonable deductions, foreign particles were used for injections. These could be followed microscopically and macroscopically and an analogy could therefore be drawn between their behavior and those of bacteria. A colloidal solution of carbon or India ink was requisitioned and filtered through hard filter paper before use.

As the study was to be one mainly of absorption, a series of dissections of normal tissue was made to find out accurately the disposition of the lymphatics of the pelvis and posterior abdominal wall in rabbits. The dissections were carried out in a regular method which will be described in detail.

TECHNIQUE.

The rabbit was first killed with chloroform. The abdomen was opened and the intestines and associated digestive glands removed after ligating their vessels. A cannula was next inserted into the abdominal aorta and the animal perfused with normal saline until the fluid returning from the inferior vena cava was clear. The next step was the removal of the peritoneum and fascia off the muscles on the posterior abdominal wall, along with the kidneys, ureters, aorta and vena cava. The dissection commenced just below the diaphragm and was continued to the brim of the bony pelvis. Then the whole of the pelvic contents was shelled out <u>en masse</u>. The thin sheet of tissue plus pelvic organs was stretched out on a cork mat with pins and placed in formalin for twenty-four hours. The careful stretching out is a very essential step, since with the shrinkage of the tissues in formalin, the

ureters, especially the right, become approximated to the lymphatic chains around the aorta. Particles in these chains may therefore appear to be in the peri-ureteral plexus unless careful technic is observed. (Note also that this shrinkage takes place even if the tissue is fixed in situ on the muscles.)

The pelvic organs were then dissected. First the bladder was bisected, and each half retracted laterally to expose either the uterus and tubes or the ampullae of the vasa and the seminal vesicles. These were carefully dissected free and removed. The peritoneum and pelvic fascia were incised around the rectum and the rectum enucleated. The thin pelvic peritoneum and fascia were left as a thin sheet with the two halves of the bladder drawn laterally. At the same time the kidneys were enucleated from their capsule and removed.

The specimen was returned to formalin for a further twenty-four hours. The tissue was then removed and fixed to a large glass slide, and dehydration in 94 per cent alcohol commenced. After twenty-four hours it was put in absolute alcohol for forty-eight hours, and then in chloroform to clear.

At a variable period depending upon the amount of fat to be dissolved the sheet of tissue was removed and placed under the binocular dissecting microscope and the peritoneum carefully stripped off along with any foreign material such as muscle tags.

The lymphatic vessels and glands were dissected free, commencing at the bifurcation of the aorta and working upwards and downwards. The specimen was then either mounted on a slide with a large cover-glass for future microscopic purposes or placed

in a narrow specimen jar for future macroscopic study. See illustrations.

After carrying out a series of normal dissections, names were given to the various groups of glands. These were most conveniently classed in relation to their adjacent blood vessels. A dissection of the pelvic blood vessels was made in a rabbit. The abdominal aorta divides into the two common iliacs and these in turn into the external and internal iliacs. The internal iliac gives off a superior vesical branch, then an inferior vesical branch and continues on as the obturator artery. In the angle between the two common iliacs running caudally in the middle line is the middle sacral artery. See illustration.

The lymph glands have been classed as follows:

The sacral glands lie usually, but not constantly, in the hollow of the sacrum behind the upper part of the rectum, one on either side of the middle sacral artery. These are not constant.

The inferior vesical glands are situated between the inferior vesical artery and the obturator artery. These are not constant. One may be present.

The superior vesical glands lie in the angle between the superior vesical artery and the continuation of the internal iliac artery. These also are not constant. One may be present only.

Mention might here be made that a false impression is likely to be taken from the position of those glands in the finished specimens as the structures are enclosed in the conical bony pelvis in their normal surroundings and now have been forcibly stretched on a flat surface. Relations to organs have been disturbed, but not to the blood vessels from which they have been named.

The internal iliac lymph glands usually comprise two groups, one above and one below the bifurcation. They may, however, be fused into one mass lying either anterior or posterior to the arteries. Occasionally one group lies on a distinctly more superficial plane than the other. From the region of the bifurcation of the aorta two lymphatic chains pass up to the renal glands. The left chain is usually the more distinct as the right often lies in front of the artery. The chains may communicate and may even fuse. They are usually interrupted by a variable number of small lumbar glands.

The renal glands usually have the form of an isosceles triangle with the apex downwards and lie in the inferior angle between the renal vein and the vena cava. The right lies cephalad to the left. It may be situated ventral or dorsal to the vena cava. If the latter, it lies at a much deeper plane than the left. See illustration.

The glands at times, even in ordinary dissections, have a darker color, especially the renal. This is due to the presence of small brown granules and can easily be distinguished from the jet black of India ink particles. Further, any blood left in the vessels after inadequate perfusion turns dark and is likely to be confused with dye, hence the necessity for careful perfusion.

PERSONAL WORK.

Experiment I.

Animals used - Rabbits.

Anaesthetic - None.

Problem - The presence or absence of lymphatic absorption from the healthy bladder mucous membrane.

Dye used - India ink.

Technique - A small glass catheter was passed into the normal bladder through the urethra.
This is difficult to do in both male and female rabbits owing to certain anatomical factors. In the male the tip of the catheter must be kept in close contact with the roof of the urethra, otherwise the catheter passes into the large seminal vesicles rather than take the more acute turn into the bladder.

In the female the external urinary meatus is found in the folds of the anterior vaginal wall which must be put on the stretch.

In this experiment no trauma was caused to the bladder mucosa and half an ounce of India ink was injected through the catheter into the bladder. The animals were left for one week then killed and immediately perfused. The sheet of tissue was removed from the posterior abdominal wall in the manner already described. Careful examination and dis-

section under the binocular microscope revealed no trace of dye either in the lymphatics or bladder wall: sections of the kidneys, ureters and bladder were negative for the presence of dye. See illustration.

Experiment 2.

Animals used - Rabbits.

Anaesthetic - None.

Problem - The presence or absence of lymphatic absorption from the traumatized bladder mucous membrane.

Dye Used - India ink.

Nature of Trauma -Physical, thermal, chemical and bacterial.

Technique - Half an ounce of india ink was passed to the bladder in the same way as in the first experiment through a glass catheter after the vesical mucosa had been traumatized by one of various means.

In some cases a small bead was passed into the bladder; in others the bladder was scalded with water; in others the bladder was treated with lysol for ten seconds; and in others the dye was mixed with streptococcal toxin.

The bladder wall proved quite resistant to infection and seemed capable of providing stout reactionary barriers to prevent bacterial invasion and toxic absorption.

In most cases small amounts of dye could be traced in the bladder wall.

Where an acute ulcerative cystitis had resulted, dye was found in the lumbar chains even within twenty-four hours. See illustration.

Experiment 3.

Animals used - Rabbits.

Anaesthetic - Intravenous Nembutal.

Problem - Route of absorption from various areas of the bladder wall.

Dye Used - India ink.

Technique - The animal was shaved over the lower abdomen and a mid-line supra pubic incision was made and the muscles separated. In most cases the peritoneum was opened to allow of easy access to the bladder.

Three areas of the bladder were chosen for investigation. (See illustration).

1) Trigone.
2) Around both ureteral openings.
3) Around the bladder neck, both on the vesical side and on the urethral aspect.

At those sites in different animals a small quantity of India ink 0.1 c.c. to 0.2 c.c. was injected through a fine needle as accurately as possible into the submucous coat of the bladder. To do this, after exposing the bladder, the organ is pulled forward by a dissecting forcep at the vertex. This brings forward the lower ends of the ureters and also the posterior aspect of the trigone. Also by pulling the bladder cephalad, the bladder neck is brought into view.

After injection of the dye the wound is closed in layers.

In an attempt to hasten absorption different procedures were employed.

In some cases, as in Experiment 2, a bead was introduced into the bladder to produce as much activity and motility in the tissues as possible, while in other cases the dye was mixed with streptococcal toxin. In neither instance, however, was there any appreciable increase in the absorptive rate, so the dye was used alone in most of the series.

The animals were left for periods varying from seven to ten days.

The animals were then killed and perfused with saline and the specimens prepared in the method previously described.

The striking feature was that the appearance of the ureter suggested that no dye passed up either the lymphatics of the ureter or the periureteral network, no matter the site of the original injection. Whether the dye was placed around the intramural portion of the ureter or at the bladder neck was of no significance.

The findings were arrived at only after careful examination under the binocular microscope.

Microscopic sections of the kidney parenchyma, kidney pelvis and ureteral walls, were negative for dye.

The glands varied in the extent of their involvement, but the path of absorption was invariably to the internal iliac group at the bifurcation of the aorta, thence along the aortic chain through the lumbar glands up to the renal glands. See illustrations.

Summary of Experiment 3.

(a) Dye injected into trigone of bladder. Dye passed to the common iliac group of lymphatic glands, thence upwards along the abdominal lymphatic chains.

(b) Dye injected into the bladder wall around the ureteral openings. Dye passed apparently upwards around the loose tissue surrounding the first two millimeters of the ureter, then by the peri-cascular lymphatics swung into the glands at the bifurcation of the aorta, and thence up the abdominal lymphatic chain to the renal lymphatic glands in the angle between the vena cava and renal veins.

(c) Dye injected into the bladder wall around the bladder neck and posterior urethra. Dye passed to the common iliac group of lymphatic glands, thence upwards in the same manner as the previous two groups.

One specimen (rabbit No. 9) demonstrated very clearly two of the methods by which dye passed from the bladder. The dye had been injected into the bladder wall around the ureteral openings. On the right side, the ureteral wall was perfectly clear and the dye had passed along the perivascular lymphatics of the inferior vesical artery. On the left side the dye had apparently passed into the peri-ureteral network for one millimetre, thence almost immediately collected into two bundles, one passing medially anterior and the other medially posterior to the ureter to get to the common iliac lymph nodes. See illustration.

Experiment 4.

Animals used - Rabbits.

Anaesthetic. - Intravenous Nembutal.

Problem - To trace the path of lymphatic absorption from the cervix uteri of the rabbit.

Dye used - India ink.

Technique - Several attempts were first made to inject the dye into the cervix from the vaginal aspect. This proved most difficult to carry out accurately, both from the point of view of site and quantity injected.
Subsequently a mid-line supra pubic approach similar to that in experiment 3 was employed. The bladder was pulled forward and then also the body of the uterus.
By means of a fine needle 0.25 c.c. of India ink was then injected into the cervix of the uterus and the wound closed.
After ten days the animals were killed and perfused with saline and the tissue from the posterior abdominal wall prepared in the manner previously described. The result after careful examination both macroscopically and microscopically was as in the previous experiments, a drainage of the dye towards the common iliac group of glands and thence upwards along the aortic lymphatic chain. Sections of kidneys and ureters were negative for the presence of dye. See illustration.

Experiment 5.

Animals used - Rabbits.

Anaesthetic - Intravenous Nembutal.

Problem - To trace the path of lymphatic absorption from different levels of the ureter.

Dye used - India ink.

Technique - In the first series the lower thirds of the ureters were injected.
The route was always transperitoneal, to interfere with the lymphatics of the posterior abdominal wall as little as possible.
The lower thirds of the ureters were exposed as described in experiment 3, and 0.05 c.c. of India ink injected into the walls.
The animals were left for fourteen days then killed and perfused with saline and the specimens prepared in the usual manner.
The result was rather striking.
The movement of the dye was toward the mid-line and there was no apparent attempt to follow the course of the ureter. The lumbar portion of the abdominal chain contained dye.
Section of kidneys and ureters above the point of injection were negative for the presence of dye.

In the second series the middle thirds of the ureter were exposed transperitoneally through a mid-line lower abdominal incision and 0.05 c.c. of India ink injected into their walls.

The animals were left for fourteen days, then killed and perfused with saline and the specimens prepared in the manner previously described.

Examination macroscopically and microscopically showed that the dye had passed to the lumbar lymphatic chain, apparently by the perivascular lymphatics. Sections of kidneys and ureters were negative for the presence of dye. See illustrations.

Although not part of one's present personal investigation, the work of Dr. D.M. Morison, (36) Edinburgh with whom one was associated, on lymphatic absorption from the ureter might be summarized, to complete this part of the picture.

"A patchy area of dye absorption was found in the middle third zone. The dye appeared to lie in fine channels running at right angles to the long axis of the ureter, probably coursing along the periphery of the ovarian or spermatic vessels to reach the lumbar glands."

In the upper third the patches of dye absorption appeared to connect with vessels running toward the renal pelvis. From the renal pelvis dye passed along behind the main renal vein and communicated with the lumbar glands.

Experiment 6.

Animals used - Rabbits.

Anaesthetic - Intravenous Nembutal.

Problem - The previous experiments tending to indicate the unwillingness of foreign particles to ascend along the peri-ureteral lymphatics, and the apparent constant drainage along the main aortic abdominal lymphatic chains, the problem was really the attempt to open up subsidiary pathways by breaking the main lymphatic chains.

