Bacterial diseases of pets

Leptospirosis

Leptospirosis is caused by infection with the **Gram-negative**, thin, spiral, and motile bacterium of the genus *Leptospira.*

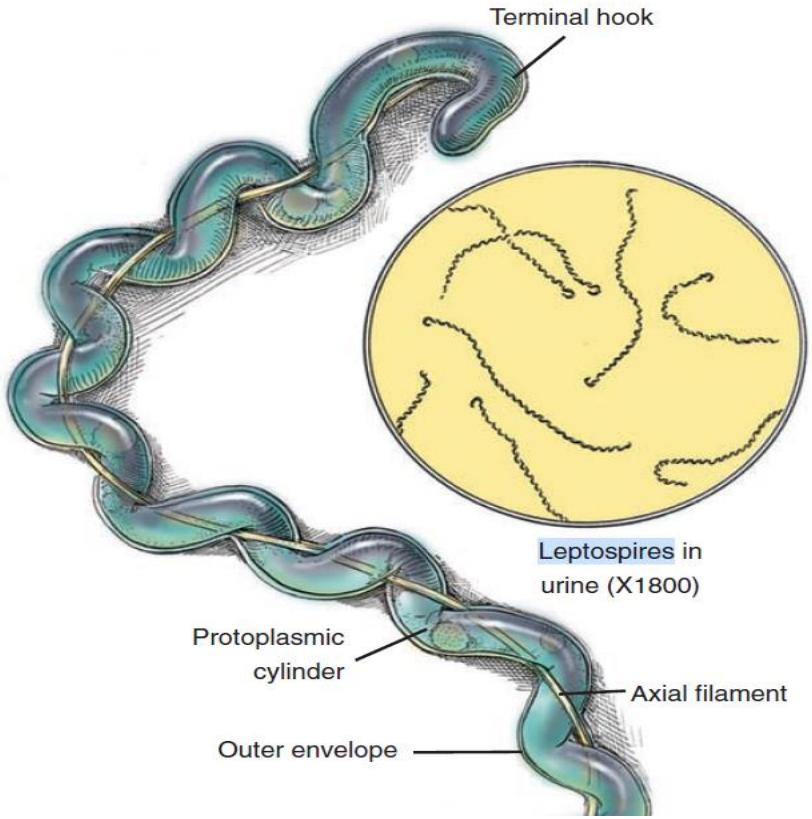
Leptospires enter the body through the mucous membranes or through the skin if its barrier functions have been disrupted.

Contaminated water, bedding, and soil are common sources of infection because the organism is shed in urine.

Fetuses can develop transplacental infection and are often aborted.

Cause

- Dogs are susceptible to several serovars of *Leptospira*, although ***L. icterohaemorrhagiae*** and ***L. canicola*** are determined to be themost common canine isolates



Pathogenesis

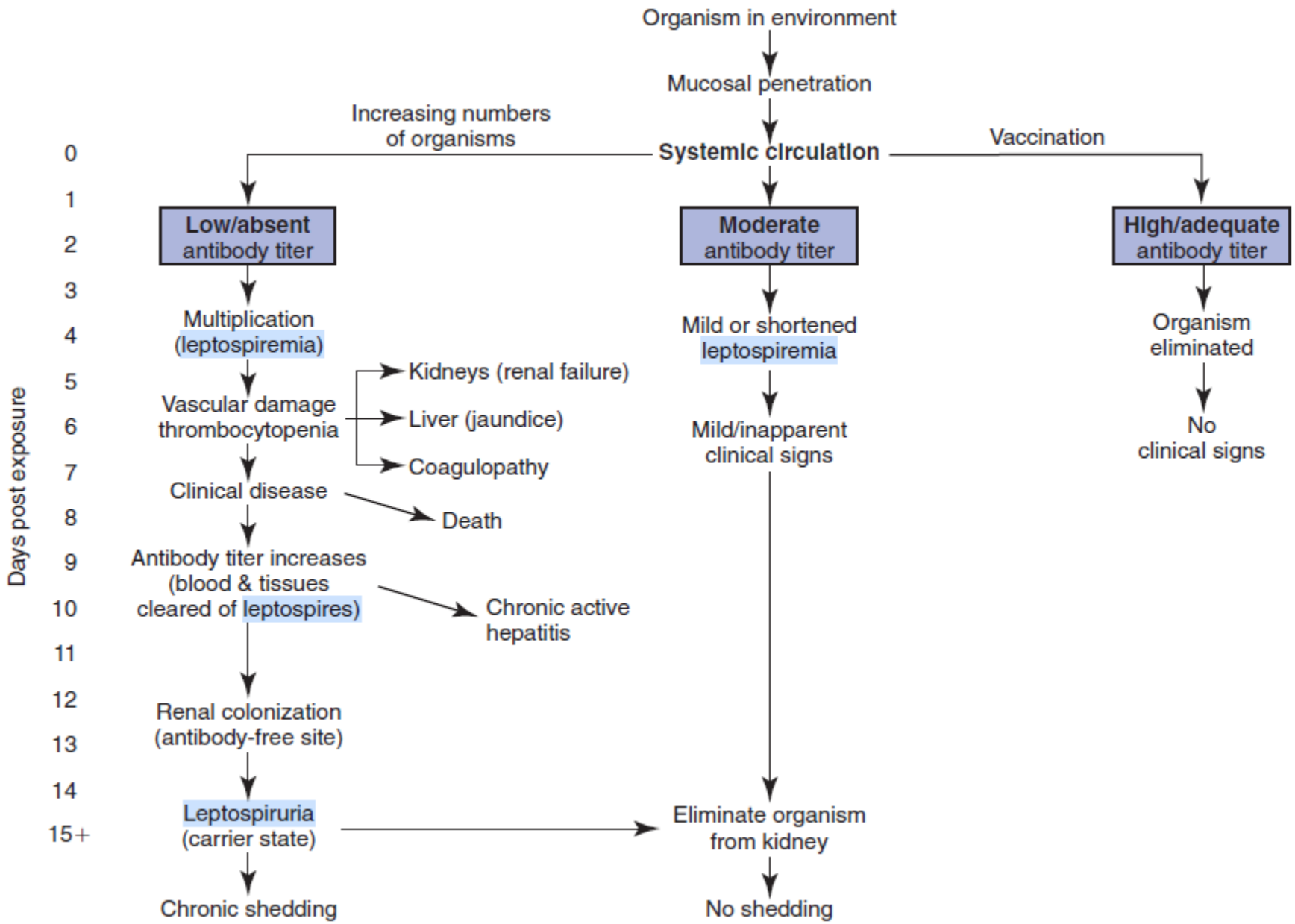


FIG. 42-2 Pathogenesis of leptospirosis.

For infection to occur, it has been suggested that the skin and mucosae must have small cuts or abrasions that allow the bacteria to penetrate into the vascularized submucosal or subcutaneous connective tissues and gain access to capillaries and/or postcapillary venules.

However, the bacteria are motile and likely able to penetrate mucus layers and invade mucosae by moving directly through mucosal epithelial cells or between the cells through intracellular junctional complexes.

In all three of these portals of entry, **the goal is for the bacteria to reach well-vascularized ECM tissues**.

As a group, these spirochetes are highly motile and invasive and using its invasive motility (virulence determinate), it is able to penetrate the vascular wall and endothelial cells of capillaries and postcapillary venules to gain access to the circulatory system.

Leptospira spp. may also invade lymphatic vessels and through this system and the thoracic duct eventually gain access to the circulatory system.

Leptospira spp. are able to grow and replicate in the circulatory system and then spread systemically to all organ systems.

To infect other organs such as the **kidney and liver**, it appears that the **bacteria** must first **attach to endothelial cell membranes** via **adhesins** before invading these cells and their underlying vascularized tissues and **then interact** with **renal tubular epithelial cells** and **hepatocytes.**

Leptospira spp. initially spread through the vascular system to all tissues of the body and do not appear to specifically target the kidney or liver via a tropism (attraction to a specific cell type or tissue) mechanism.

However, once epithelial cells are infected, the reason for dominance of lesions in these organs is unclear and may be related to some essential trophism (nourishment of tissues) provided by these cells to the bacteria for colonization and proliferation

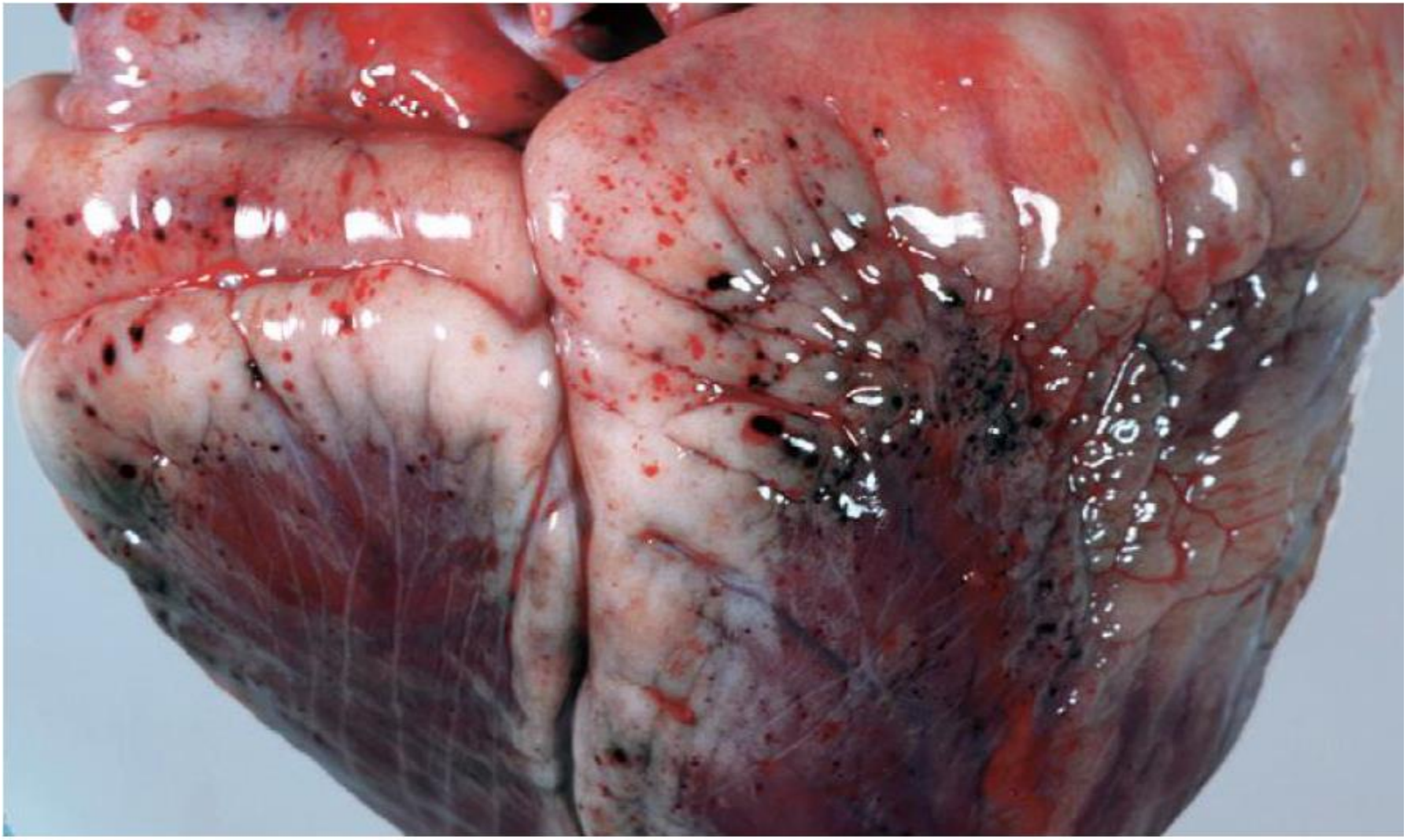
Vascular Leptospirosis (Leptospira *spp.)*

- The mechanism of injury in vascular leptospirosis is cell death caused by

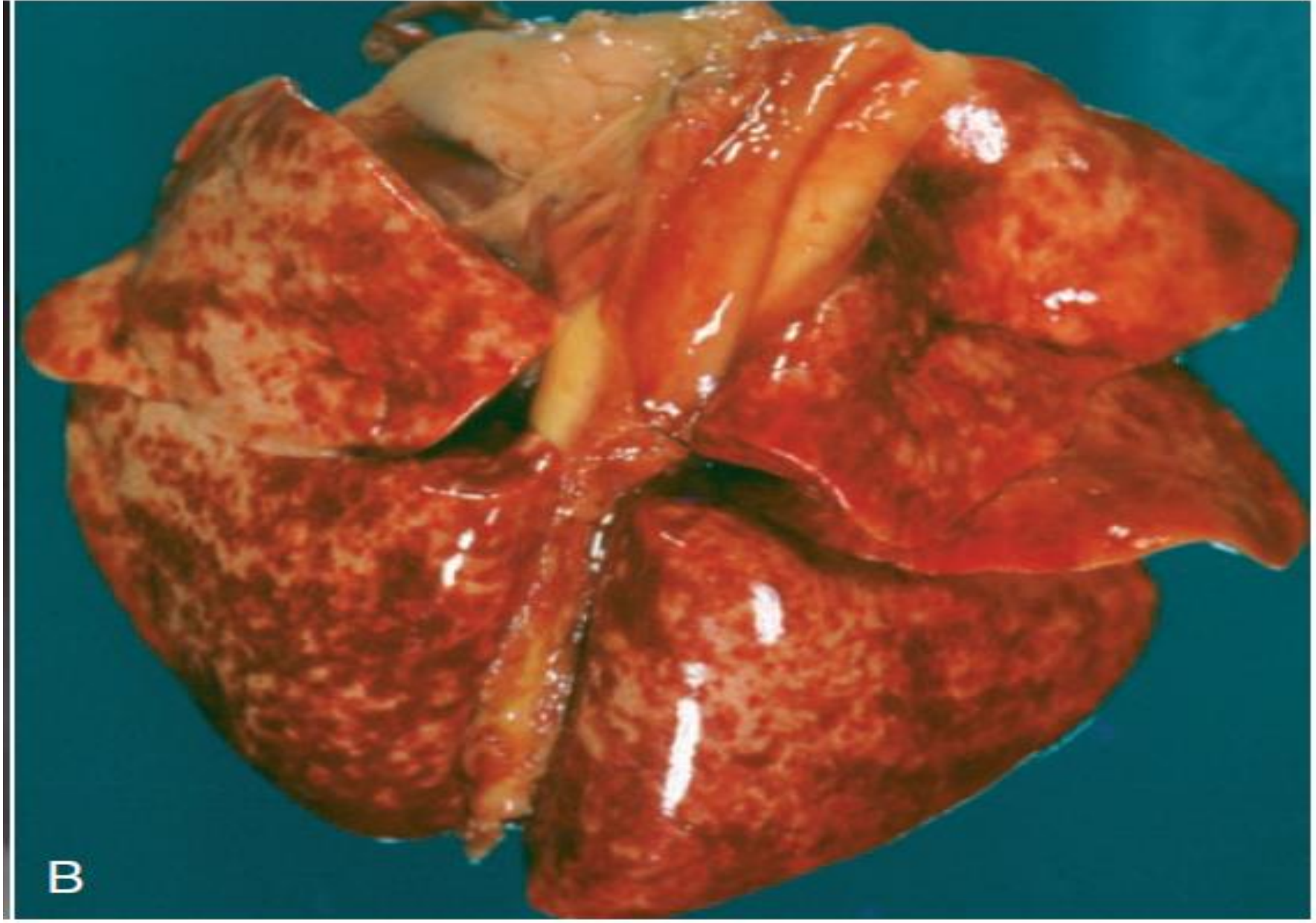
(1) physical properties (penetrating movements) of bacteria that disrupt functions of endothelial cells and

(2) bacterial toxins that act directly on membranes of endothelial cells of small blood vessels, including capillaries of the systemic vasculature in all organ systems, leading to coagulative necrosis of affected cells.