Dye Used - India Ink.

Technique - A mid-line incision was made over the central part of the abdomen. The small bowel was packed upwards and the descending and pelvic colons laterally. A satisfactory exposure of the lower portion of the abdominal aorta was obtained. The parietal peritoneum over it was incised, and the upper half of the terminal inch of the aorta was stripped on both sides to break the two main lymphatic chains. The ends were then seared with the cautery in order to prevent as far as possible any leakage of lymph or tissue fluid, and too rapid repair.

(Note in most of the experiments it is preferable to use lean animals as the lymphatics can then be readily made out. This experiment is almost impossible in a fat animal.)

The object then of this experiment was to ascertain whether, on destroying the lymphatic highways, any by-paths opened up, especially any tract along the ureters leading to the kidneys.

Having finished the dissection of the aorta, 0.25 c.c. of India ink was injected into the bladder wall around both ureteral openings, as in experiment 3. The animal was left for fourteen days.

The result again was quite definite. Dye was absorbed into the common iliac group of glands and stopped where the aortic chain was divided. What was most illuminating, however, was the fact that no dye was seen along the ureters. As a result of the lymph blockage, there was a marked lymphatic edema of the pelvic organs with suffusion of dye therein. In addition, surrounding the traumatized area of the lower end of the aorta, numerous fresh lymphatic vessels had arisen and these were all seen to be passing towards the midline and none draining to the ureter. A small lymph chain had opened up posterior to the aorta in an attempt to drain the pelvic edema. See illustration.

Experiment 7.

Animals used - Rabbits

Anaesthetic - Intravenous Nembutal.

Problem - The previous experiments had tended to show no evidence of direct lymphatic spread to the kidneys.

The assumption was that the dye passed directly through the lymphatic chains until eventually it reached the venous system and was carried to the heart and then to the kidneys.

The problem was to substantiate the lympho-haematogenous spread to the kidneys.

Technique - Before describing the experiment it may be stated that the site of junction of the lymphatic and venous systems in animals is a very inconstant factor. It varies in different species and in different animals of the same species. The lymphatic chain may pass into the vena cava at any level, or it may form a thoracic duct in the usual way and follow the course in the human.

Following upon MacKenzie and Hawthorn's (37) observations that dye in small quantities passes through the renal circulation, but is deposited when the circulation is slowed as in hydronephrosis, an experiment was

framed to make use of these facts.

Through a midline supra pubic incision, the bladder was exposed and pulled forward from the vertex. By means of an aneurysm needle a silk ligature was passed around the lower end of the right ureter and tied firmly to occlude it's lumen.

A small quantity of dye 0.2 c.c. was then injected into the bladder wall around the left ureteral opening by means of a fine needle.

The animal was killed in four week's time and then perfused and the specimen obtained in the manner previously described.

A right sided hydronephrosis was found.

By means of the binocular dissecting microscope, dye could be followed from the region of the left ureteral opening in the perivascular lymphatics to the common iliac group of lymphatic glands and thence upwards along the left aortic lymphatic chain.

Sections of both ureters were negative for the presence of dye, as were also sections of the left kidney.

Appearance of Section of the Right (Hydronephrotic) Kidney.

Dye was present in the intertubular capillaries the glomerular vessels, and in the cells of the proximal convoluted tubules.

The experiment tended to show that the dye was carried by the lymphatics to the blood stream and then passed to all the viscera including the kidneys, where it was deposited if some factor was present producing stasis of the renal circulation.

That the dye did not reach the renal parenchyma by the blood stream on the original injection is supported by the small quantity of dye injected and the fact that the hydronephrosis was not at

that time a reality. Had dye reached the kidney at that time, it would have passed through and been carried away in the venous circulation. See illustrations.

Experiment 8.

Animals used - Rabbits.

Anaesthetic - Intravenous Nembutal.

Problem - To trace the path of lymphatic absorption of dye from the renal pelvis.

Dye Used - India ink.

Technique - At first the approach from the loin was employed but this opened too many lymphatic and tissue spaces, for accurate readings. A transperitoneal approach was therefore favored.

0.2 c.c. of India ink was injected into the wall of the renal pelvis and the wound closed in layers.

The animal was left for ten day's time then killed and perfused with saline and the tissue dissected in the usual manner and examined.

The dye was found to have moved toward the lumbar chain of lymphatics. (See illustration.)

Roentgenological Evidence of Lymphatic Absorption.

Animal used - Dog.

Anaesthetic - Intravenous Nembutal.

Problem - To trace the paths of lymphatic absorption under discussion, radiologically.

Contrast Medium -Thorotrast.

Technique - A plain X Ray photograph of the dog's abdomen and pelvis was taken before operation.
Through a midline supra pubic incision the bladder was pulled forwards to expose the lower ends of the ureters. Through a fine needle 0.25 c.c. of thorotrast was injected into the bladder wall around both ureteral openings. Extreme care was taken to avoid any leakage of the medium.
Immediately following operation an X Ray photograph was taken of the dog's abdomen and pelvis to show the location of the injected thorotrast.
A further photograph was taken four days later and again four weeks later. The movement of the thorotrast proved to be extremely slow. It was definitely in an upward direction and suggested movement towards the midline but proved inconclusive. See illustrations.

RESULTS OF EXPERIMENTS.

The result in every experiment was a lymphatic absorption of dye, no matter what the site of the original injection. In each case the dye passed to the lymphatic chains running up along the aorta. No dye could be found in any instance passing up the ureteral wall nor along the peri-ureteral lymphatics.

CONCLUSIONS.

Dye injected in small quantities in rabbits to different areas of the bladder wall, different levels of the lower ureteral wall, and into the cervix, is absorbed and passes to the common iliac group of glands either directly or through interposed smaller nodes. The dye then passes upwards towards the thoracic duct, and the implication from one series was that the dye then passes to the blood stream to the kidneys.

SUMMARY.

A method of preparing the lymphatics of the posterior abdominal wall in rabbits which maintained the anatomic relations of surrounding structures, has been described.

A series of experiments was carried out in rabbits on the role of the lymphatics in the absorption of dye from some of the pelvic organs, and the relation of the upward drainage to the kidneys, with the following results:

1. No absorption was obtained from the healthy mucosa of the bladder.

2. There was no marked absorption after varied forms of trauma to bladder mucosa unless an acute ulcerative condition was produced.

When rapid absorption ensued to the common iliac lymphatic glands thence up the Lumbar chain.

3. Dye injected into the trigone of the bladder, around the ureteral openings, and around the bladder neck passed to the glands at the bifurcation of the aorta through the lymphatic vessels, thence along the para aortic lymph chains. No dye passed along the peri ureteral lymphatics.

4. Dye injected into the middle and lower third of the ureteral wall passed towards the lumbar glands to the main lymphatic chain. No dye passed up the peri ureteral lymphatics.

5. Breaking the continuity of the main lymphatic pathways by stripping around the termination of the aorta does not lead to the opening up of subsidiary peri-ureteral lymphatic routes, but causes a lymphatic edema of the pelvic organs.

6. Tying off the lower end of one ureter leading to a hydronephrosis and the simultaneous injection of dye into the bladder wall around the lower end of the other ureter results in the absorption of dye from the site of injection into the aortic chain of lymphatics as before, and suggests its passage thence into the thoracic duct to the venous circulation then to the heart and thence to the kidneys. Dye was caught in the hydronephrotic kidney, due to circulatory stains, but no dye was present in the healthy kidney,

7. Dye injected around the renal pelvis resulted in absorption to the lumber lymphatic chain.

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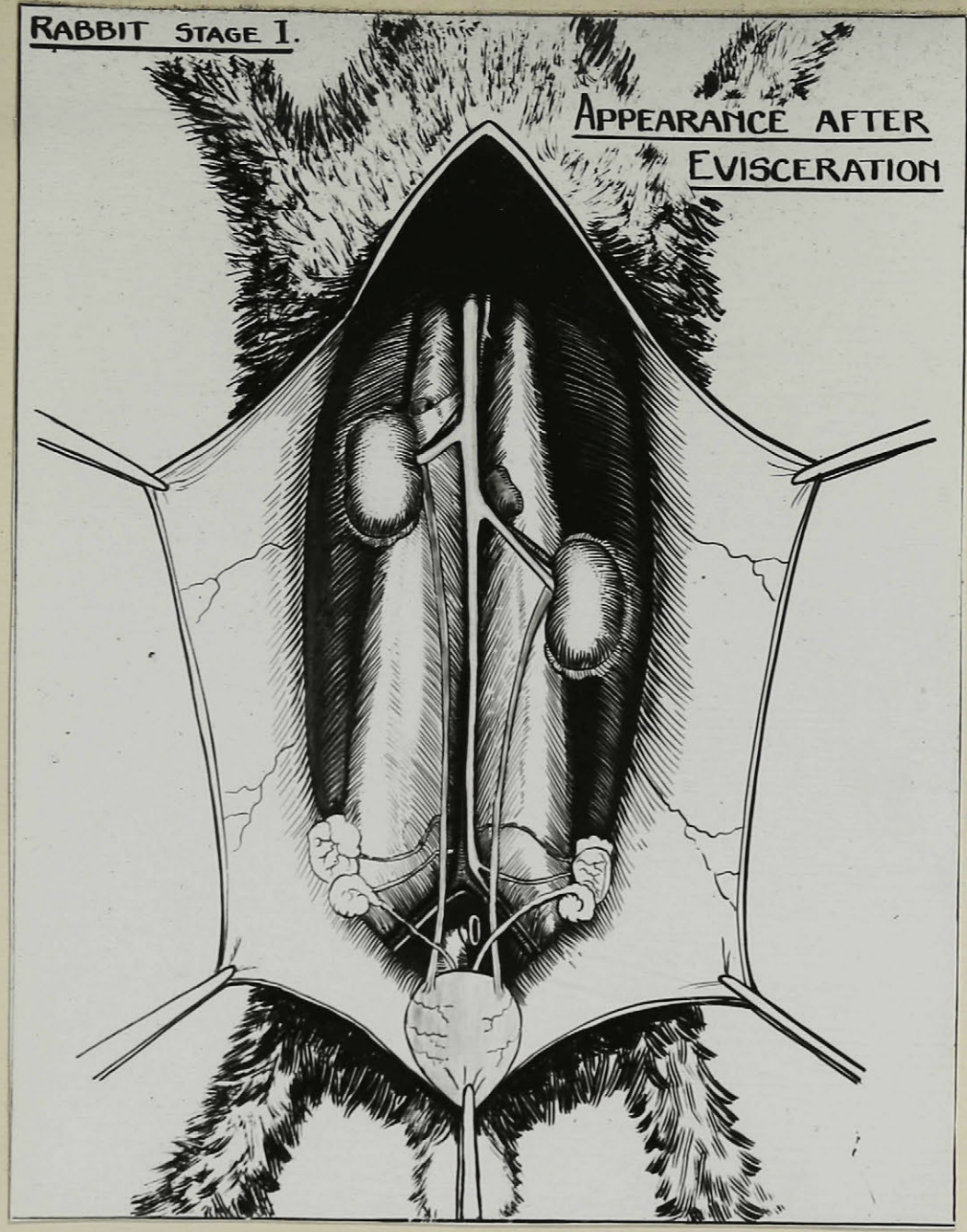
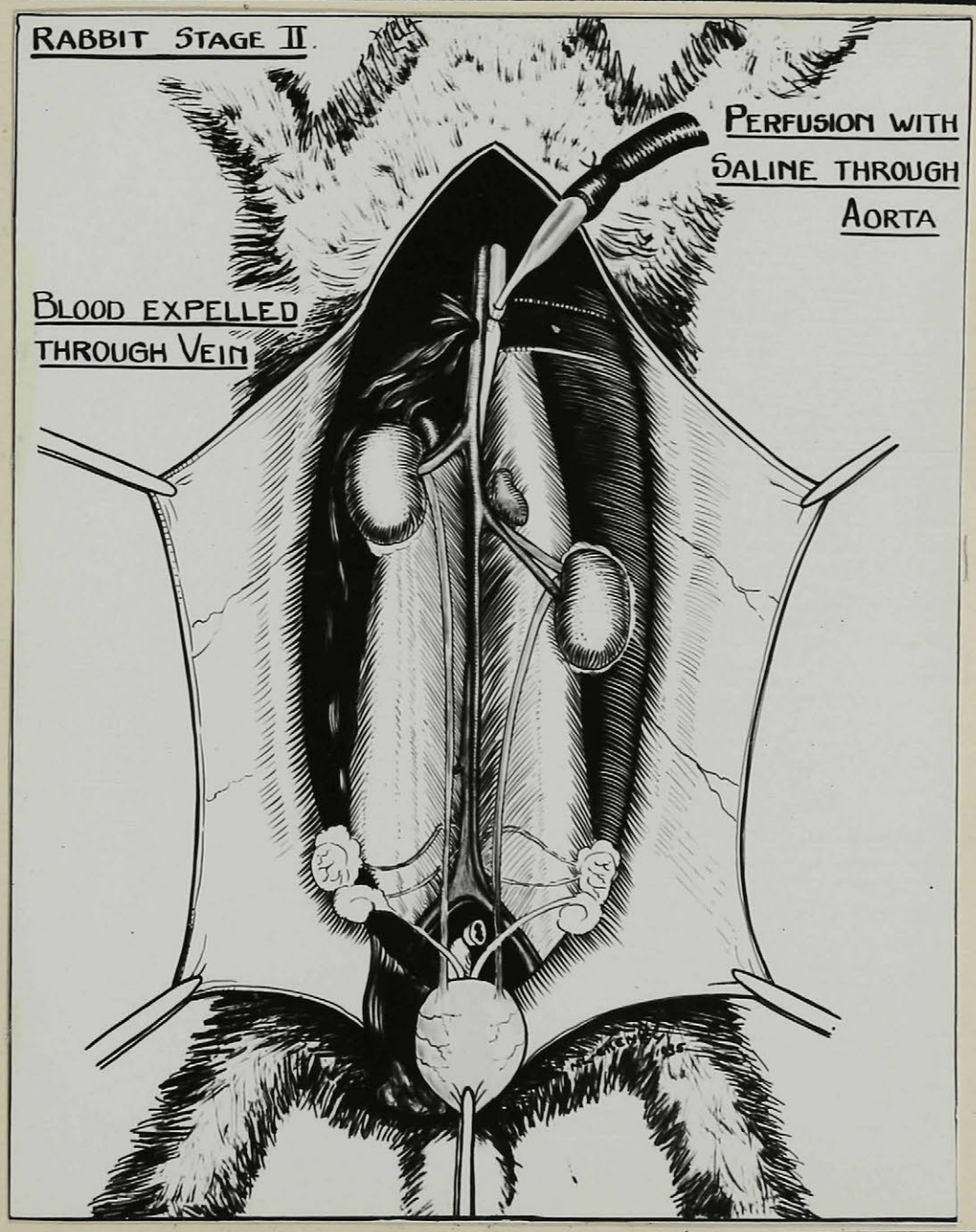
~ILLUSTRATIONS.~