- Gross lesions include acute vasculitis (endothelial cell necrosis) with systemic petechial and ecchymotic hemorrhages, edema, and DIC affecting all organ systems and serosal surfaces.

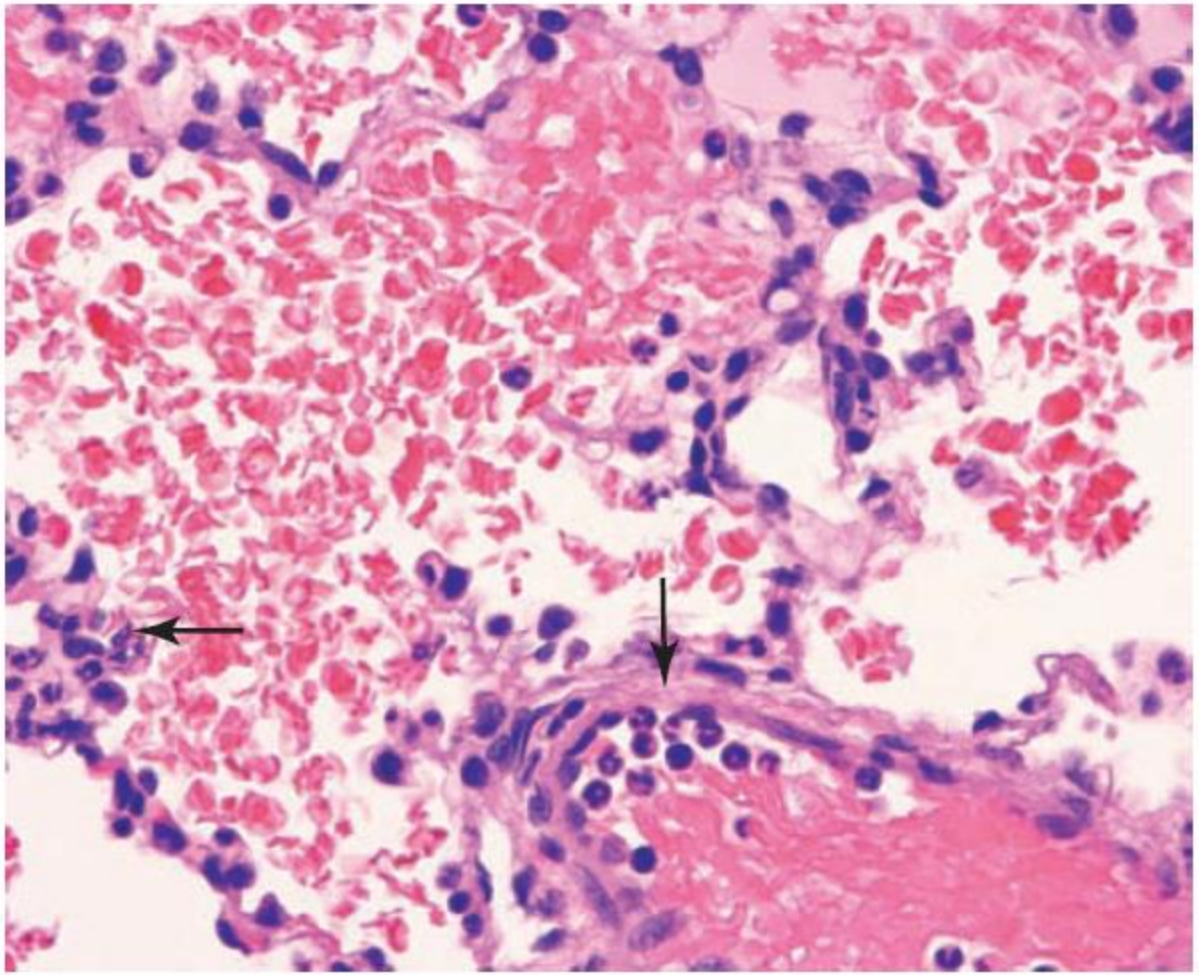


epicardial and subepicardial hemorrhages in the fat of the coronary groove (a common site), from injury to the endothelium from endotoxin (component of the cell wall of Gram-negative bacteria). The smaller, pinpoint hemorrhages (1 to 2 mm) are petechiae. The larger, blotchy hemorrhages (3 to 5 mm) are ecchymoses.



Petechial and ecchymotic hemorrhages on the serosal surfaces of the lungs from a fatally infected dog.

Histopathology



Acute pulmonary hemorrhage in a dog with acute leptospirosis. Alveoli contain large numbers of extravasated erythrocytes. Note margination of neutrophils within blood vessels *(arrows).* (H & E, stain, × 400).

*Hepatic Leptospirosis (*Leptospira *spp.)*

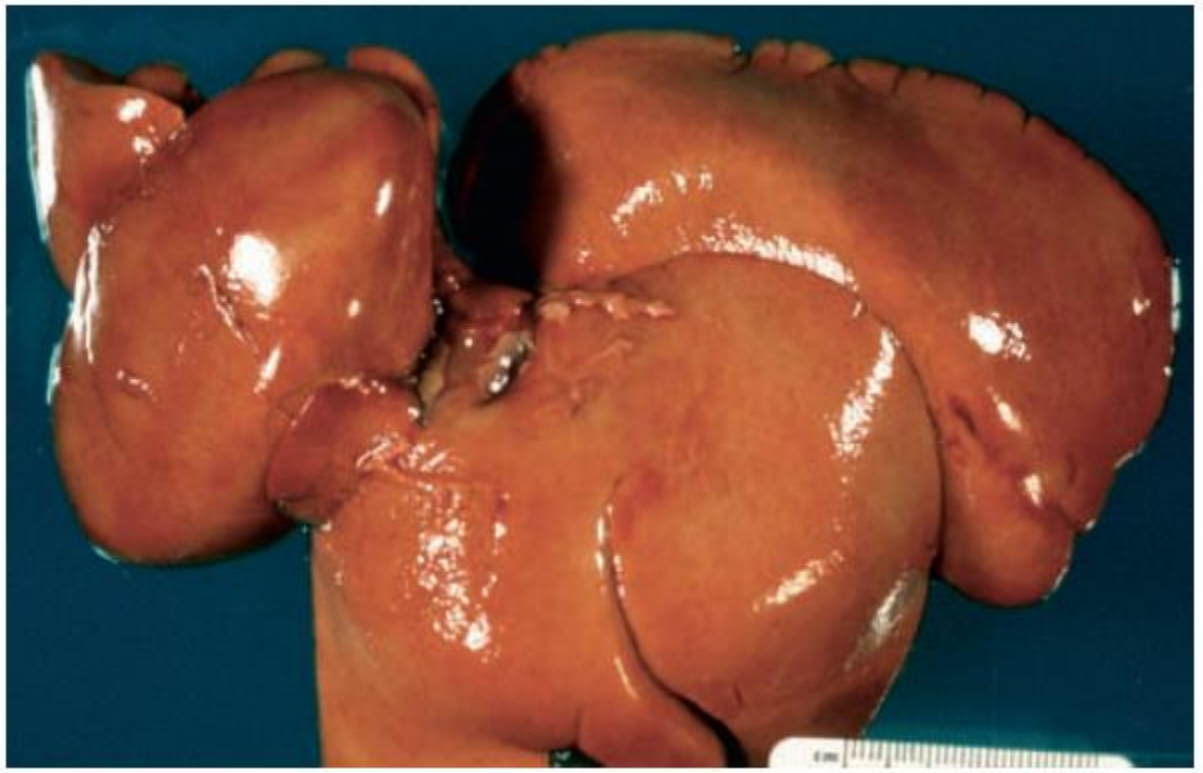
- The pathogenesis of hepatic leptospirosis begins as vascular leptospirosis caused by *Leptospira* spp.

Gross lesions of hepatic leptospirosis

- discrete and coalescing white-to-gray foci of hepatic necrosis scattered at random throughout hepatic parenchyma that are intermixed with hemorrhage

- icterus when animals are infected with serovars that produce hemolysis.

- Hepatic hemorrhage and ascites can occur, depending on the course of infection and the serovar involved.



Swollen necrotic liver from a dog with acute leptospirosis.

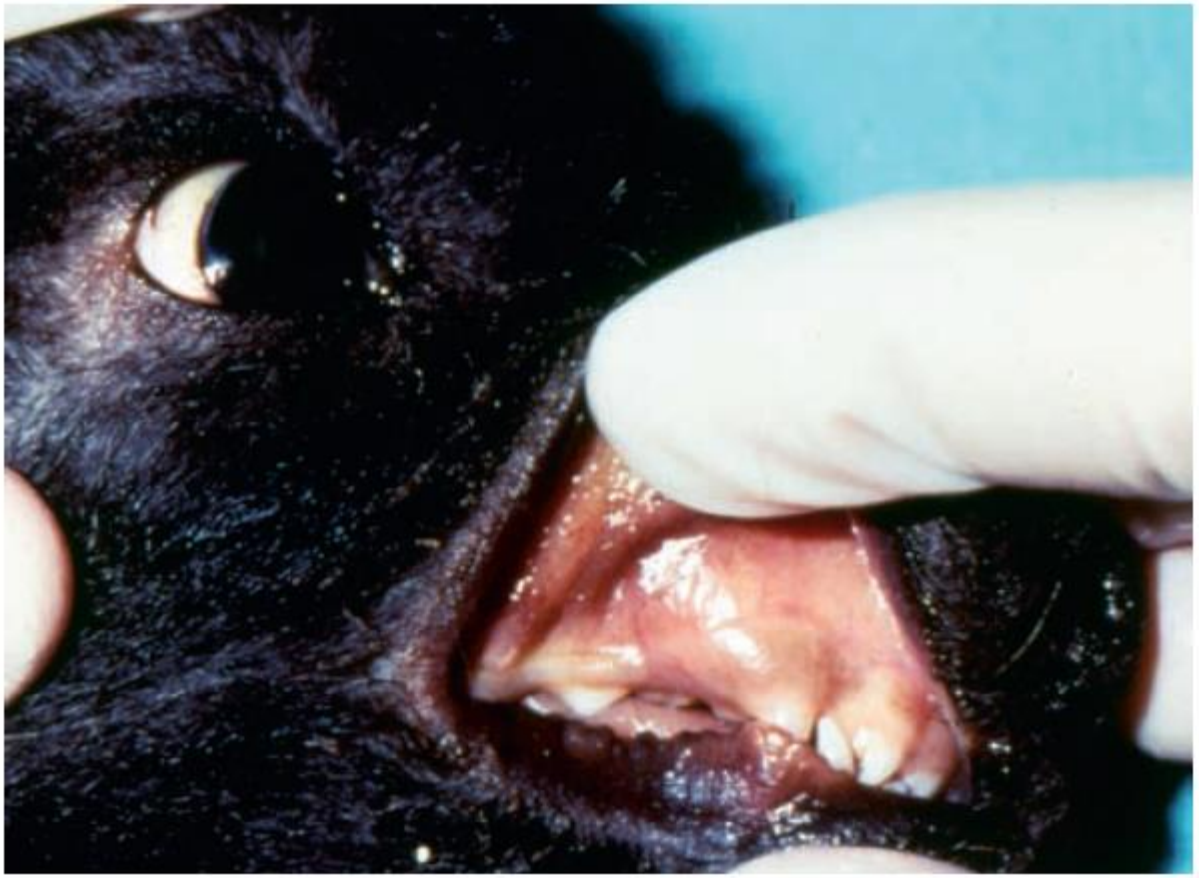
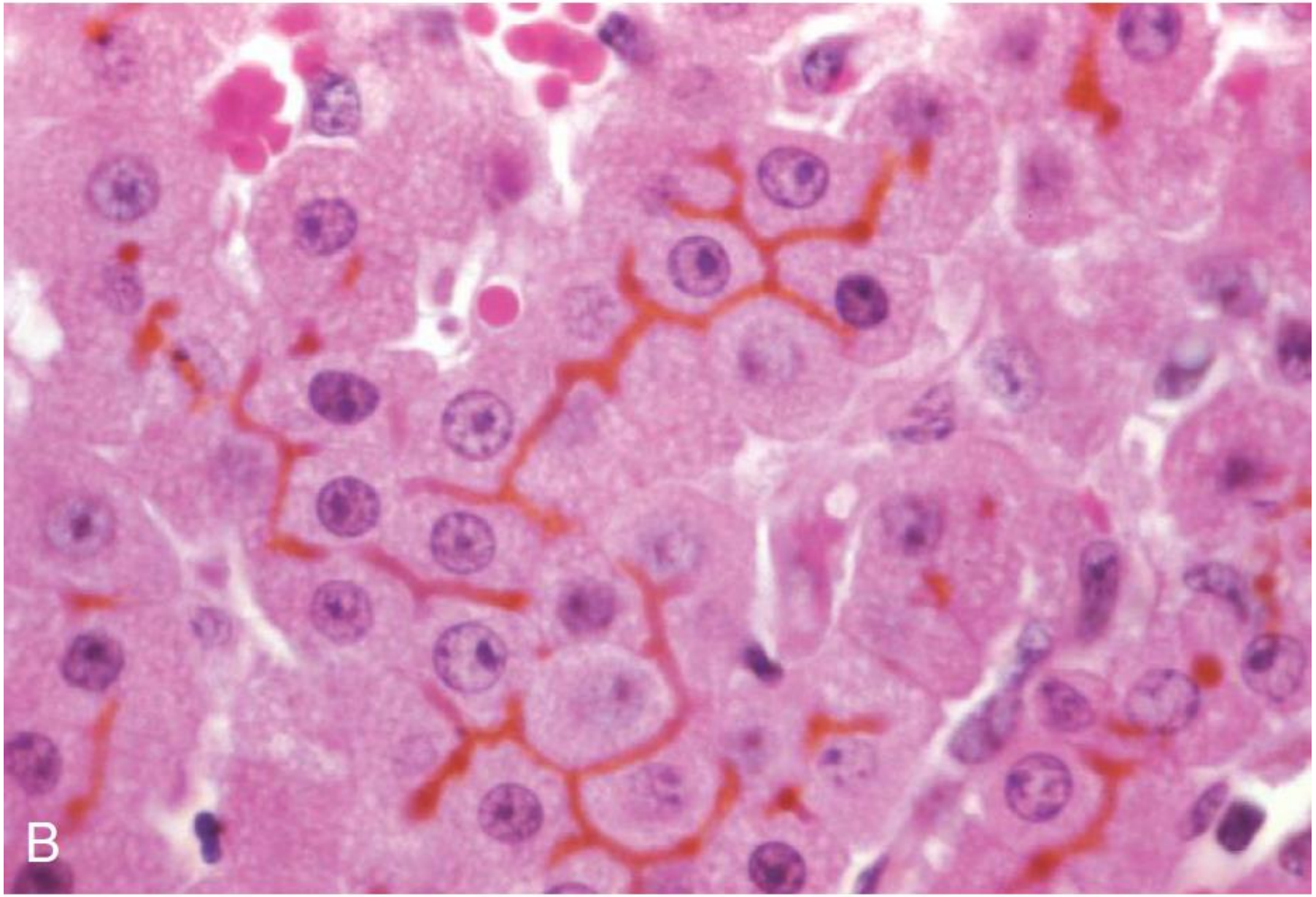


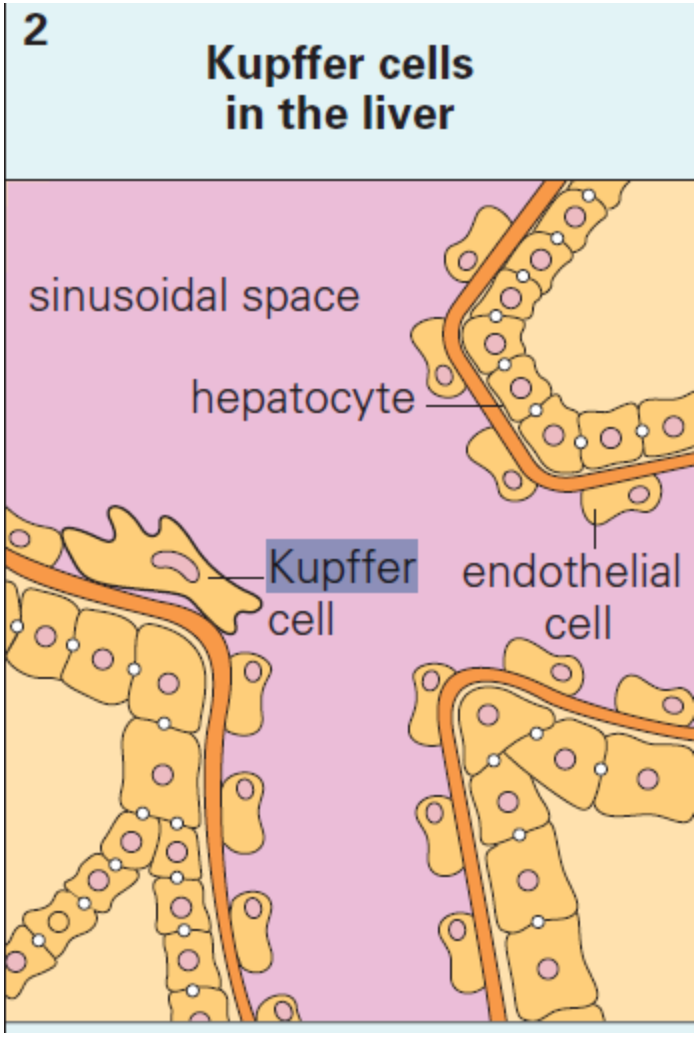
FIG. 42-3 Icterus of mucous membranes of a young pup with acute leptospirosis. (Photograph by Craig Greene © 2004 University of Georgia Research Foundation Inc.)

Microscopic lesions of hepatic leptospirosis

- In some cases, acute infection can cause **focal necrosis** in addition to or instead of **centrilobular necrosis**.
- A common but nonspecific change in the liver of infected dogs is **dissociation of hepatocytes. Affected cells** become **rounded and have eosinophilic granular cytoplasm and dark, shrunken hyperbasophilic nuclei.**
- **Bile casts** in canaliculi are often apparent.
- **Kupffer cells may** contain abundant hemosiderin.



Bile casts in bile canaliculi.


2
Kupffer cells
in the liver
sinusoidal space
hepatocyte
Kupffer
cell
endothelial
cell

Renal Leptospirosis (Leptospira *spp.)*

- The pathogenesis of renal leptospirosis begins as vascular leptospirosis .
- The mechanism of injury in renal leptospirosis is cell death caused by:

(1) physical properties (penetrating movements) of bacteria that disrupt functions of endothelial cells,

(2) bacterial toxins that act directly on membranes of tubular epithelial cells, and

(3) acute and chronic inflammation and their effector molecules and degradative enzymes.

Gross lesions

Gross lesions include

- discrete and coalescing, often linear to radiating white to gray foci of tubular cortical necrosis and acute inflammation intermixed with hemorrhage.

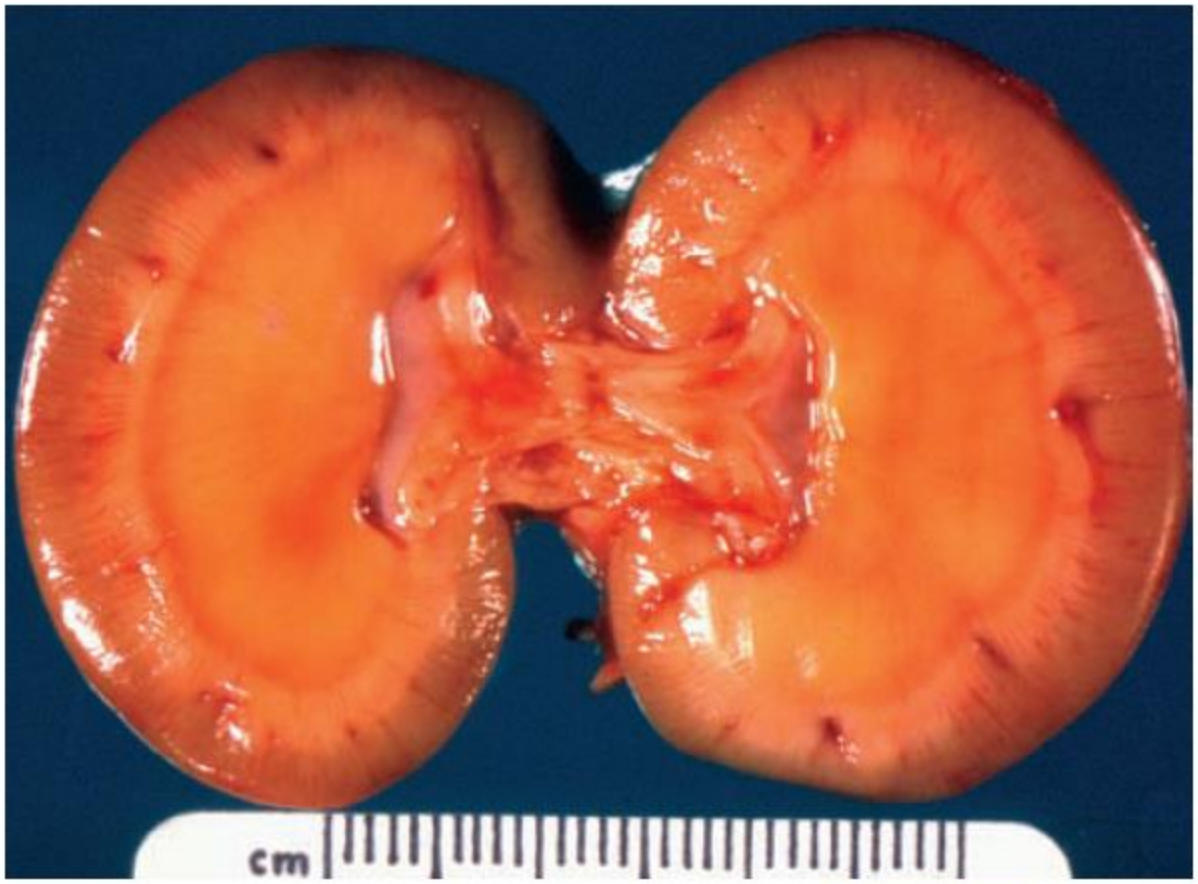
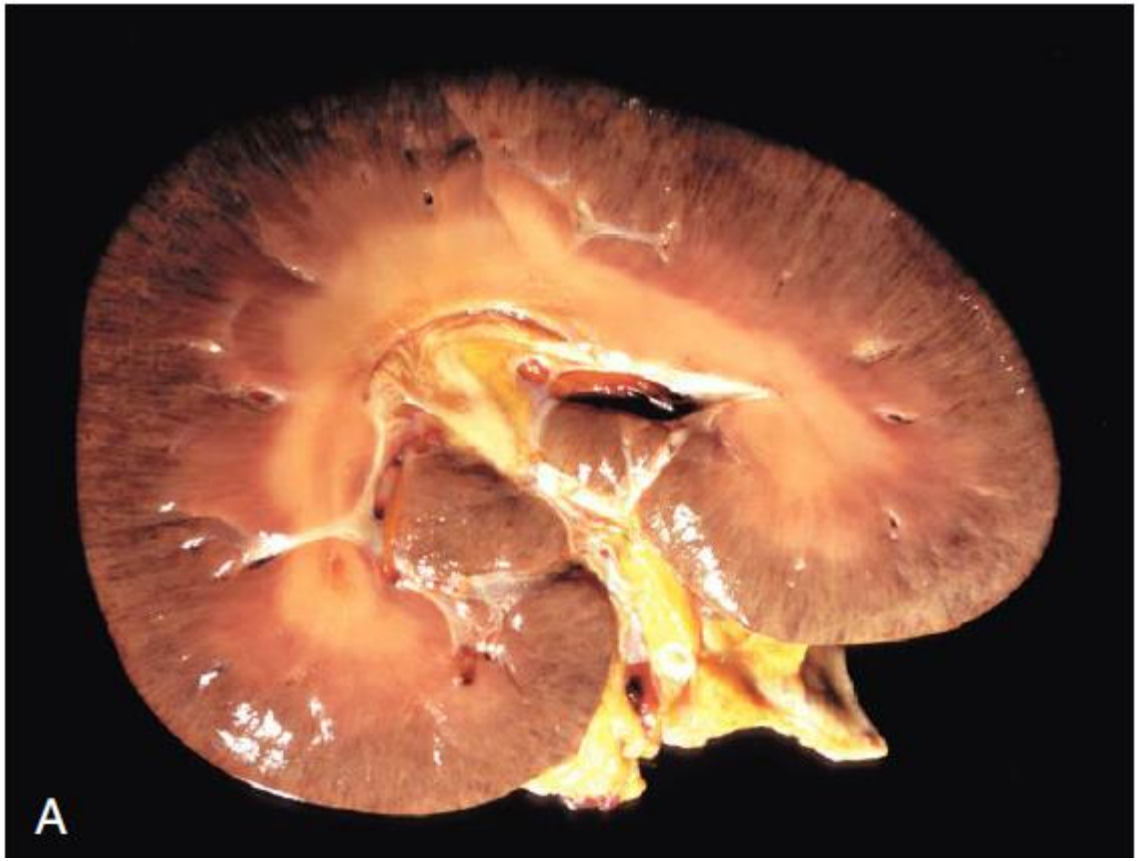