(ALL PERSONAL WORK.)

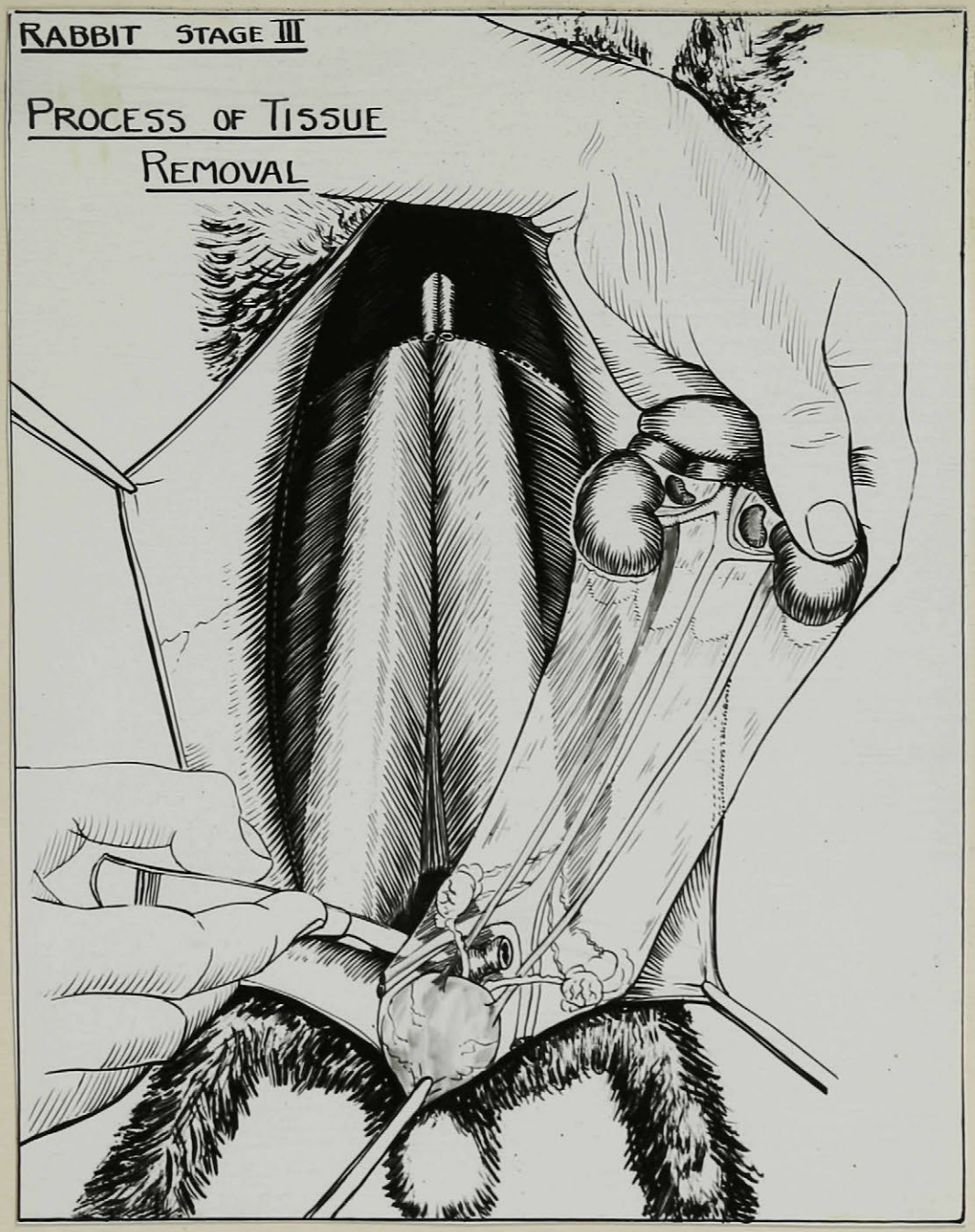




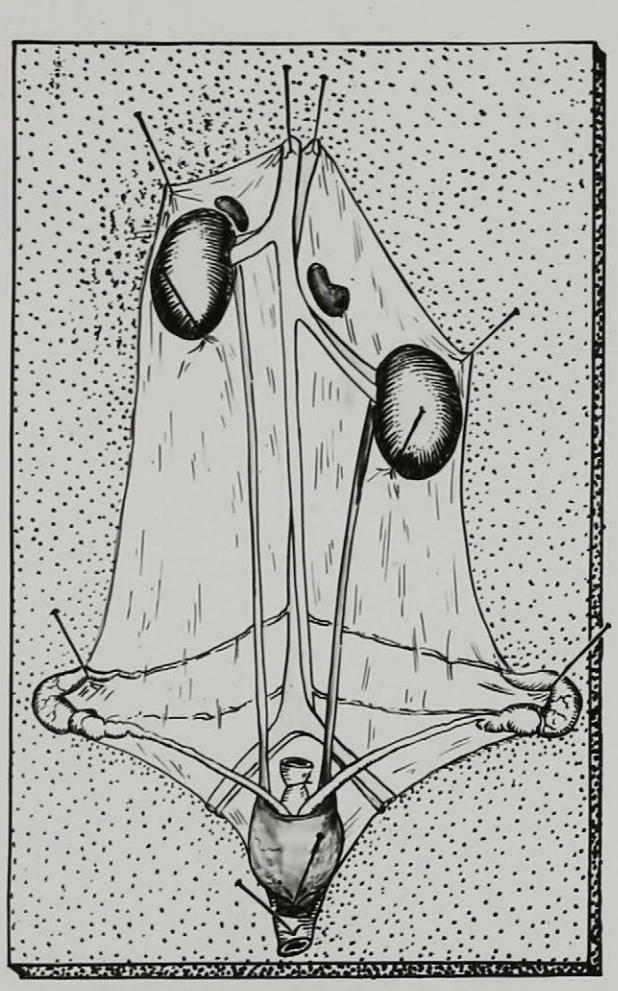
~TECHNIQUE OF LYMPHATIC~
~DEMONSTRATION~

RABBIT STAGE III

PROCESS OF TISSUE REMOVAL



RABBIT STAGE IV.

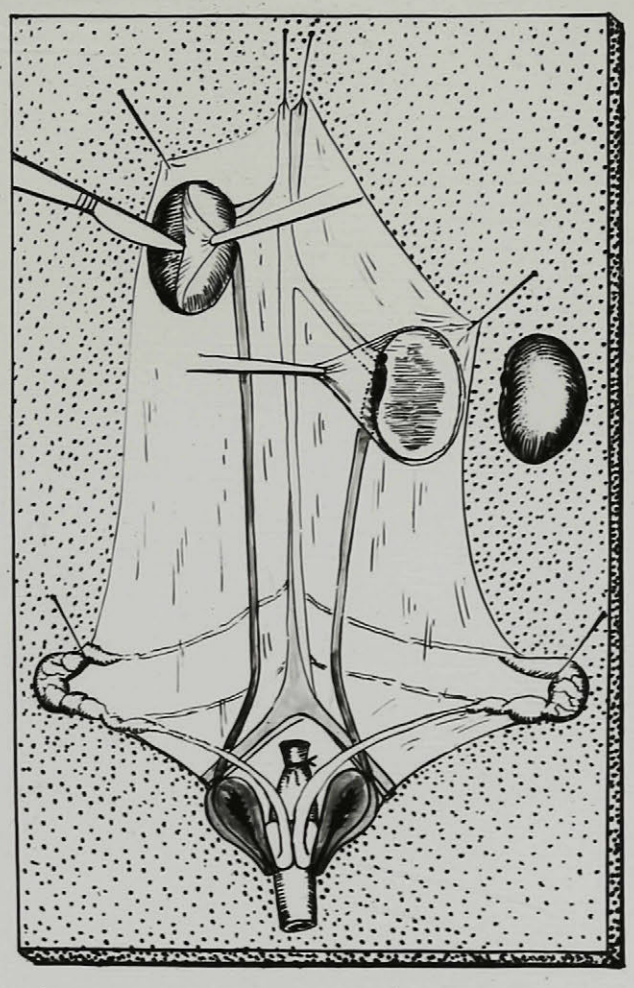


COMPLETION OF TISSUE REMOVAL

SPECIMEN PINNED ON CORK BOARD.

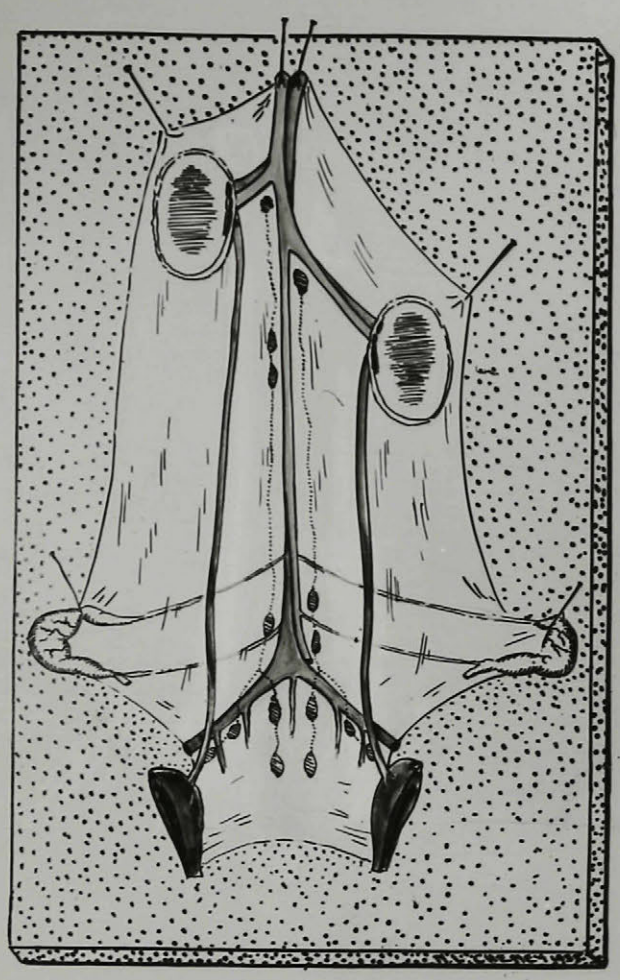
TECHNIQUE OF LYMPHATIC DEMONSTRATION.

RABBIT STAGE V.