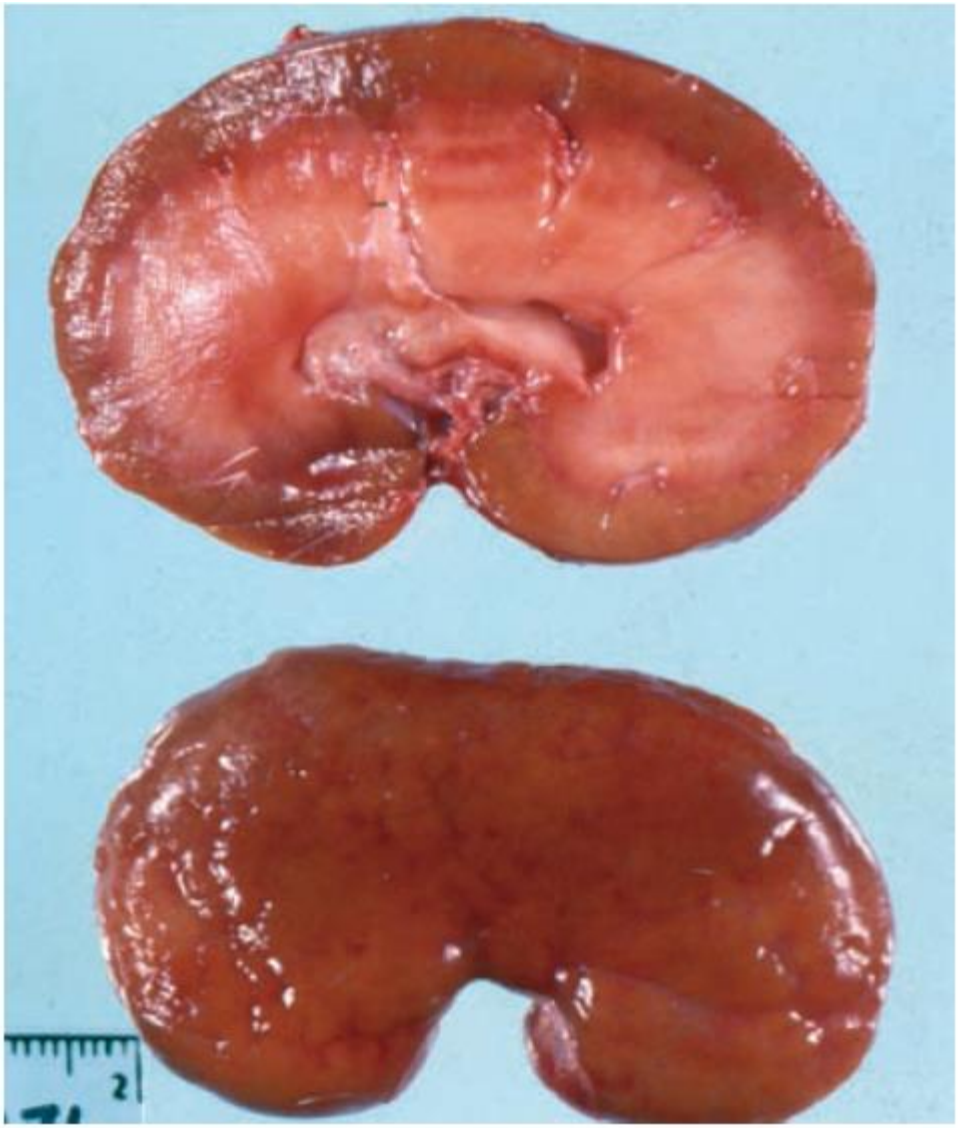
FIG. 42-7 Swollen kidney from a pup that died of acute leptospirosis. (Photograph by Craig Greene © 2004 University of Georgia Research Foundation Inc.)



Acute leptospirosis, kidney.

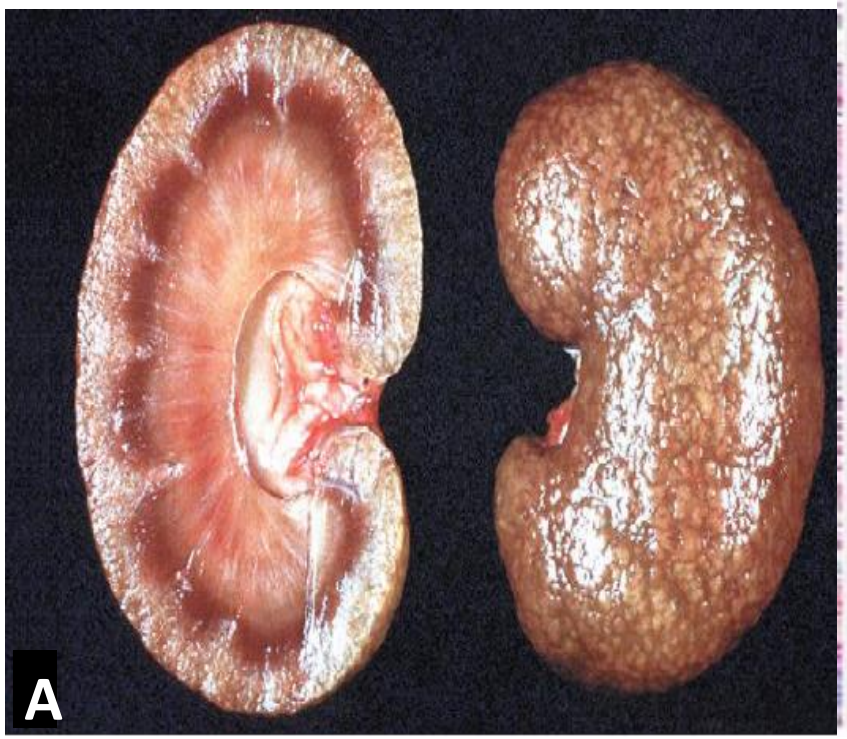
A, Interstitial nephritis, acute leptospira infection, dorsal section, dog. Radiating pale streaks are caused by cortical tubular necrosis, and acute interstitial inflammatory infiltrates. The hilar fat and medulla are yellow from jaundice

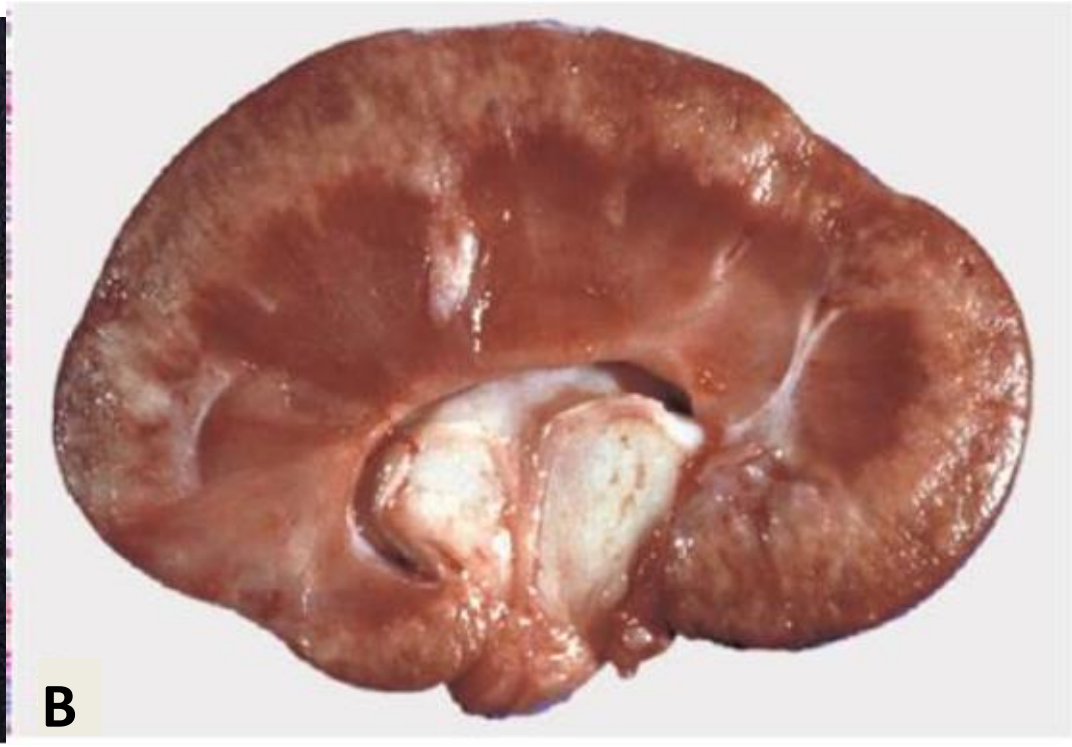
- In chronic renal leptospirosis, lesions include discrete and coalescing, often linear to radiating white to gray foci of chronic inflammation and fibrosis.



Shrunken and fi brotic kidneys from an 8-month-old puppy that had acute icterus and renal failure; the illness had been diagnosed as leptospirosis by serologic testing 5 months previously. The dog had been treated and was clinically

- healthy until the time of death from an automobile accident.





Chronic tubulointerstitial nephritis.

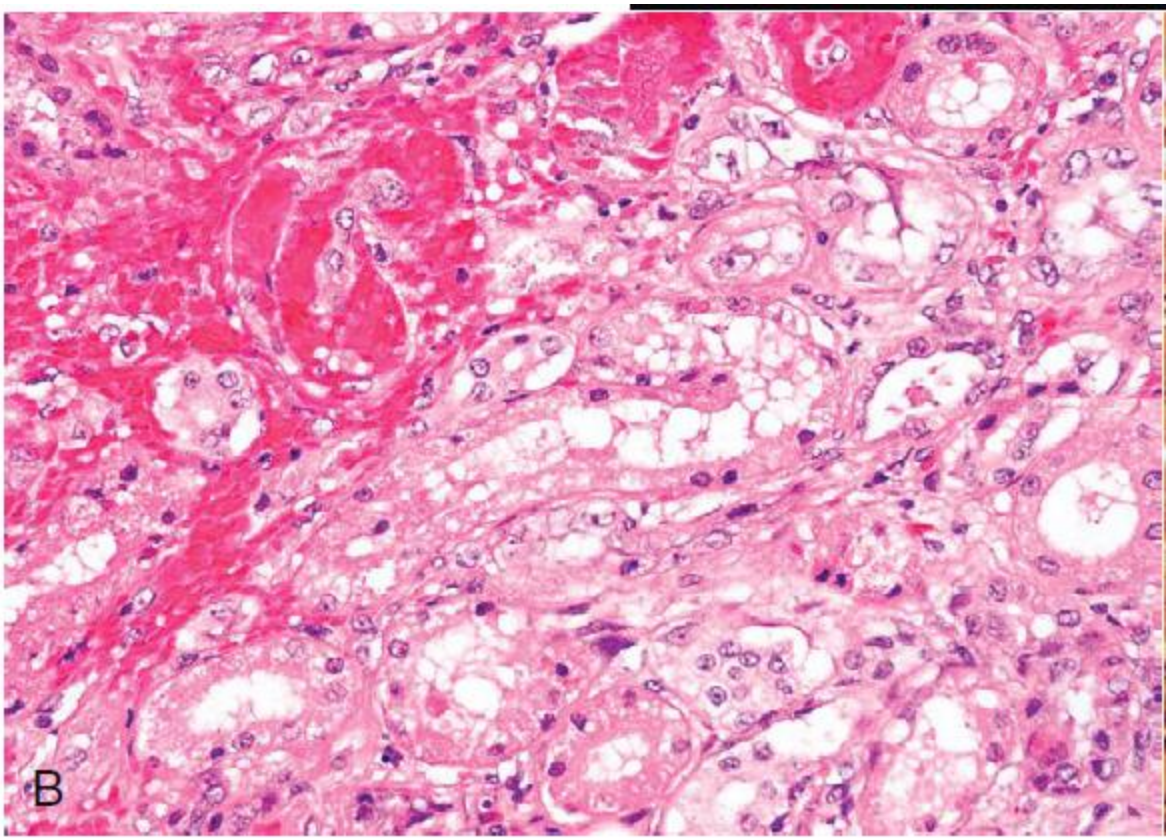
A, Kidney, dorsal surface and dorsal section, dog. Note **the nodularity of the capsular surface (right)** from **cortical interstitial fibrosis** and the **reduced width of the cortex** (**atrophy**) *(left)*.

B,The **pale streaks and foci in the cortex are chiefly interstitial lymphoplasmacytic infiltrates.**

Histopathology

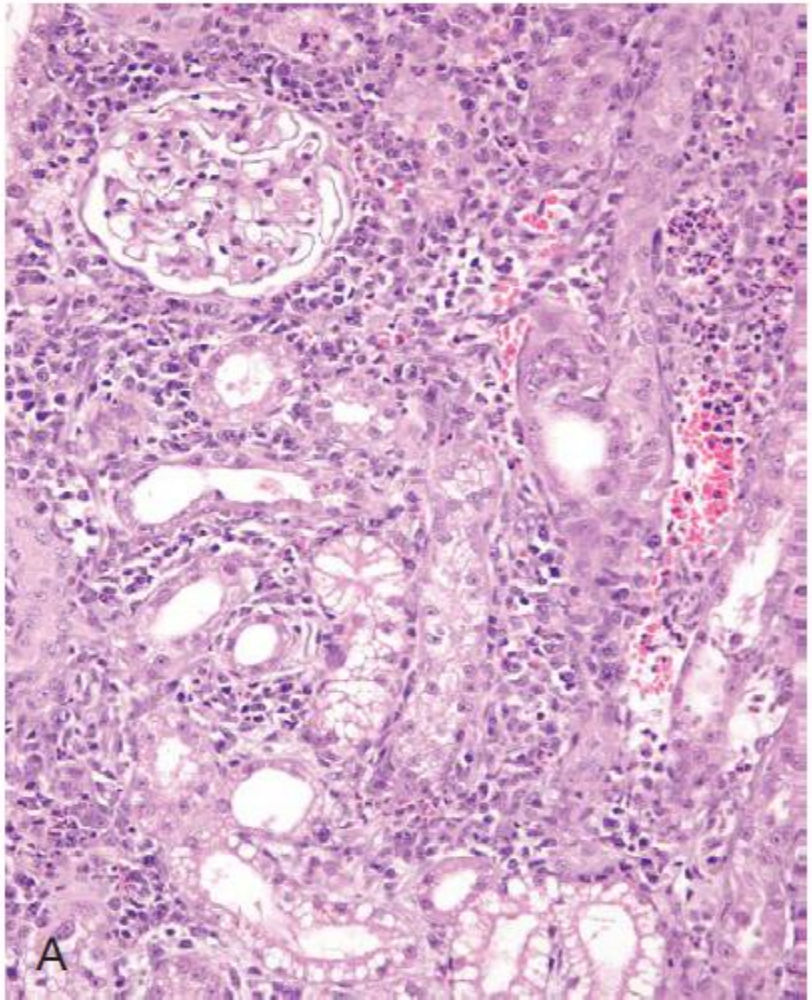
- In the **more acute stages**, in which **tubular damage is prominent**, there will be **neutrophilic infiltrates**, but this rapidly changes to **lymphocytes and plasma cells**.

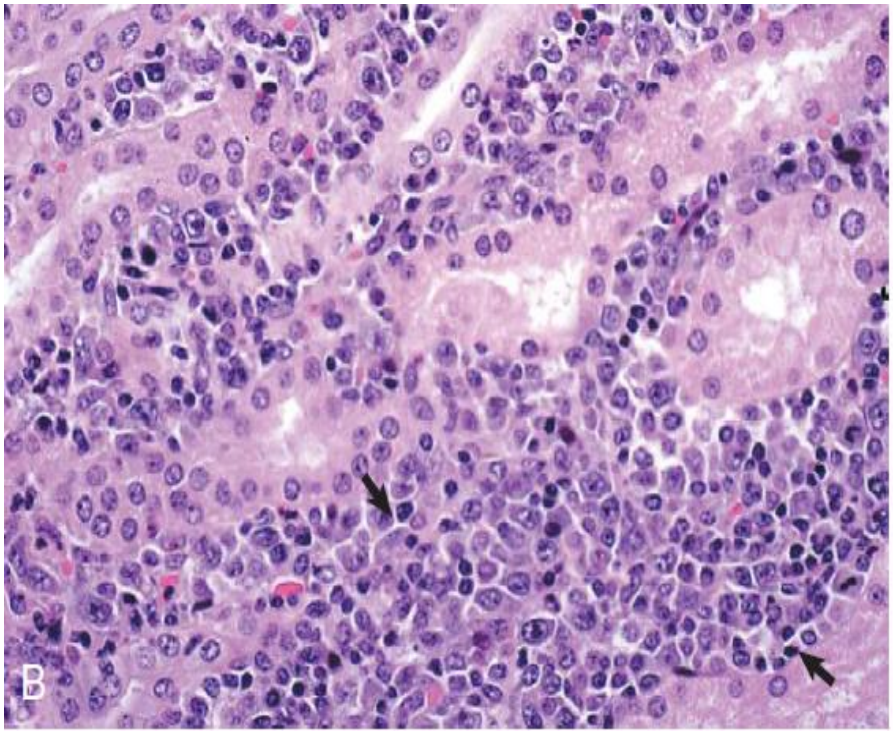
- In **more chronic cases**, variable amounts of **fibrosis** and **subcapsular scarring occur** (Fig, *B*).



B, Acute tubular necrosis, early regeneration, dog. Note the segments of tubular epithelium devoid of nuclei (coagulation necrosis) *(top left)* and the hemorrhage. At this early stage, there is an almost complete lack of inflammatory cells in the interstitium, but later in the subacute stage of leptospirosis there are interstitial infiltrates of lymphocytes and plasma cells, which tend to be near the corticomedullary junction. H&E stain.

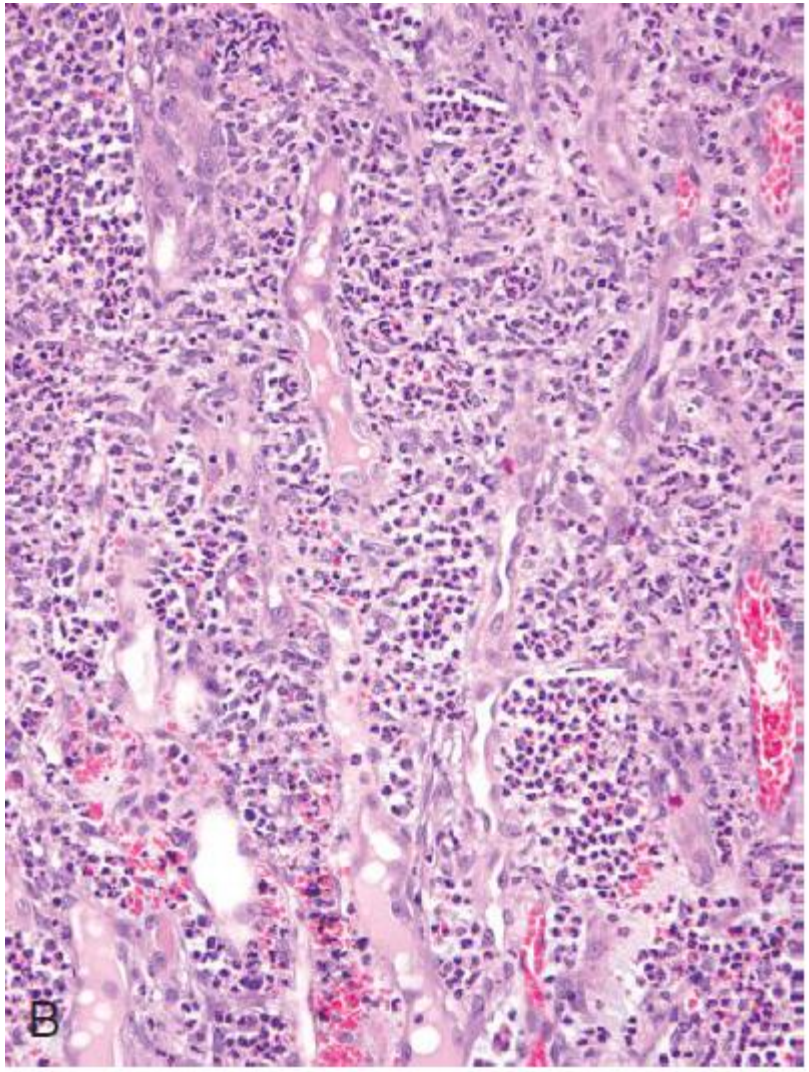
- In the kidney, primary target cells for infection appear to be epithelial cells of the proximal convoluted tubules (cortex) (**Fig., *A***) and then later, epithelial cells of the loops of Henley (medulla) **(Fig., *B*).**





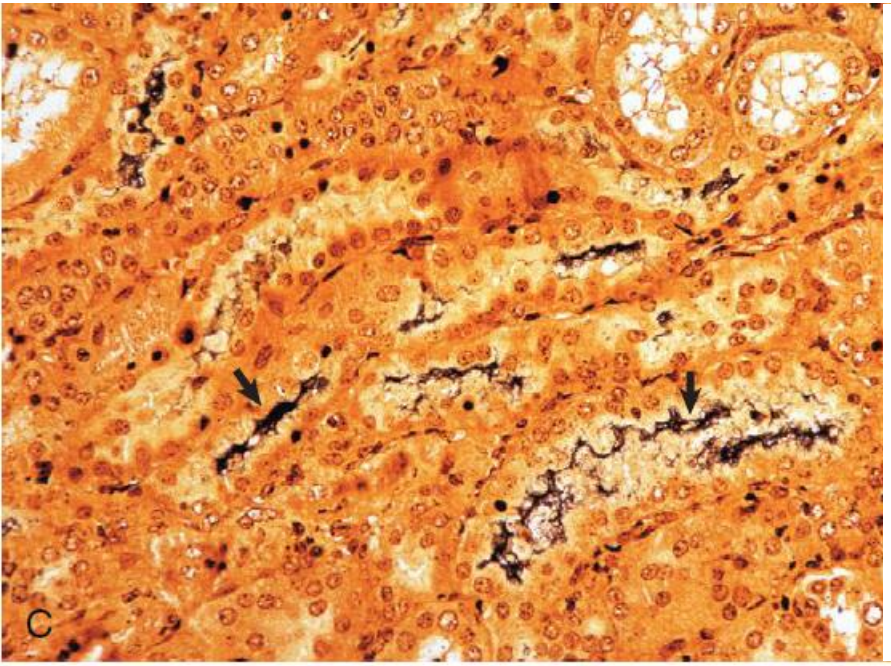
Renal leptospirosis.

A, Kidney, **outer cortex**. Note the **infiltration of mononuclear** cells, chiefly **macrophages, lymphocytes and plasma** cells in the interstitium between the proximal convoluted tubules, the result of the leptospires infecting the proximal tubule cells after exiting the intertubular capillaries.



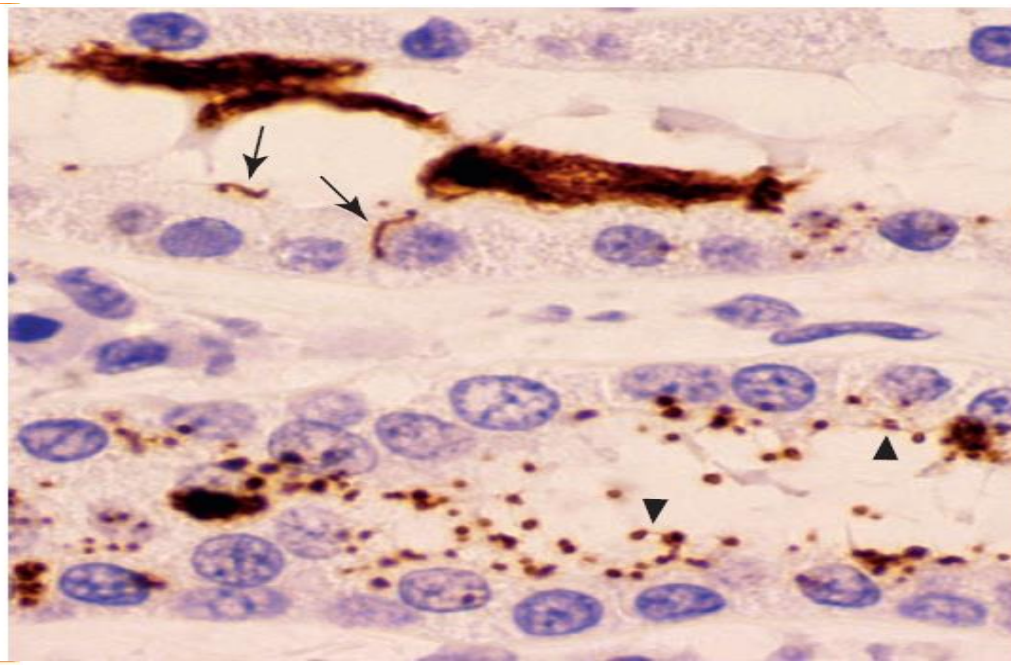
B, Kidney (same as **A**), **inner cortex**. Numerous neutrophils distend the interstitium between the loops of Henle. This acute inflammatory response further down the nephron from the area in **A**, supports the concept that the cells of the loop of Henle are infected later than those in the proximal convoluted tubule. H&E stain.

- **Leptospires** may often be identified within the **cytoplasm** and **the lumen of affected tubules** when special silver stains are used (Fig. *C*) and IHC.



silver stains

Numerous leptospira *(arrows)* are present in the lumens of tubules. Leptospira colonization of tubule epithelial cells is typical of this bacterium. Warthin Starry silver stain



***Leptospira* immunohistochemistry**

Once *Leptospira* spp. gain access to the circulatory system, they disseminate in glomerular capillaries and then intertubular capillaries of proximal convoluted tubules.

Bacteria could access proximal tubular cells via their apical or basolateral surfaces by two routes, vascular by glomerular capillaries and migration into the lumen of the urinary space (apical) or vascular via intertubular capillaries and migration into th interstitium (basolateral).

Because glomerular changes are usually unremarkable and bacteria and inflammation are observed in the interstitium, it appears that epithelial cells of the proximal convoluted tubules are infected via the basal-lateral surfaces of the cells via migration through intertubular capillaries.

The bacteria likely attach to endothelial cell membranes of intertubular capillaries via adhesins then penetrate the vessel wall by moving directly through the cells or through their junctional complexes to gain access to the interstitium. In reality, the distance in the interstitium between capillaries and proximal tubular epithelial cells is probably no more than 100 μm and it is likely that the flagella of these motile bacteria propel them to the epithelial cells.

It is unclear why the bacteria target proximal tubular epithelial cells for infection. Although undetermined, such specificity could be attributed to ligand-receptor interactions or to a chemical gradient, such as an iron concentration, that could be required for bacterial growth and replication.

The bacteria are present in the cytoplasm of these cells; endocytosis and phagosome-lysosome fusion are not involved in cell entry. It appears that the bacteria are able to directly enter these cells via their motility.

The cause of death of proximal tubular cells is probably multifactorial, involving vasculitis and ischemia, trauma from physical injury caused by bacterial motility, inflammatory mediators and degradative enzymes, and bacterial toxins.

The inflammatory cells in this lesion progress from neutrophils (suppurative) to lymphocytes, macrophages, and plasma cells (chronic).

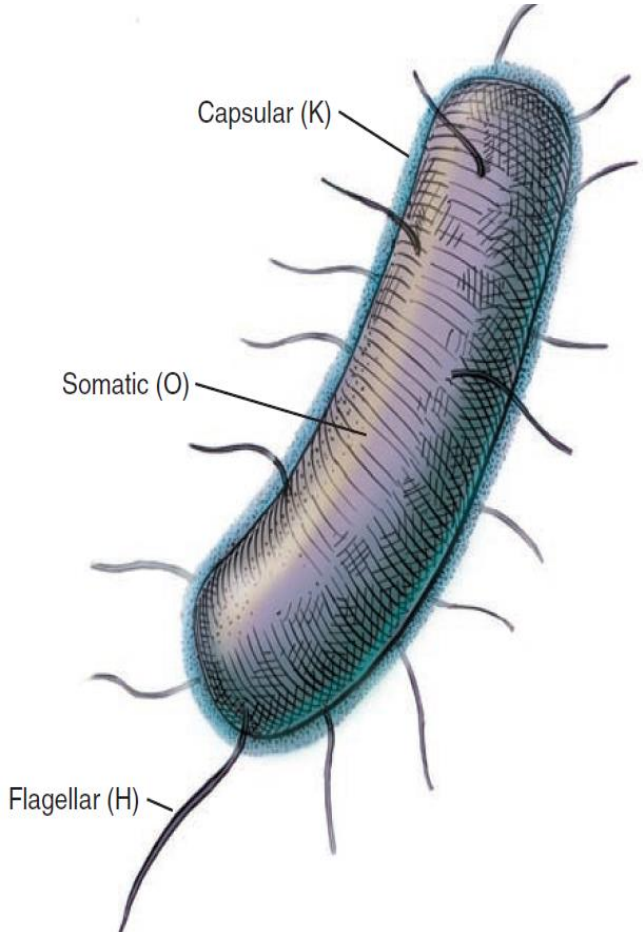
Epithelial cells lining the loop of Henle could also be infected by an intertubular capillary interstitial route. This mechanism has not been confirmed.