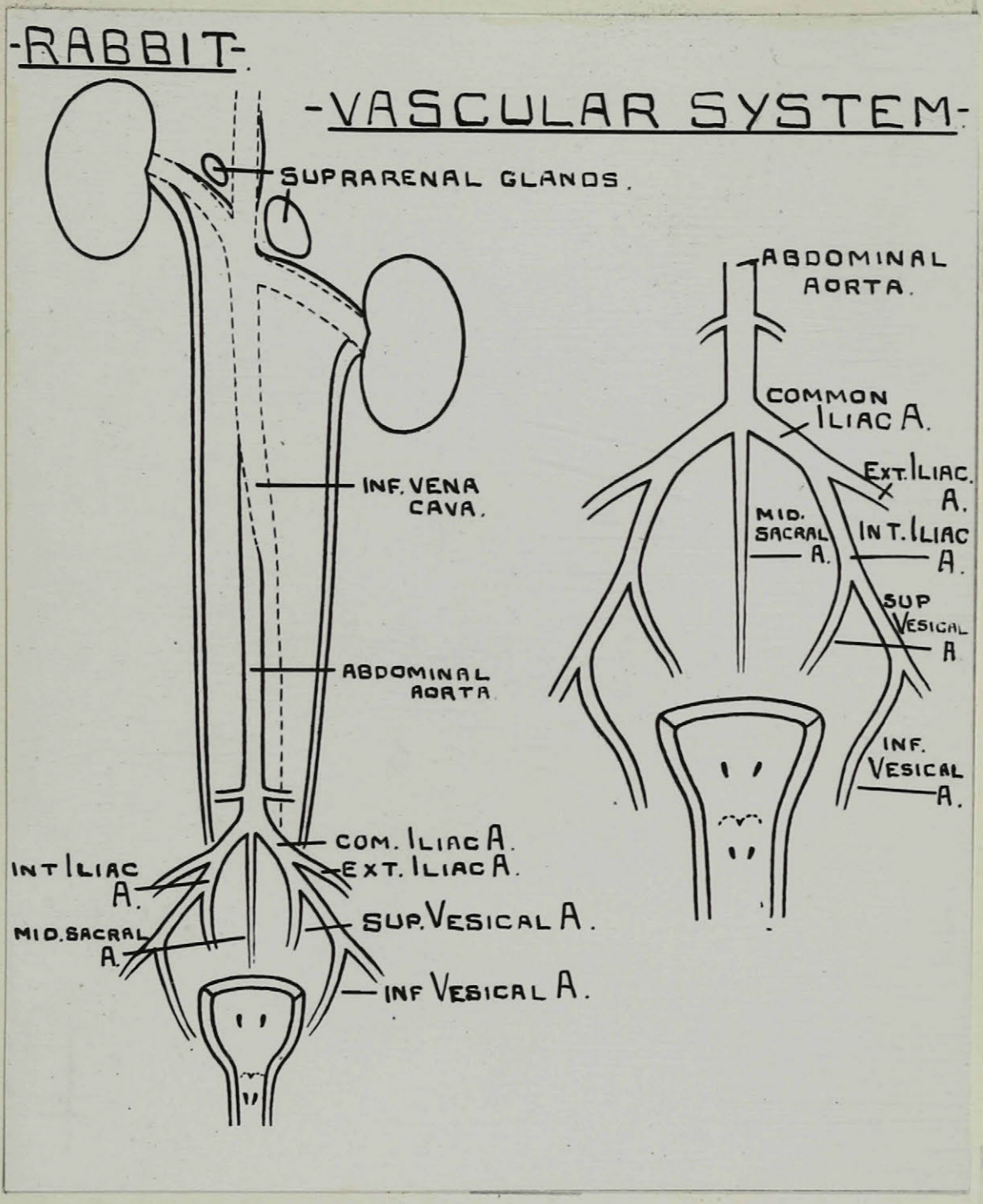
BLADDER BISECTED
ENUCLEATION OF KIDNEYS,
VESICLES AND RECTUM

RABBIT STAGE VI



COMPLETION OF DISSECTION

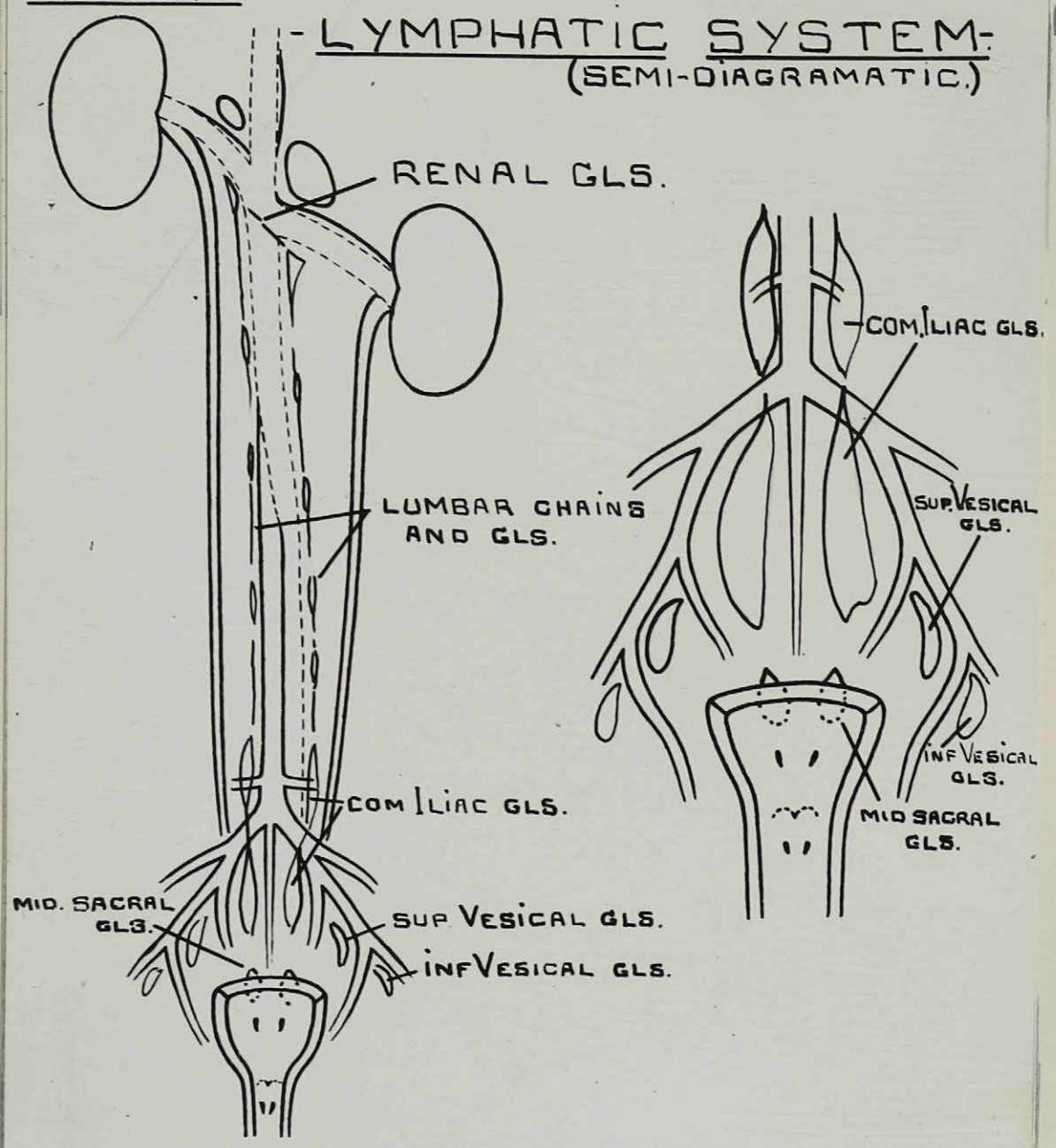
~TECHNIQUE OF LYMPHATIC~
~DEMONSTRATION.~



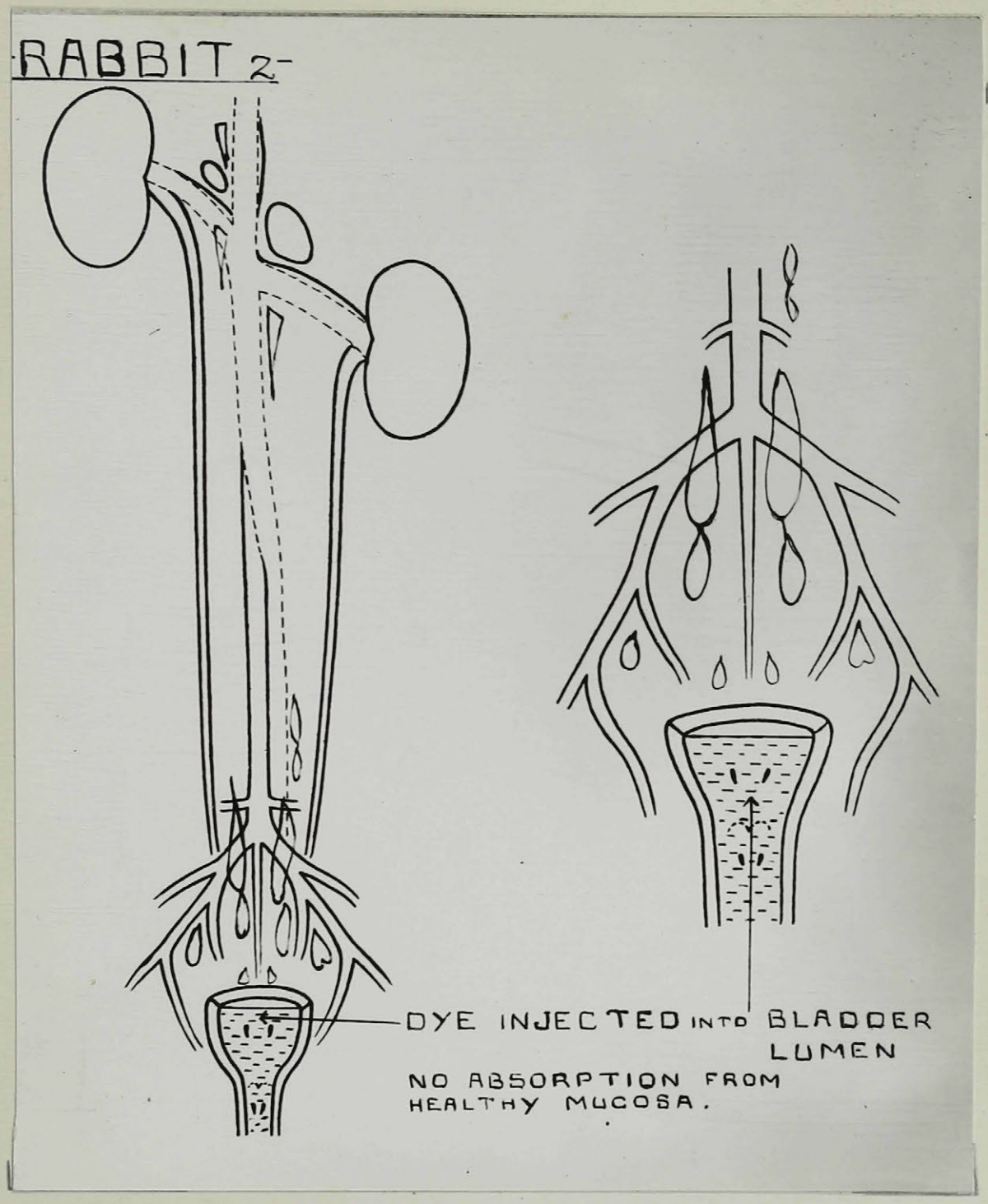
~VASCULAR SYSTEM~
~OF RABBIT~

-RABBIT-

-LYMPHATIC SYSTEM-
(SEMI-DIAGRAMATIC.)