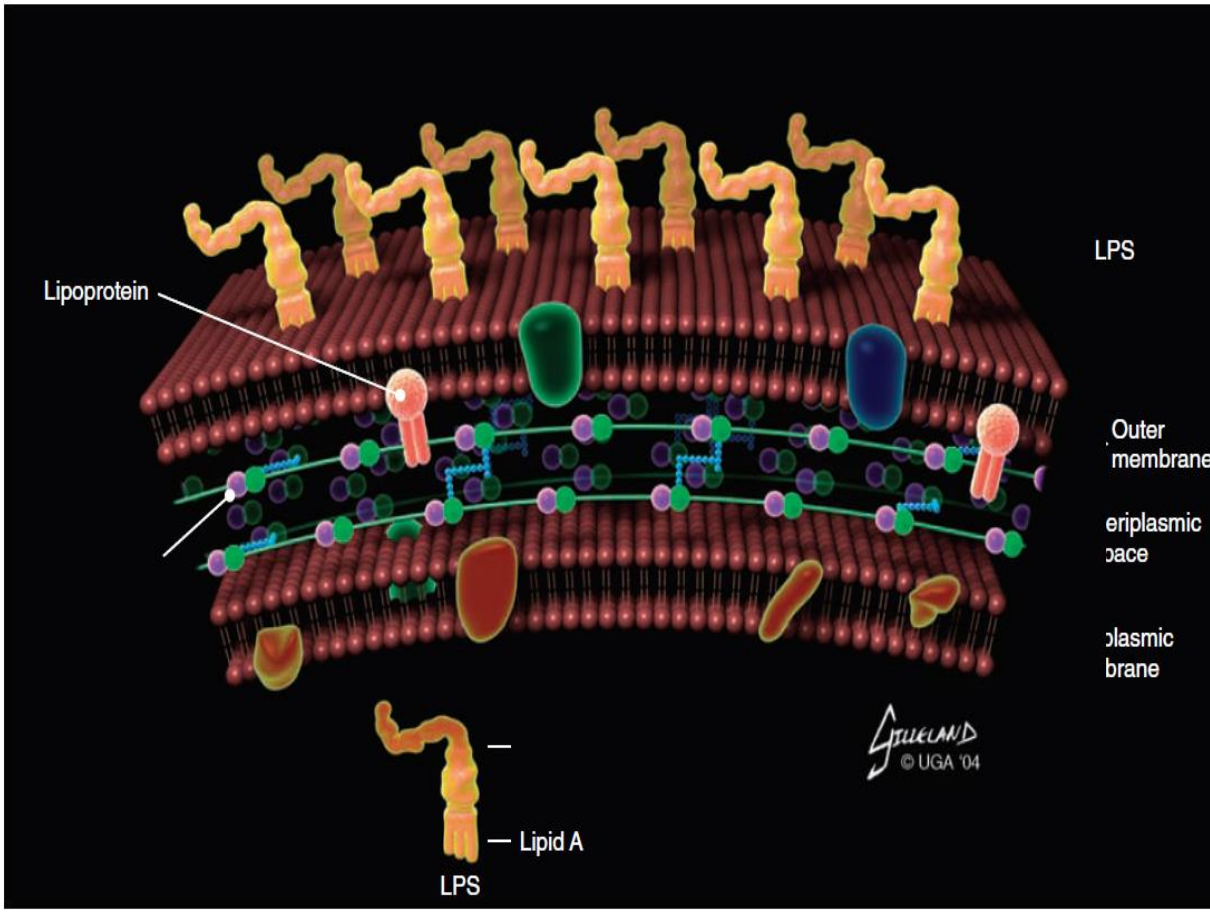
When proximal tubular cells die, they release bacteria into the urinary lumen where they are carried in urine and spread into the environment via urination.

During this luminal transit, the bacteria also encounter the apical surfaces of epithelial cells lining the loop of Henle.

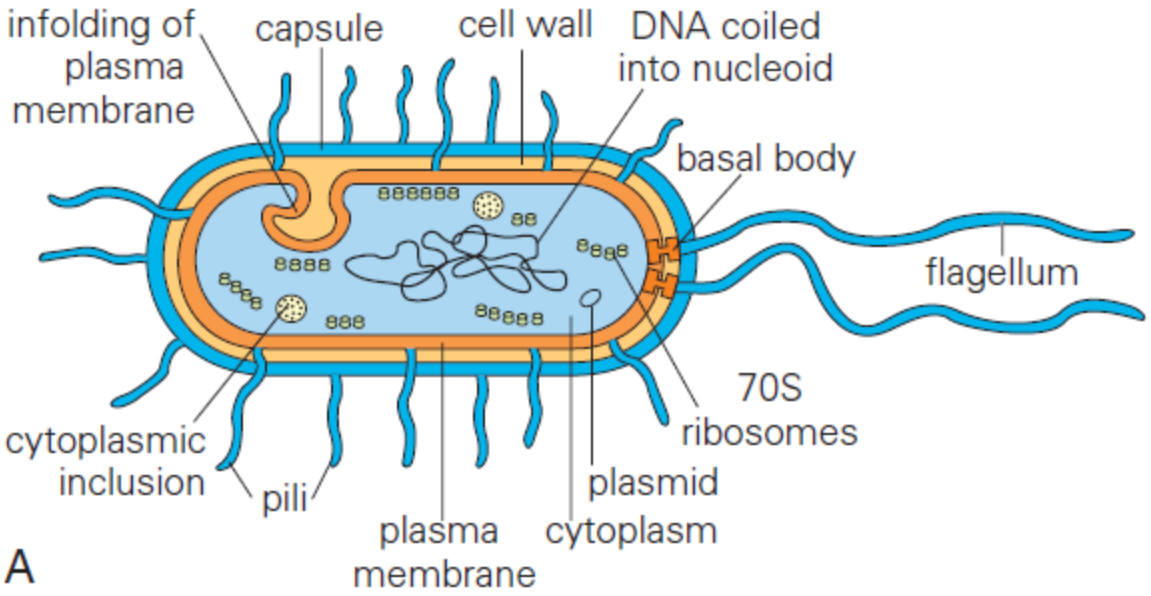
E.coli

E.Coli infection

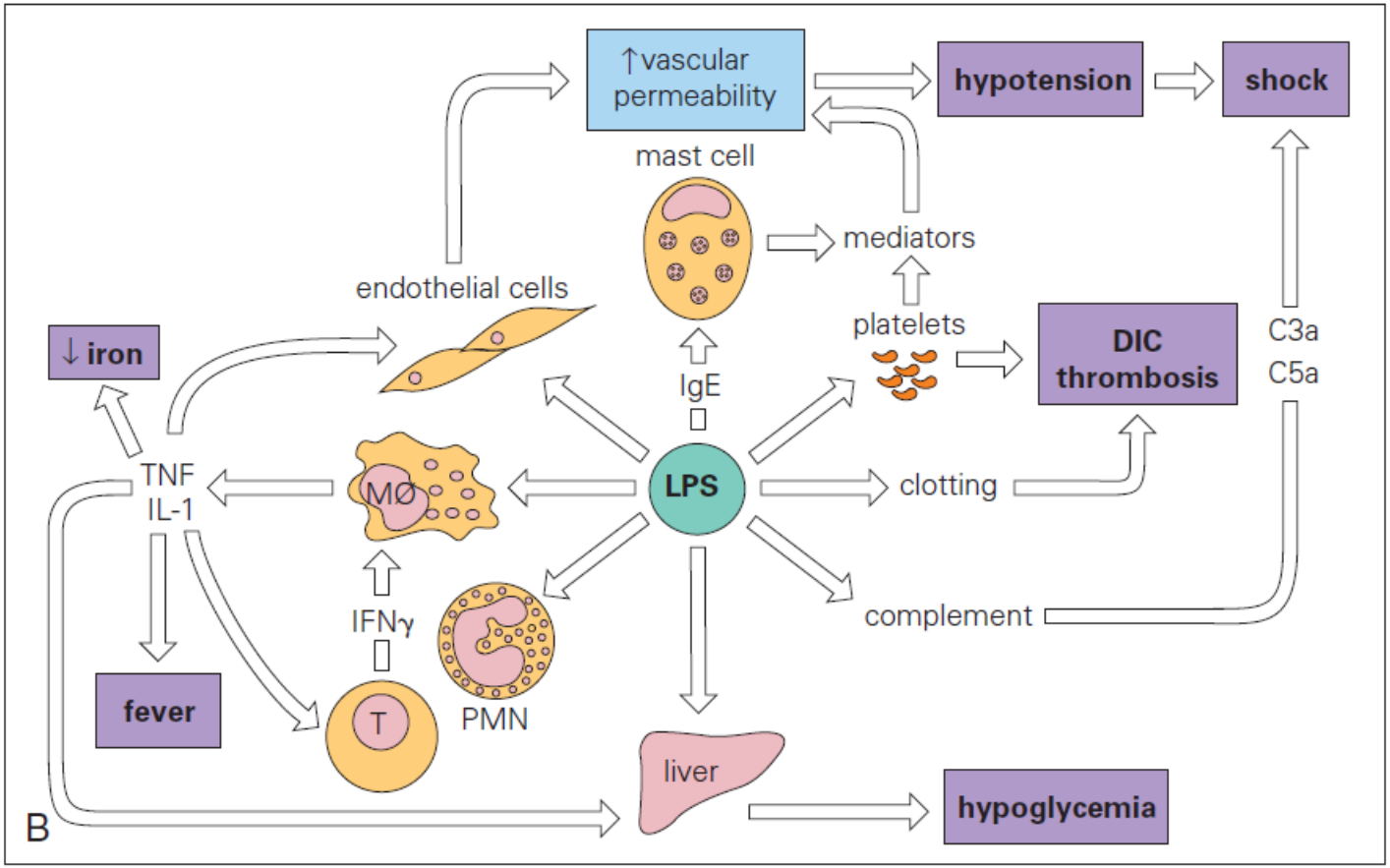




- Structures of cell surface of gram-negative bacterium

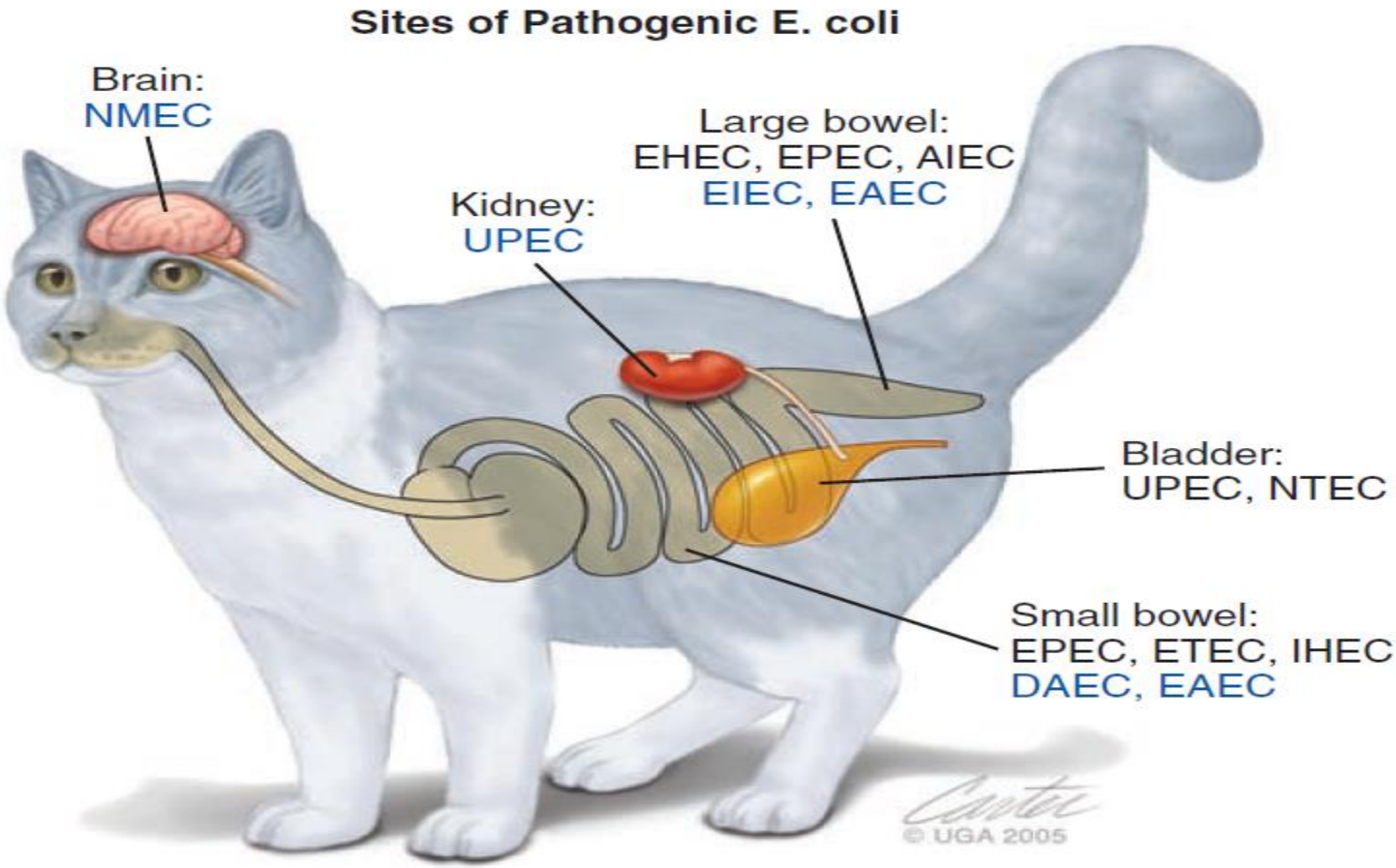

infolding of plasma membrane
capsule
cell wall
DNA coiled into nucleoid
basal body
flagellum
70S ribosomes
cytoplasmic inclusion
pili
plasma membrane
plasmid
cytoplasm

A


↑vascular permeability
hypotension
shock
mast cell
mediators
endothelial cells
platelets
DIC thrombosis
C3a
C5a
↓iron
IgE
TNF
IL-1
MØ
LPS
clotting
IFNγ
complement
fever
T
PMN
liver
hypoglycemia
B