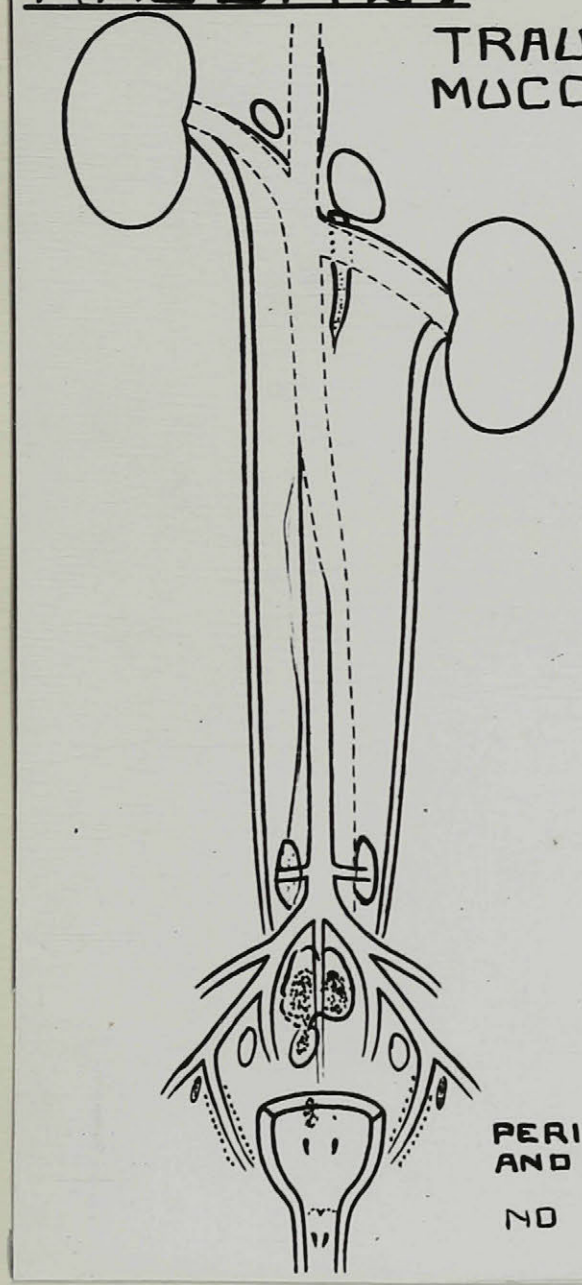
~LYMPHATIC SYSTEM~
~OF RABBIT~



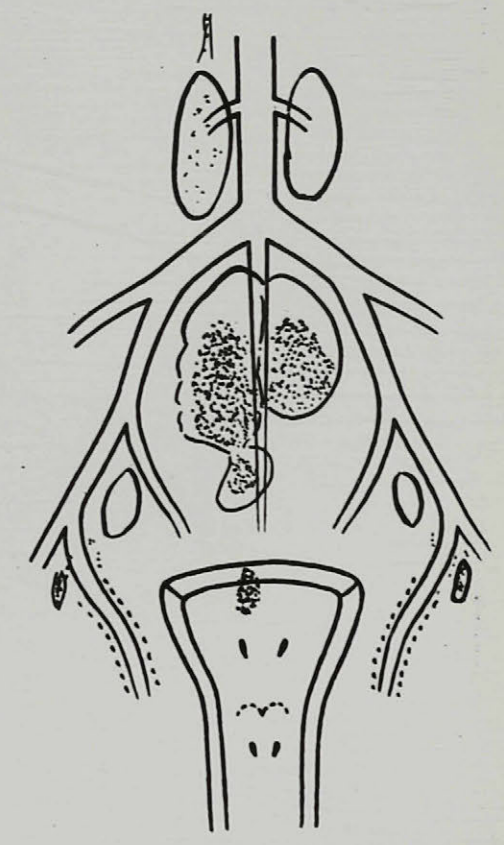
~NO ABSORPTION FROM~
~HEALTHY BLADDER.~

EXP 1.

-RABBIT 24-



TRAUMA TO BLADDER MUCOSA; DYE INJECTED INTO LUMEN.



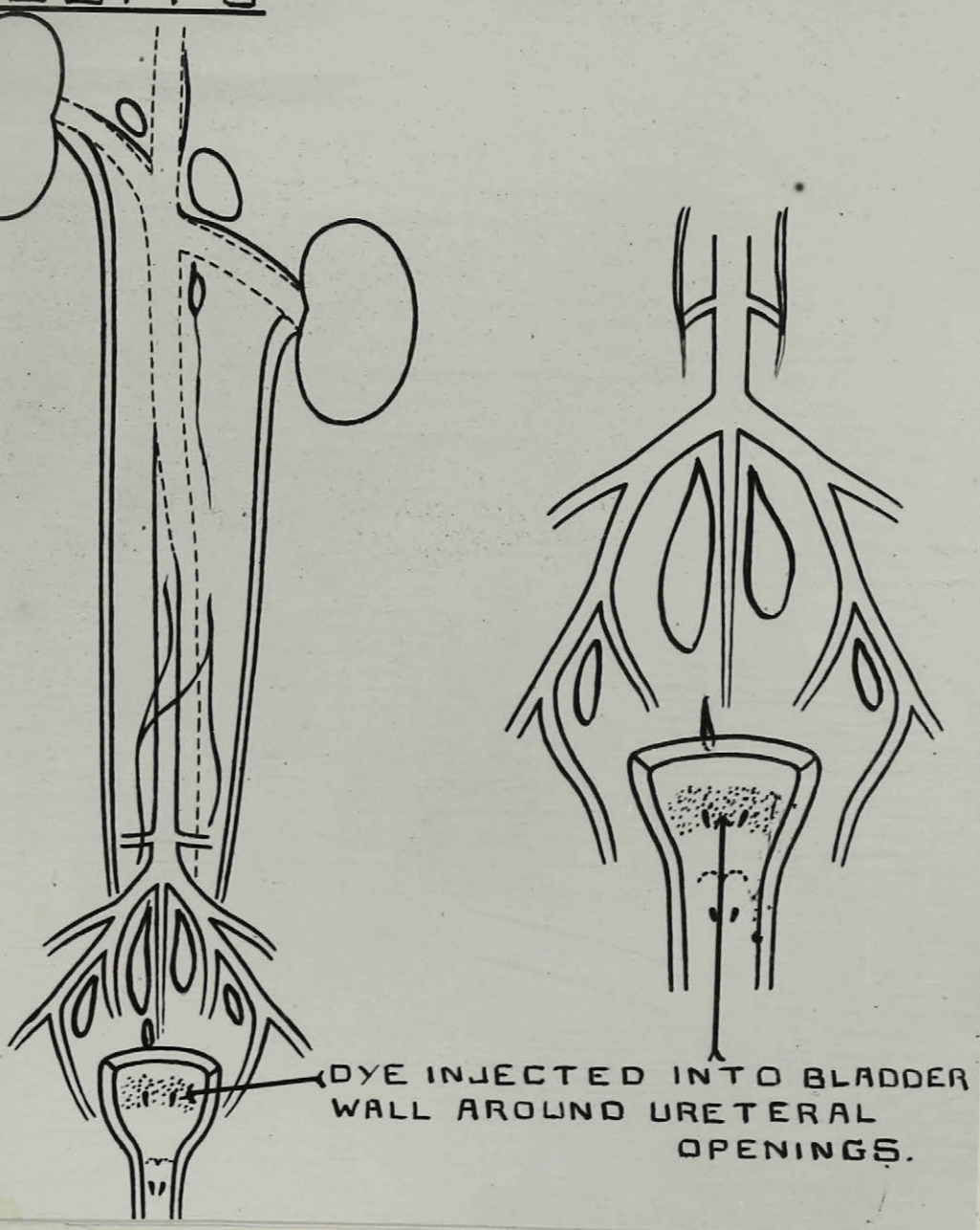
PERI-VASCULAR ABSORPTION AND GLANDS WITH DYE SEEN.

NO PERI-URETERAL ASCENT

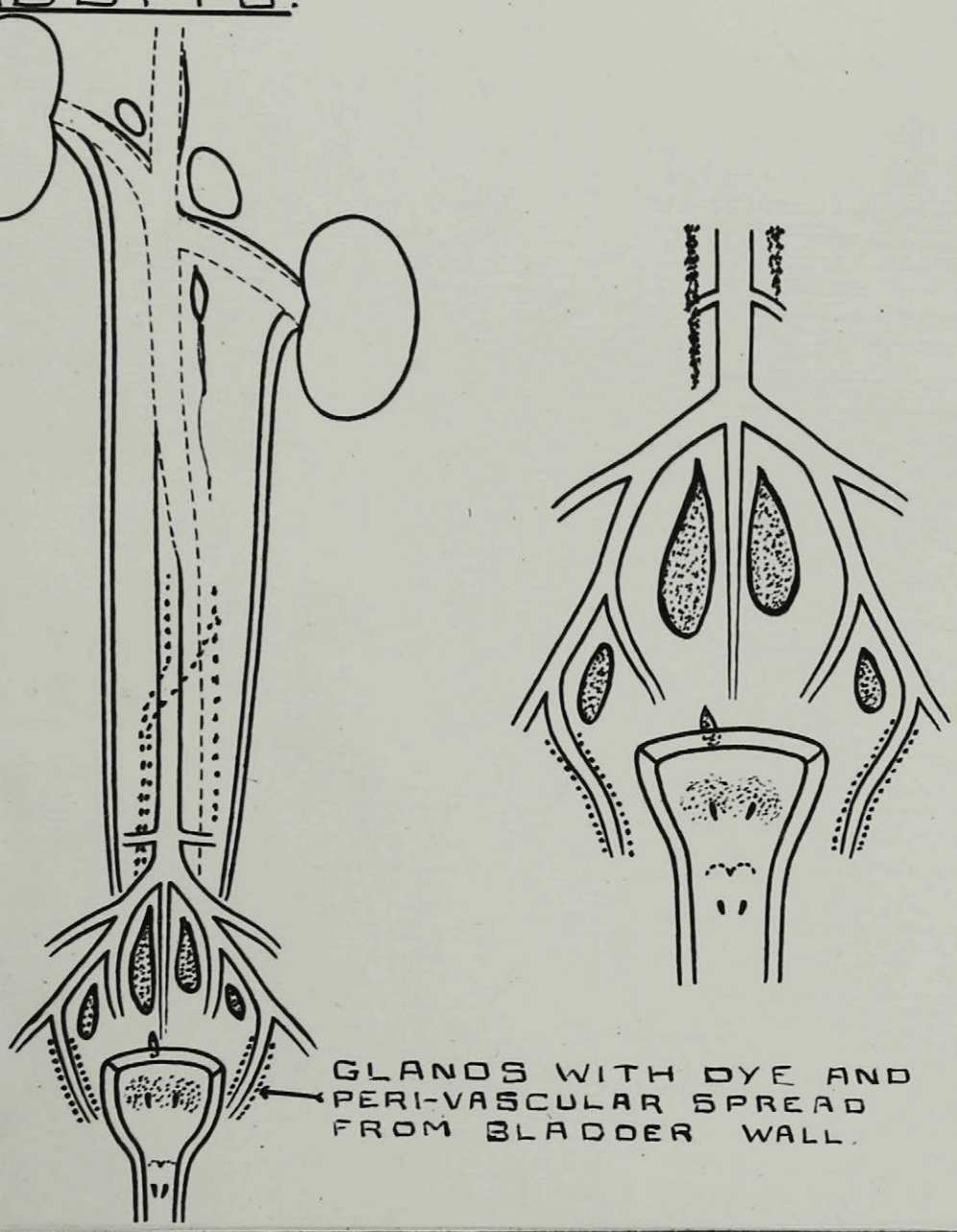
~ABSORPTION FROM~
~TRAUMATIZED BLADDER~

EXP 2.

-RABBIT 8-



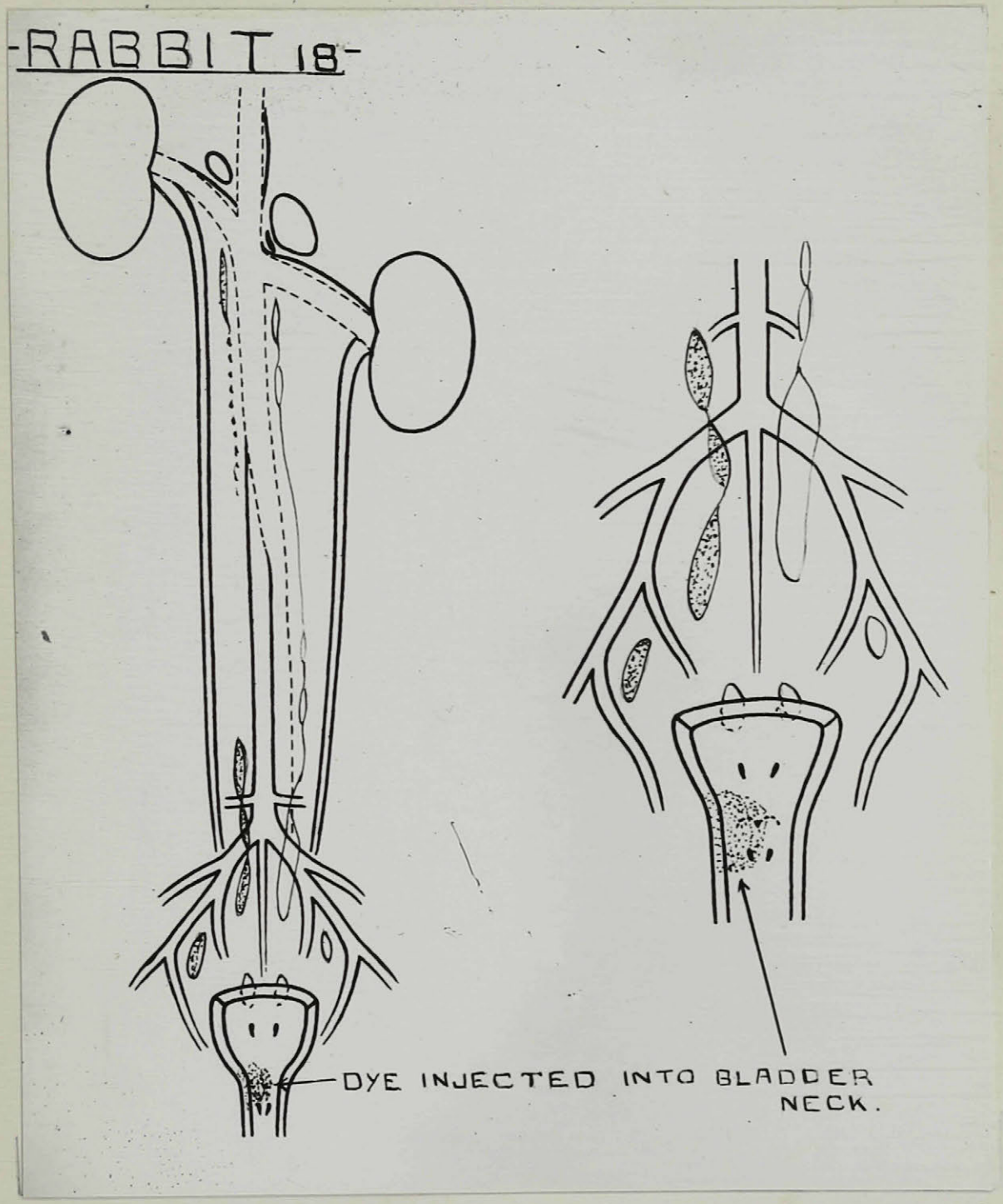
-RABBIT 8-



~ABSORPTION FROM AROUND URETERAL OPENINGS.~

EXP 3.