Pathogenic and Clinical Characteristics of Pathogenic *Escherichia coli* Strains

Classification	Mechanism of Pathogenicity	Clinical Characteristics of Pathogenic *Escherichia coli* Strains
Enteropathogenic *E. coli*	Attaching and effacing lesions	Loss of microvilli, watery and chronic diarrhea
Enterohemorrhagic *E. coli* and *E. coli* O157:H7	Attaching and effacing lesions, toxins	Hemorrhagic colitis, diarrhea, hemolytic uremic syndrome
Enterotoxigenic *E. coli*	Toxins	Secretory diarrhea without fever
Necrotoxigenic *E. coli*	Toxins	Diarrhea, sepsis, and urinary tract infections in people; diarrhea, sepsis, and pneumonia in small animals
Adherent invasive *E. coli*	Invasion	Granulomatous colitis
Enteroaggregative *E. coli*	Attachment, toxin	Nonhemorrhagic, watery small bowel diarrhea with some inflammation in humans; not documented in dogs and cats
Enteroinvasive *E. coli, Shigella*	Invasion	Mucohemorrhagic diarrhea with leukocytes (dysentery)
Extraintestinal pathogenic *E. coli* or uropathogenic *E. coli*	Attachment	Urinary tract infections, pneumonia, sepsis, meningitis
Diffusely adherent *E. coli*	Attachment	Small bowel diarrhea and urinary tract infections in humans, not documented in dogs and cats
Neonatal meningitis *E. coli*	Attachment and invasion	Neonatal meningitis in humans, not documented in dogs and cats
Cell-detaching *E. coli*		Diarrhea in children, not documented in dogs and cats



Sites of pathogenic *Escherichia coli* documented in cats, dogs, and humans (*black*) and, as yet, only humans (*blue*). *EPEC* , Enteropathogenic *E. coli* ; *EAEC* , enteroaggregative *E. coli* ; *ETEC* , enterotoxigenic *E. coli* ; *DAEC* , diffusely adherent *E. coli* ; *EHEC* , enterohemorrhagic *E. coli* ; *EIEC* , enteroinvasive *E. coli* ; *NMEC* , neonatal meningitis *E. coli* ; *NTEC* , necrotoxigenic *E. coli* ; *AIEC* , adherent invasive *E. coli* ; *ExPEC* , extraintestinal pathogenic *E. coli* ; *UPEC* , uropathogenic *E. coli* .

Extraintestinal Pathogenic *Escherichia coli*

Some strains of *E. coli* can cause extraintestinal infections, including UTIs, pneumonia, sepsis, and meningitis;

Uropathogenic *E. coli* (UPEC) have been shown to ascend from the bladder through the ureters to the kidneys where they can colonize the collecting ducts, distal and proximal tubules, glomeruli, Bowman ’ s capsule, and the blood vessel walls

- Pyelonephritis
- may be associated with renal abscess formation. 358,427 Renal
- abscesses are rare but may result from hematogenous or contiguous
- spread of bacteria, from penetrating wounds, or from contamination
- associated with renal surgery or biopsy. Renal abscesses may be
- parenchymal or perirenal.

The major host defense mechanisms against UTI are clearance of bacteria through complete voiding and the intrinsic antibacterial properties of the urinary epithelium.

Development of UTI indicates an alteration in the host and bacterial flora relationship.

To accomplish infection, bacteria must attach to and colonize the mucosa of the urethral orifice and transport themselves up the urethra, adhering to the uroepithelium.

Both host defense mechanisms and bacterial virulence properties are important in determining whether infection occurs, as well as which part of the urinary tract is affected (Box 90-6).

BOX 90-6

Major Host Defenses Against Urinary Tract Infection[301]

Normal micturition
Normal anatomy
Intact mucosal defense
Surface glycosaminoglycans
Cell exfoliation
Normal microflora
Local antibody production
Epithelial cell antimicrobial properties
Antimicrobial properties of urine
Hyperosmolality concentration
Tamm-Horsfall mucoprotein
Systemic immunocompetence

Bacteria adhere poorly to healthy bladder epithelium because of the presence of a glycosaminoglycan coating.

This coating, which can be replaced within 24 hours if injured, is extremely hydrophilic, so a layer of water forms at the surface. This aqueous layer provides a barrier between the transitional epithelium and the urine, explaining in part why bladder epithelium can tolerate constant exposure to a substance as irritating as urine.

Infection is more likely to occur if this surface coating is damaged as by uroliths, neoplastic transformation, or exposure to chemical irritants such as cyclophosphamide.

The kidney has no natural barrier against bacterial adherence.

Bladder epithelial cells exfoliate in response to infection and are cleared with the flow of urine, an important defense mechanism.

The bladder epithelium normally has a slow turnover rate of approximately 40 weeks in humans and mice. In humans with a UTI, large numbers of bladder epithelial cells exfoliate. Although this exfoliation is considered a host defense mechanism, it is also a way for bacteria to be spread into the environment and may also expose the underlying epithelial cells to infection.

The antibacterial effects of urine include osmolality, urea concentration, and organic acid concentration

Markedly acidic (pH 5) or highly concentrated urine has an inhibitory effect on bacterial growth.

- The ability of cats to highly concentrate their urine may be one explanation for the low incidence of bacterial UTIs in young cats. However, results of one large study ndicated that decreasing urine specific gravity was not correlated with UTI in cats, although increasing age, chronic renal failure, diabetes mellitus, and uncontrolled hyperthyroidism were associated.

Urine that is less acidic and not well concentrated supports multiplication of urinary tract pathogens almost as well as nutrient broth

Bacterial Virulence Factors

UPEC are a genetically heterogeneous group of *E. coli* that differ from nonpathogenic *E. coli* by the presence of virulence factor genes (see Chapter 35

UPEC typically carry large blocks of genes called pathogenicity-associated islands (PAIs), which are not found in fecal isolates. PAIs code for virulence factors such as hemolysins, adhesins, iron acquisition systems, fimbriae, and toxins.

E. coli from UTIs in dogs has been found to have varying propensities to cause pyelonephritis and renal damage in mice based on urovirulence factors.

pyelonephritis

- Pyelonephritis is rarely responsible for renal failure in the absence of other underlying kidney disease, such as urolithiasis.

- In the early stage of acute renal injury caused by infection, renal tubular cells produce local inflammatory mediators such as cytokines and nitrous oxide, which recruit macrophages and neutrophils. In association with bacterial virulence properties, this leads to renal injury.

- Dogs with acute bacterial pyelonephritis may be systemically ill with fever, depression, anorexia, renal pain, and leukocytosis. Gastrointestinal (GI) signs, particularly vomiting, may be seen.

- Clinical signs in cats with pyelonephritis include fever, lethargy, anorexia, renal pain, and vomiting.

- Chronic pyelonephritis may be asymptomatic or associated with polyuria and secondary polydipsia. Polyuria can occur before the onset of renal lesions and can resolve with eradication of infection.

Uropathogenic *Escherichia coli*

Some uropathogenic strains of *E. coli* , designated UPEC, express virulence factors that facilitate the colonization of the urinary system .

The major determinant of their pathogenicity is the ability to adhere to the uroepithelium via adhesins such as type 1 pili

(mediated by fimbrial adhesion H at its tip) or P fimbriae, the gene of which (*papG*) has been identified in canine isolates.

After attachment, pili and endotoxin incite neutrophil migration and induce the release of cytokines, leading to an inflammatory response and characteristic signs of urgency, discomfort, and hematuria

Virulence factors

Exotoxins, especially hemolysins, may also be important in the development of clinical signs of lower UTIs. Iron acquisition is also an important virulence factor, as are bacterial capsules and antiphagocytic systems.

Numerous virulence factors have been identified in canine and feline UPEC strains, including CNF1 and genes encoding adhesins, hemolysin, and aerobactin.

UPEC can replicate and form protective biofilmlike complexes within the cells. It is possible that this characteristic internalization of the organism may explain some relapsing UTIs in dogs and cats.

UPEC are carried in the colons of many dogs; comparing phylogenetic background, O antigens, and extended virulence genotype, 54% of urinary isolates were also found in the gut.

Hemolytic *E. coli* have also been found in UTIs in cats.

Untreated UPEC cystitis can progress to pyelonephritis if the organism is motile and motility and the degree of type 1 pili expression have been shown to be inversely related.

Within the kidney, pyelonephritis isolates oft en express P fi mbriae and fewer motility

- organelles. 78,79,81,129
- Studies based on the identifi cation of genes encoding adhesins,
- hemolysins, CNF1, and aerobactin suggest that canine uropathic
- strains may be similar if not identical to some human uropathic
- strains. 71 Similarly, *P. mirabilis* strains isolated from the urine of dogs
- have been characterized and found to be similar to human uropathogenic
- *P. mirabilis* strains. Th e signifi cance of these fi ndings for people
- and dogs is not known. 44 ExPEC can also infect almost any anatomic
- site. Pneumonia, sepsis, and meningitis are some of the infections that
- have been observed. Multidrug-resistant strains have been isolated
- from animals with recurrent infections that have been treated with
- several types of drugs. 142

Extraintestinal pathogenic Escherichia coli

- Extraintestinal pathogenic *Escherichia coli* (ExPEC) are gut inhabitants with virulence genes that differ from strains of *E. coli* that are enteropathogens or commensal organisms of the intestine.
- They contain fimbrial adhesins for attachment, cytotoxins and hemolysins responsible for tissue necrosis and hemorrhage, and siderophore receptors to sequester iron.

- ExPEC can be isolated from the feces of many healthy animals, particularly dogs and cats. When the animals are stressed, such as in group housing in shelters, aerosolized bacteria may be inhaled resulting in fulminating **necrohemorrhagic pleuropneumonia**.

Septicemia can result in **urogenital infections**. In addition, meningitis has been reported in humans. There is concern about the zoonotic potential of these

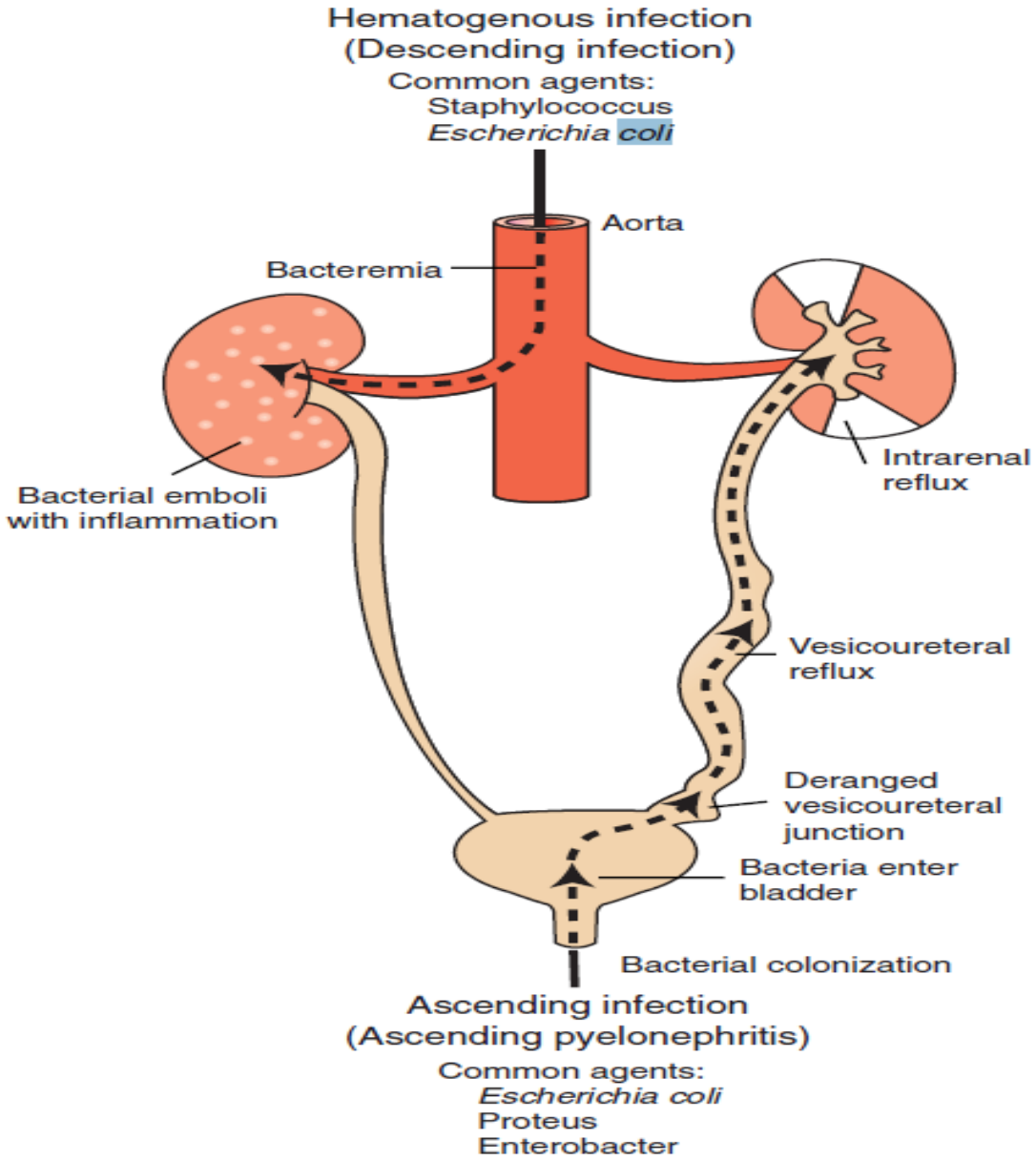
- organisms.

Escherichia coli, especially uropathogenic strains that produce virulence factors such as α-hemolysin, adhesions, and P fimbria, is one of the most common causes of lower urinary tract disease and pyelonephritis

Dogs with acute pyelonephritis can exhibit fever, depression, arched back from lumbar or renal pain, polydipsia, and polyuria.

common causes of bacterial pyelonephritis in order of frequency include infection with *Escherichia coli, Staphylococcus aureus, Proteus mirabilis, Streptococcus* sp., *Klebsiella pneumoniae, Pseudomonas aeruginosa,* and *Enterobacter* sp.

- For the most part, these organisms take advantage of altered lower urinary tract defense mechanisms and ascend from the lower urinary tract to colonize the renal pelvis


Hematogenous infection
(Descending infection)
Common agents:
Staphylococcus
Escherichia coli
Aorta
Bacteremia
Bacterial emboli
with inflammation
Intrarenal
reflux
Vesicoureteral
reflux
Deranged
vesicoureteral
junction
Bacteria enter
bladder
Bacterial colonization
Ascending infection
(Ascending pyelonephritis)
Common agents:
Escherichia coli
Proteus
Enterobacter

A gross diagnosis

A gross diagnosis of pyelonephritis is accomplished by recognizing the existence of pelvic inflammation with extension into thenrenal parenchyma (Fig. 11-53, *A*).

Pyelonephritis can be unilateral, but it is often bilateral and most severe at the renal poles.

The pelvic and ureteral mucous membranes can be acutely inflamed, thickened, reddened, roughened, or granular and coated with a thin exudate.

The pelvis and ureters can be markedly dilated and have purulent exudate in the lumina (Fig. 11-53, *B*). The medullary crest (papilla) is often ulcerated and necrotic.

Renal involvement is notable by irregular, radially oriented, red or gray streaks involving the medulla extending toward and often reaching the renal surface.

Occasionally, inflammation extends through the surface of the kidneys to produce extensive subcapsular inflammation and localized peritonitis

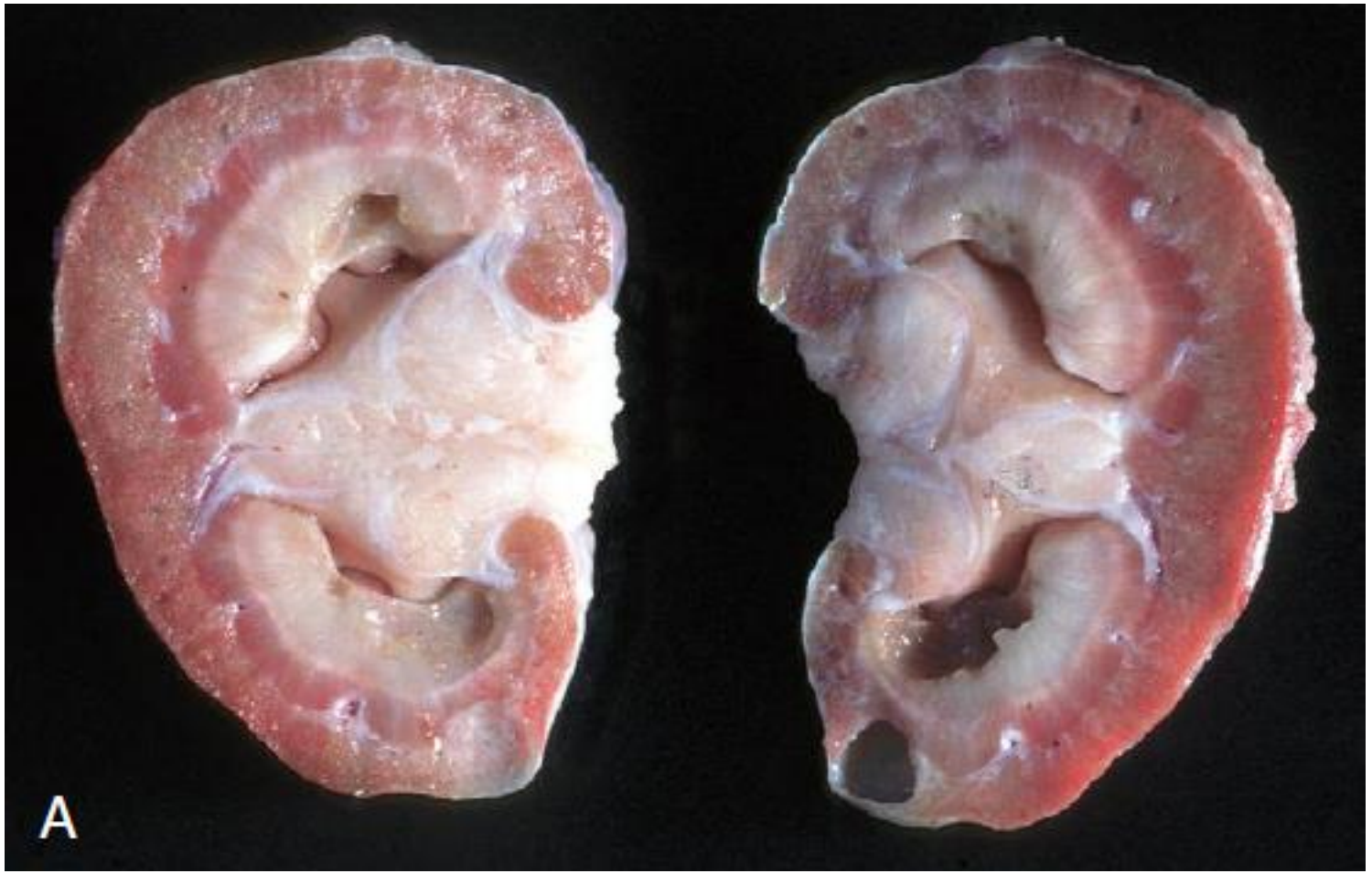


Fig. 11-53 Pyelonephritis, kidney.

A, Dorsal section, dog. **Extensive pelvic inflammation** has destroyed areas ***(gray-white)*** **of the inner medulla and extends focally into the outer medulla**.

Histopathology

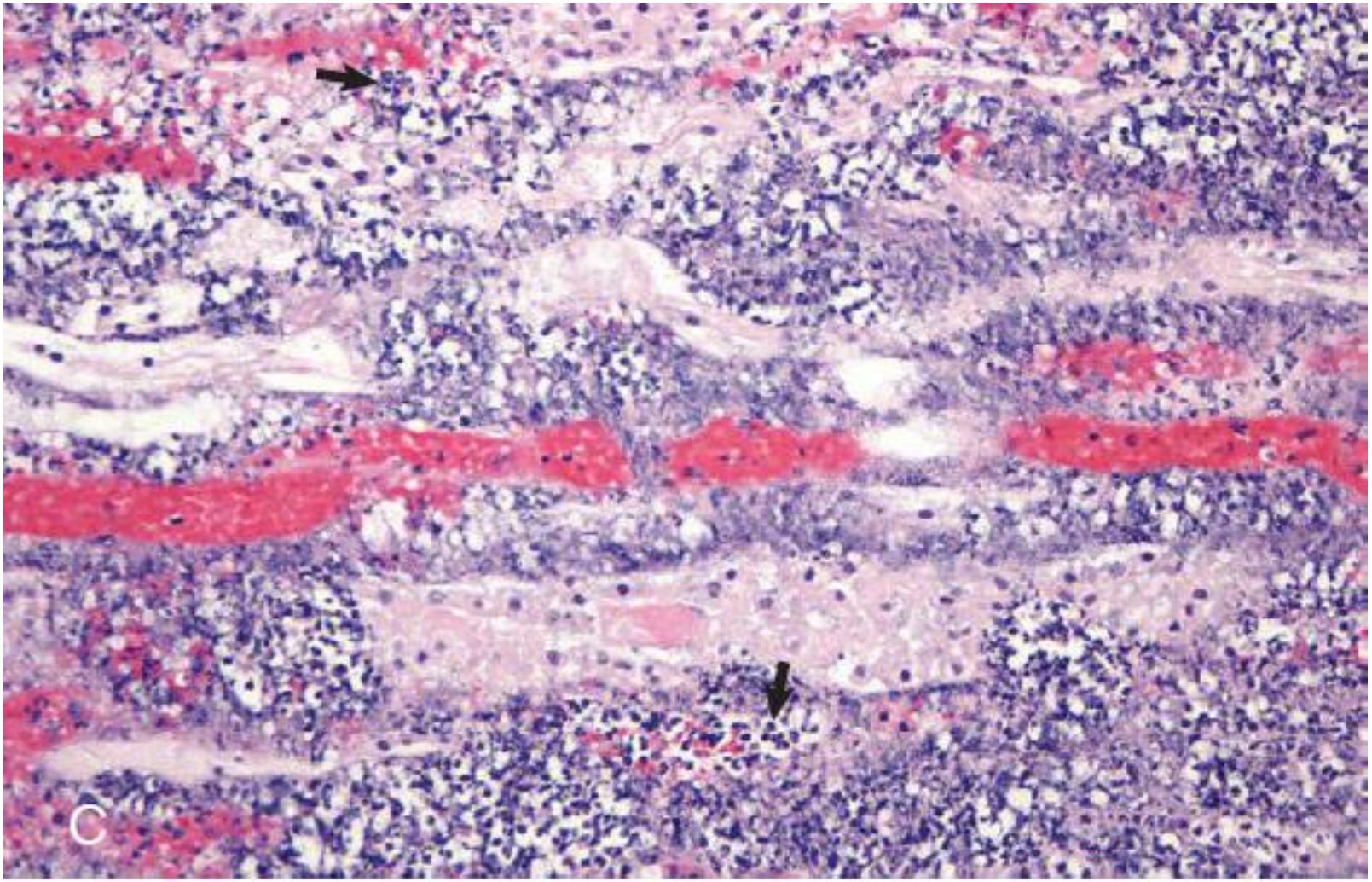
Microscopically, the most severe acute lesions of pyelonephritis are usually in the inner medulla.

1- The transitional epithelium is usually focally or diffusely necrotic and sloughed.

2- Necrotic debris, fibrin, neutrophils, and bacterial colonies can be adherent to the denuded surface.

3-Medullary tubules are notably dilated, and their lumina contain neutrophils and bacterial colonies. Focally the tubular epithelium is necrotic.

4-An intense neutrophilic infiltrate, present in the renal interstitium, can be accompanied by notable interstitial hemorrhages and edema.



C, Dog. There is both intratubular and interstitial inflammation with tubular necrosis, characterized by infiltrates of principally neutrophils *(arrows).* H&E stain.

5- If obstruction of vasa recta has occurred, coagulative necrosis of the inner medulla (papillary necrosis) can be severe.

6-Similar tubular and interstitial lesions, although less severe, extend radially into the cortical tubules and interstitium.

7-When the lesions become **subacute**, the severity of the neutrophilic infiltrates diminishes, and lymphocytes, plasma cells, and monocytes infiltrate the interstitium.

Chronic lesions have severe fibrosis.

If active bacterial infection persists or is untreated, an intense infiltrate of all inflammatory cell types interspersed with tubular necrosis and fibrosis can be seen.

All stages of disease progression can occur in a single kidney.

The renal lesions of chronic pyelonephritis, in which an active bacterial infection exists, include most of the elements of acute inflammation described previously and extensive necrosis of the medulla, patchy fibrosis in the outer medulla and cortex, and variable amounts of pelvic inflammatory exudates.

Chronic pyelonephritis often produces a grossly visible deformity of the renal parenchyma because of extensive interstitial inflammation and scarring (Fig. 11-54).

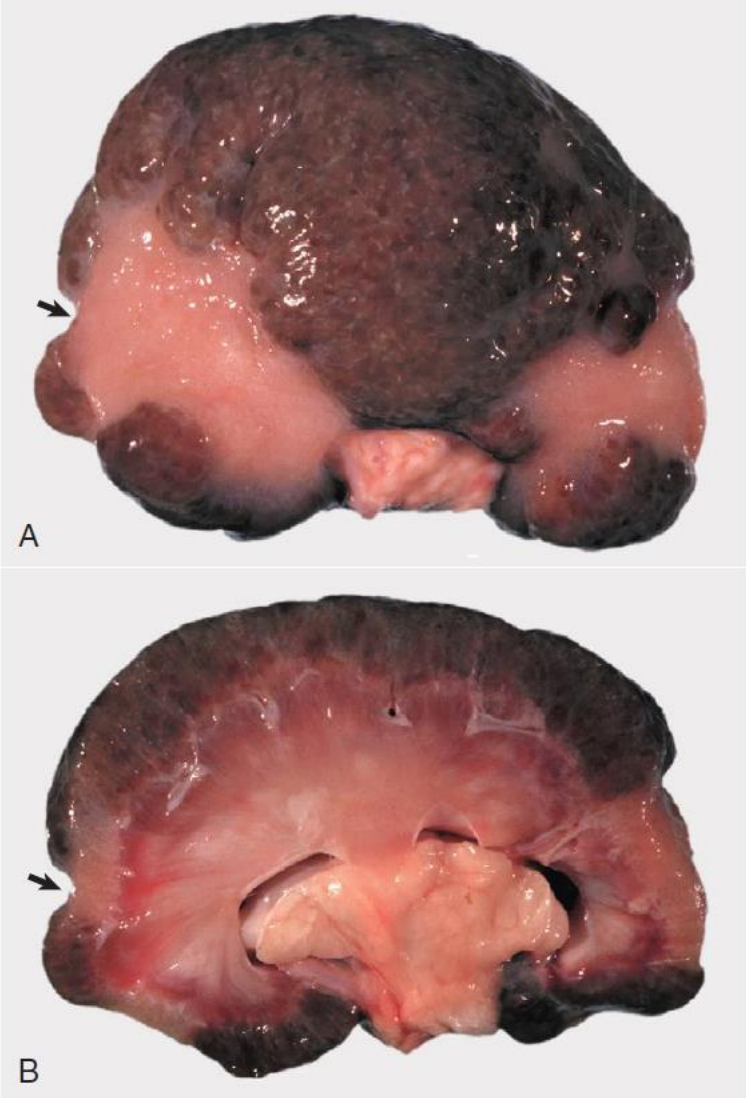


Fig. 11-54 Chronic pyelonephritis, kidney, dog.

A, Note the two large polar scars visible as large indentations on the capsular surface *(arrow).* The fine gray spots are regions of chronic inflammatory infiltrates and fibrosis.

B, Dorsal section. The cortical scars are localized to the renal poles *(arrow),* but there is a finely stippled pattern of nodularity and fibrosis in the remaining kidney.

This polar pattern of scarring suggests previous bouts of pyelonephritis.

Fibrosis secondary to the tubulointerstitial inflammation of pyelonephritis follows the pattern of the acute disease (targeting the renal poles), and results in irregularly distributed, patchy scarring that is seen as deeply depressed regions on the renal capsular surface and linear areas extending through both the cortex and medulla to the pelvis. Such lesions often resemble chronic polar infarcts.