-RABBIT 18-

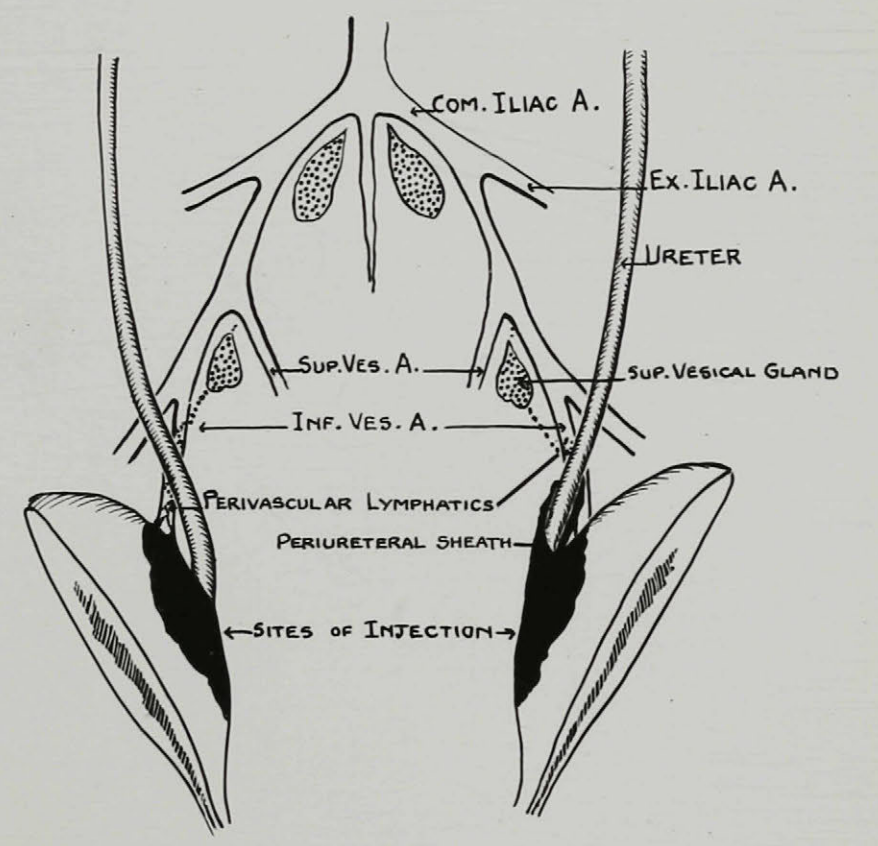


~ABSORPTION FROM BLADDER~

~NECK~

EXP 3.

RABBIT 9.

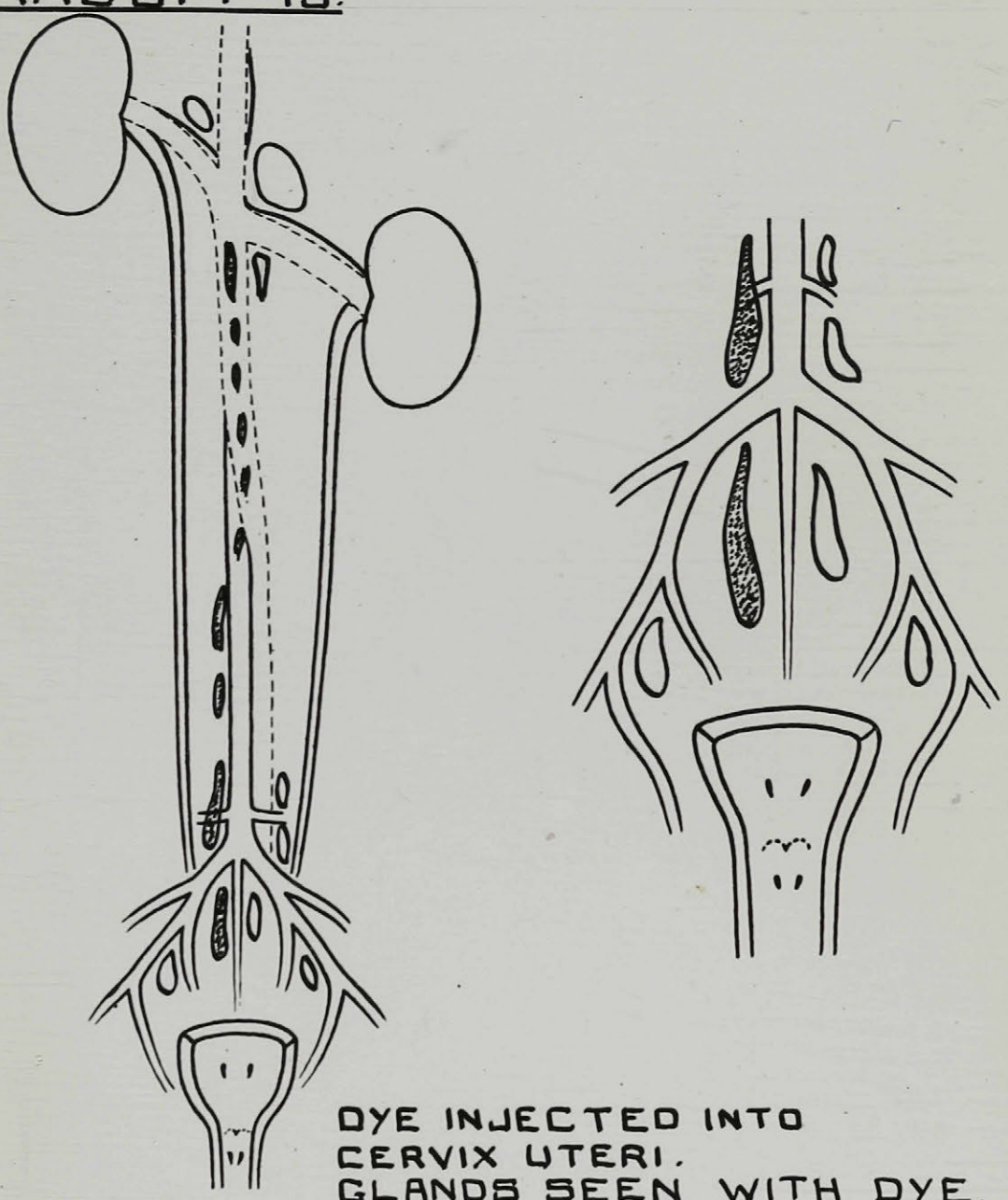


TRANSIT OF DYE FROM BLADDER WALL TO LYMPH GLANDS
(NOTE . NO PERIURETERAL ASCENT)

~PATH OF TRANSIT OF DYE~
~FROM BLADDER TO GLANDS~

EXP 3.

-RABBIT 19:-

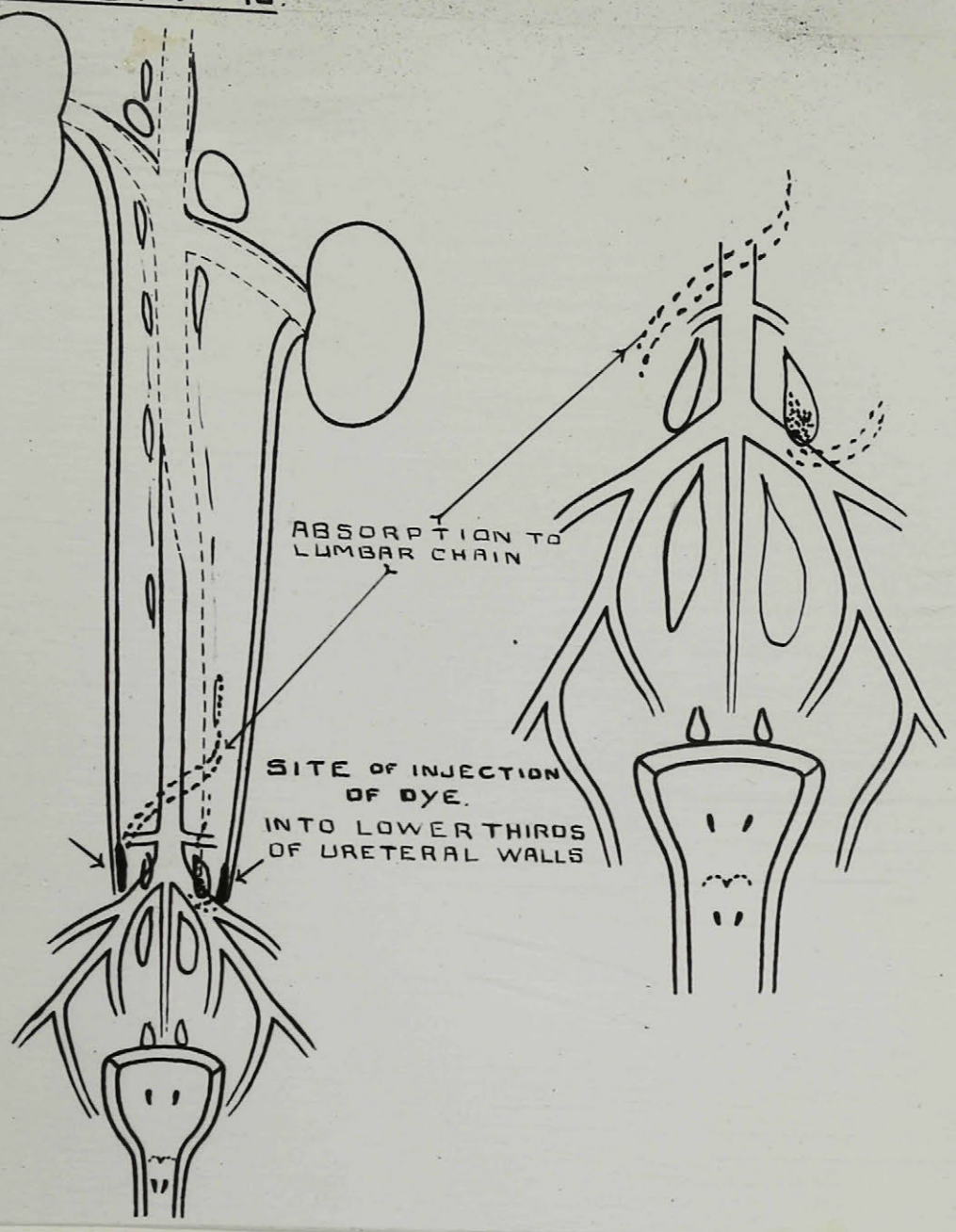


DYE INJECTED INTO
CERVIX UTERI.
GLANDS SEEN WITH DYE.

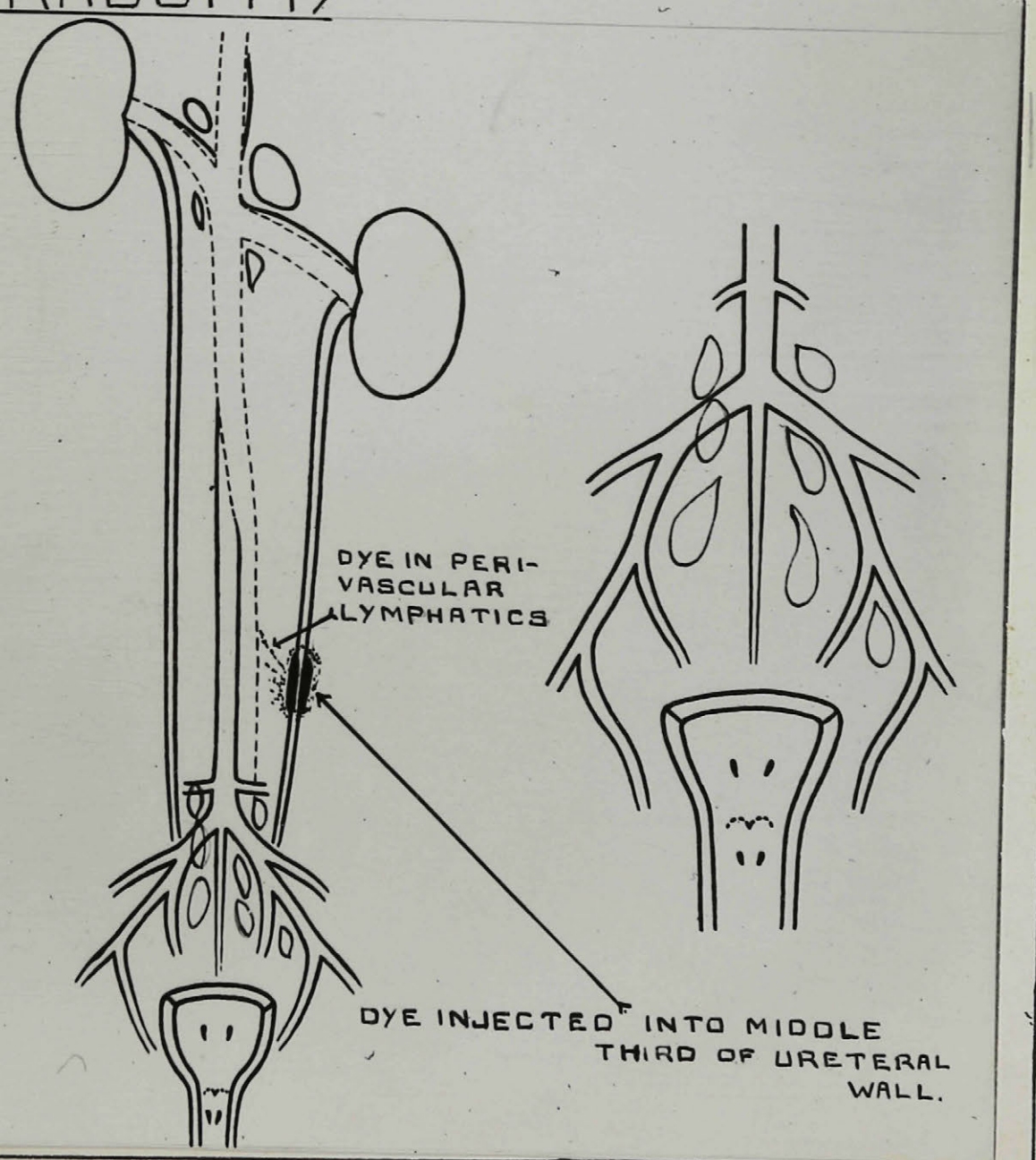
~ABSORPTION FROM ~
~CERVIX UTERI.~

EXP 4.

RABBIT 13-



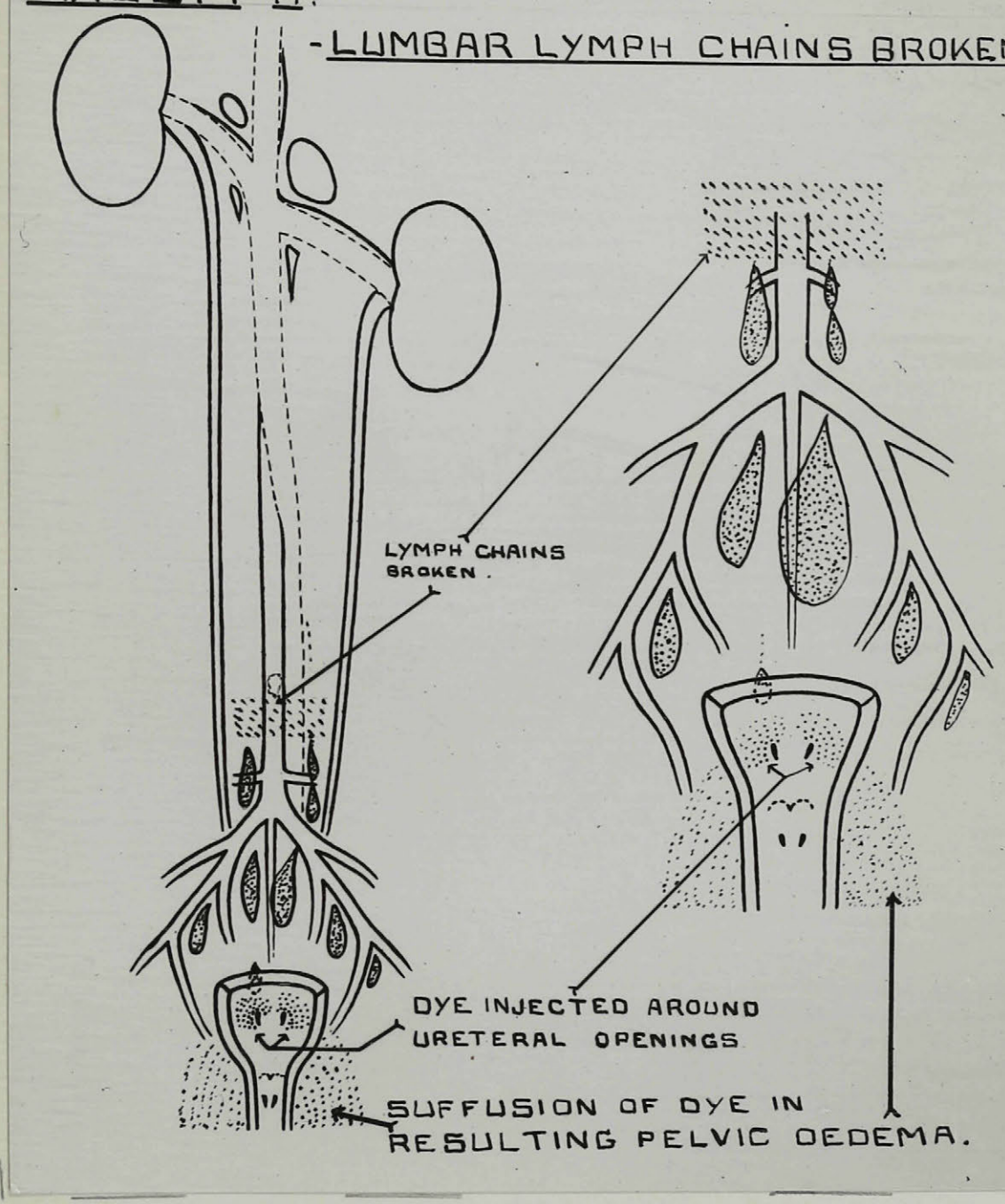
-RABBIT 17-



~ABSORPTION FROM URETER.~ EXP 5.

-RABBIT- 14.

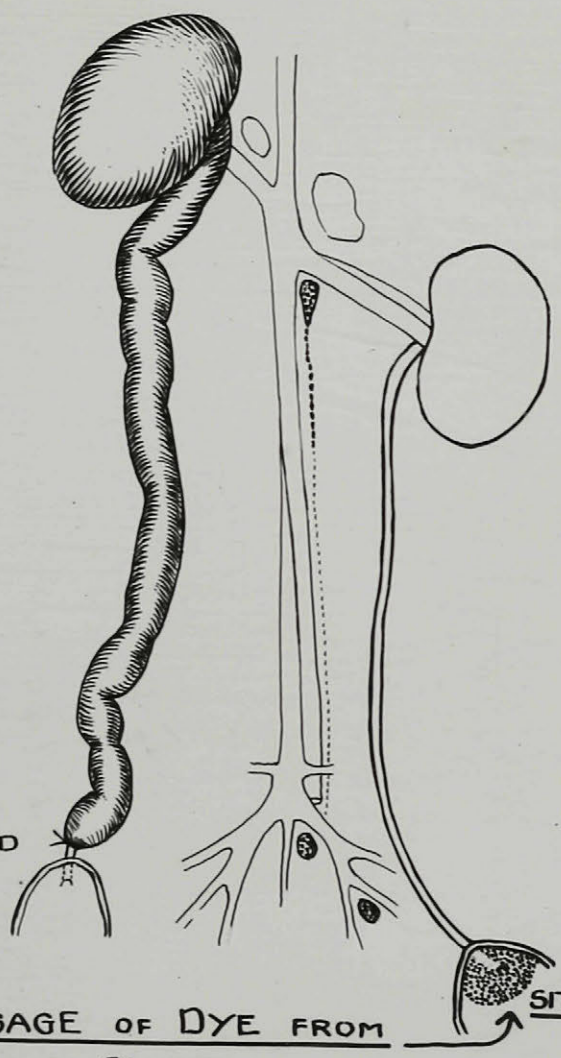
-LUMBAR LYMPH CHAINS BROKEN-



~NO SUBSIDIARY PATH IF ~
~MAIN CHAINS ARE BROKEN.~

EXP6.

RABBIT 15.



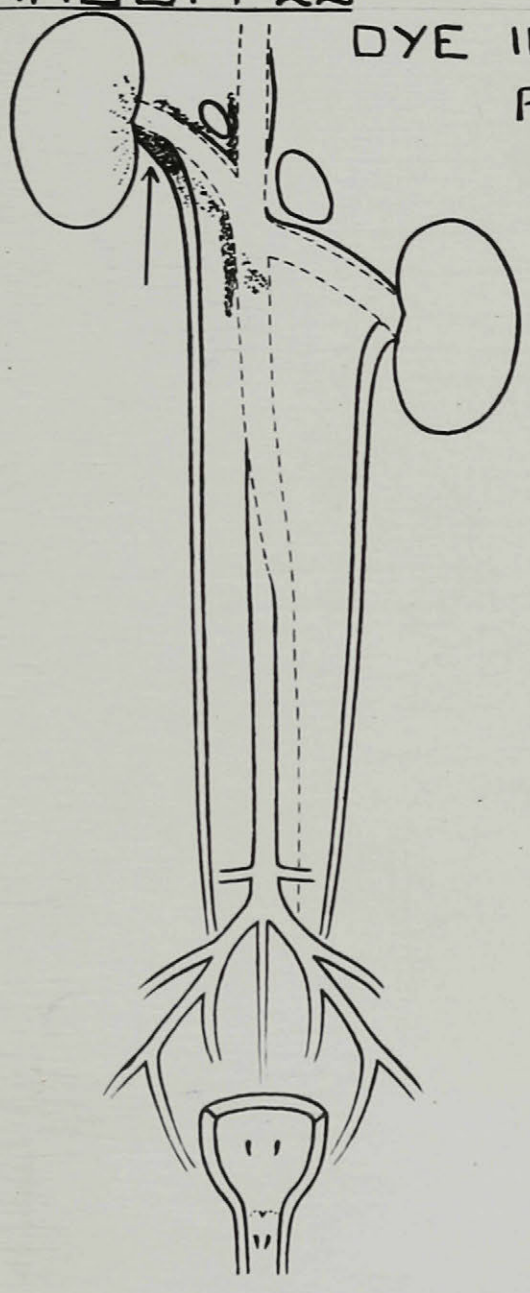
PASSAGE OF DYE FROM

1. TO LYMPHATIC GLANDS
2. TO BLOOD STREAM THROUGH THORACIC DUCT (FROM 1.)
3. TO HYDRONEPHROTIC KIDNEY (FROM 2.)
4. CAUGHT IN INTERTUBULAR CAPILLARIES (IN 3.)

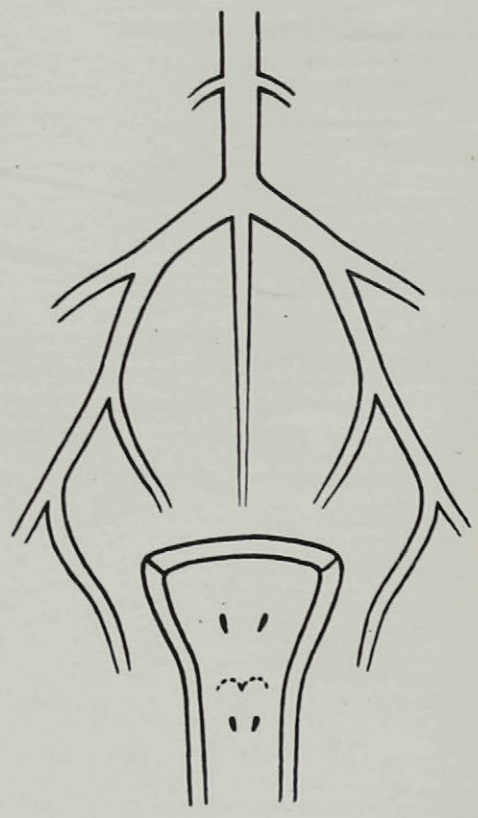
~THE LYMPHO-HAEMATOGENOUS~
~SPREAD.~

EXP 7.

RABBIT 22



DYE INJECTED AROUND RENAL PELVIS.



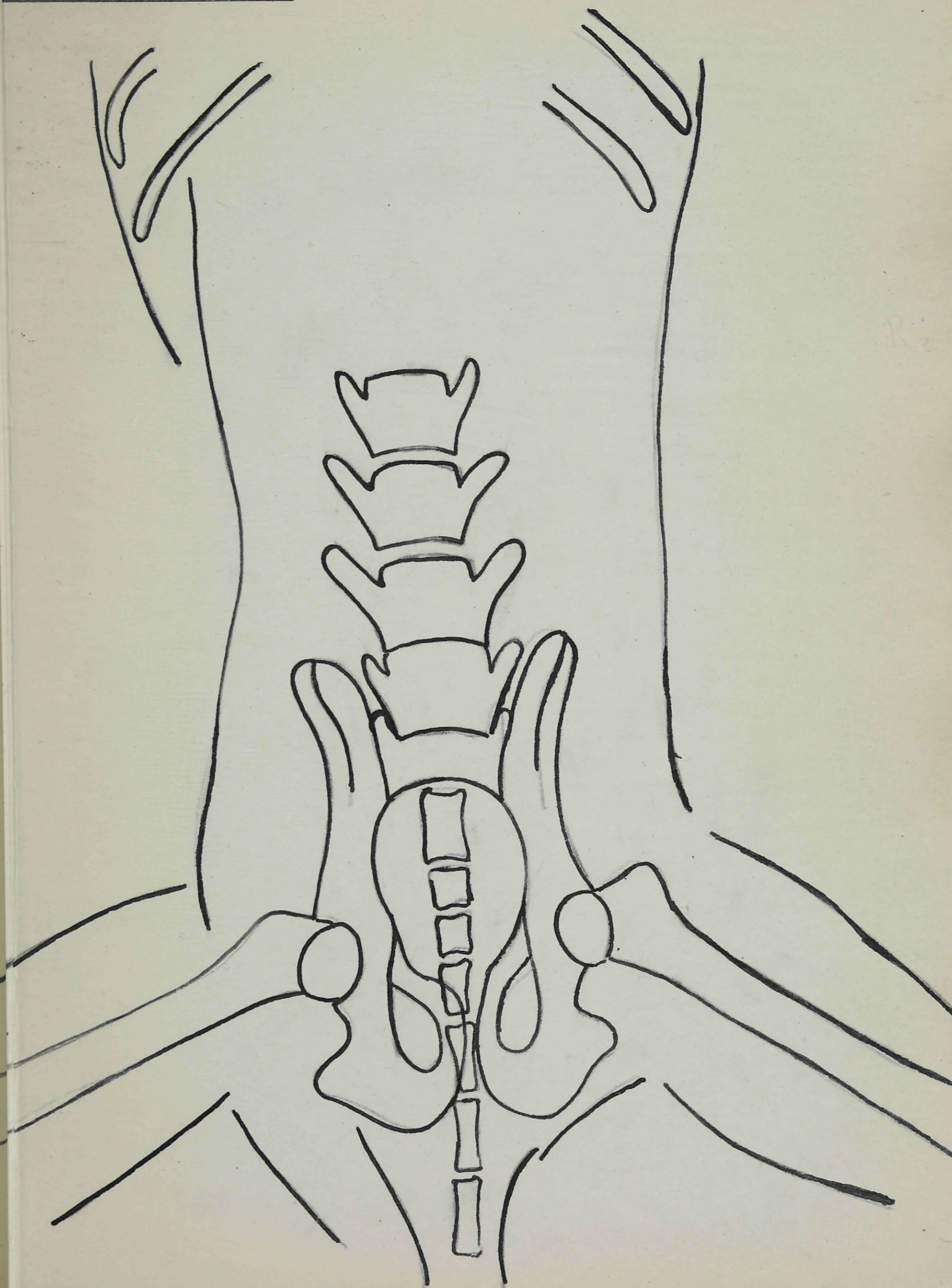
~ABSORPTION FROM RENAL~

~PELVIS~

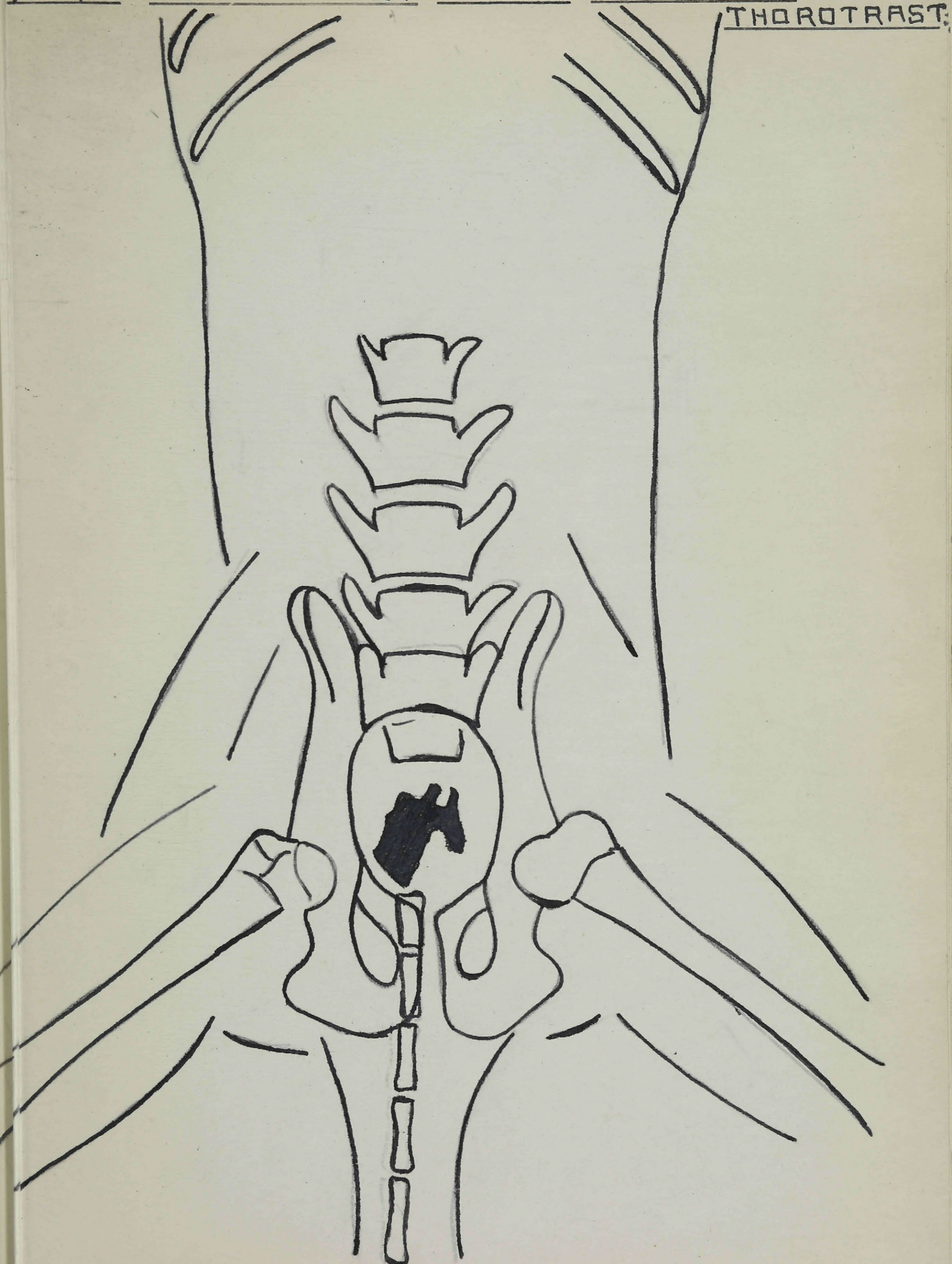
EXP 8.

ROENTGENOLOGICAL EVIDENCE OF LYMPHATIC ABSORPTION.

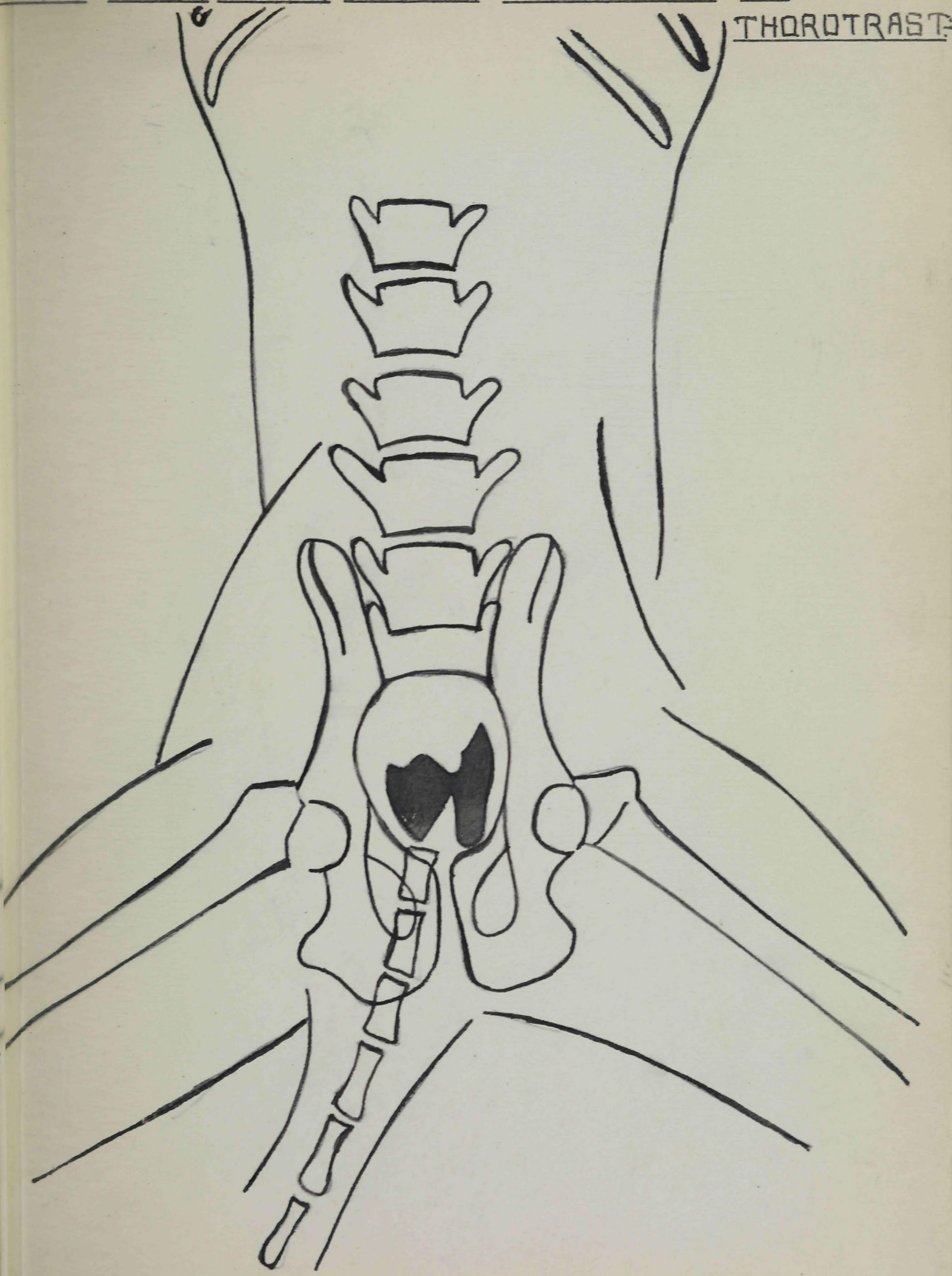
PLAIN X-RAY.—



X-RAY IMMEDIATELY AFTER INJECTION OF THOROTRAST:



X-RAY FOUR DAYS AFTER INJECTION OF THOROTRAST:



X-RAYS FOUR WEEKS AFTER INJECTION OF THORDTRAST:-