Figure 13-01. Schematic illustration of the hematopoietic hierarchy in the bone marrow. The bone marrow consists of: (1) stem cells, pluripotent cells capable of self-renewal; (2) committed progenitor cells (myeloid and lymphoid progenitor cells); and (3) maturing cells. Maturing cells develop from cells called colony-forming units (CFUs). The myeloid stem cell gives rise to CFUs responsible for the regeneration of red blood cells (erythroid CFUs), platelets (megakaryocyte CFUs), basophils (basophil CFUs), and eosinophils (eosinophil CFUs). Monocytes and neutrophils are derived from a common committed progenitor cell (granulocyte-macrophage CFU). The lymphoid progenitor cell generates the B-lymphocyte progeny in the bone marrow and T-lymphocyte progeny in the thymus.
Figure 13-02. Normal hematopoiesis, canine bone marrow aspirate. ESE, Early stage erythroid; ESM, early stage myeloid; LSE, late stage erythroid; LSM, late stage myeloid. Wright’s stain
Figure 13-03. Schematic illustration of the bone marrow. The bone marrow can be red because of the presence of hematopoietic elements, or yellow, owing to fat. Hematopoietic tissue may replace fat, or vice versa, depending on the demand for hematopoiesis. In the adult, red bone marrow is found in the skull, clavicles, vertebrae, ribs, sternum, pelvis, and ends of the long bones of the limbs. Blood vessels and nerves reach the bone marrow by piercing the bony shell. The nutrient artery enters the midshaft of a long bone and branches into central longitudinal arteries that connect with the venous sinuses. The venous sinuses empty into the central longitudinal vein, which runs parallel to the nutrient artery. The internal surface of the bone is lined by trabeculae projecting into the marrow cavity. The endosteum lines the bony surface.
Figure 13-07. Schematic illustration of the organization of the thymus. The thymus consists of several incomplete lobules. Each lobule contains an independent outer cortical region, but the central medullary region is shared by adjacent lobules. Trabeculae, extensions of the capsule down to the corticomedullary region, form the boundary of each lobule. The cortex consists of stromal cells and developing T lymphocytes (thymocytes), macrophages, and cortical epithelial cells. Major histocompatibility complex class I and II molecules are present on the surface of the cortical epithelial cells. The characteristic deep blue nucleus staining of the cortex in histological preparation reflects the predominant population of T lymphocytes as compared with the less basophilic medulla, which contains a lower number of thymocytes. Hassall's corpuscles are a characteristic component of the medulla. Hassall’s corpuscles are not seen in the cortex. (}
Schematic illustration of the histology of the thymus. The functional thymus consists of two cell populations; the stromal cells and the thymocytes. The stromal cells include (1) the subcapsular epithelial cells also lining the trabeculae and perivascular spaces; (2) the cortical epithelial cells of ectodermal origin; (3) the medullary epithelial cells of endodermal origin that give rise to Hassall’s corpuscles; (4) macrophages present in both cortex and medulla, involved in the removal of apoptotic thymocytes eliminated during clonal selection; and (5) dendritic cells of bone marrow origin, confined to the medulla. 

TCR, T-cell receptor
Figure 13-10. Schematic illustration of the histology of the lymph node and lymph circulation
Figure 13-11. Hemal node, ruminant. Hemal nodes resemble lymph nodes except that the sinuses are filled with blood. H&E stain.
Figure 13-13. Icterus, immune-mediated hemolytic anemia, subcutaneous fat, splenomegaly, spleen, dog. The marked yellow discoloration of tissues, most strikingly visible in the subcutaneous fat, is from high concentrations of serum bilirubin produced as a result of the hemolytic anemia.
Figure 13-14. **Splenomegaly, fatal hemolytic anemia, *Mycoplasma suis*, pig.** The spleen is extremely enlarged, meaty, and congested.
Figure 13-19A. Common erythrocyte morphologic abnormalities. A, Blood from a dog with a microcytic hypochromic iron-deficiency anemia was mixed with an equal volume of blood from a normal dog before blood smear was prepared. Because the hypochromic (pale-staining) cells are leptocytes (Fig. 13-19, F), they have diameters similar to normal cells even though they are microcytic cells. Wright-Giemsa stain
Figure 13-19B. Common erythrocyte morphologic abnormalities. B, Echinocytes appear as erythrocytes with scalloped borders; consequently, the old term “crenation” from Latin meaning “notched” is used. Wright-Giemsa stain.
Figure 13-19C. Common erythrocyte morphologic abnormalities. C, Three acanthocytes with irregularly spaced, variably sized spicules in blood from a dog with hemangiosarcoma. Wright-Giemsa stain.
Figure 13-19D. Common erythrocyte morphologic abnormalities. D, A keratocyte, exhibiting what appears to be a ruptured “vesicle” in blood from a cat with hepatic lipidosis. Wright-Giemsa stain
Figure 13-19E. Common erythrocyte morphologic abnormalities. E, A schistocyte (*left*), discocyte (*top*), and echinocyte (*bottom*) in blood from a dog with disseminated intravascular hemolysis. Wright-Giemsa stain.
Figure 13-19F. Common erythrocyte morphologic abnormalities. F, Two thin flat hypochromic-appearing erythrocytes (leptocytes), with increased membrane-to-volume ratios, are present in blood from a dog with severe iron-deficiency anemia. The bottom leptocyte is folded. Wright-Giemsa stain.
Figure 13-19G. Common erythrocyte morphologic abnormalities. G, Three codocytes in blood from a Cairn terrier with a regenerative anemia and hepatic hemochromatosis secondary to pyruvate kinase deficiency. These erythrocytes exhibit a central density or “bull’s-eye” and are often referred to as target cells. Wright-Giemsa stain.
Figure 13-19H. Common erythrocyte morphologic abnormalities. H, Three eccentrocytes and a discocyte (left) in blood from a dog with oxidant injury induced by the administration of acetaminophen. The cell at top center appears spherical with a small tag of cytoplasm and may be referred to as a pyknocyte. Wright-Giemsa stain.
Figure 13-23.  **Sinus histiocytosis, lymph node, medulla, dog.** The sinuses (1) are filled with mostly macrophages and a few scattered neutrophils (small dark nuclei). Most of the macrophages are derived from the perisinusoidal macrophages, but some may arrive via the afferent lymphatics. The medullary cords (2) are filled with lymphocytes and plasma cells. Plasma cell precursors are formed in the germinal centers, mature into plasma cells, and migrate to the medullary cords. Thus the presence of large numbers of plasma cells in the medullary cords is indicative of ongoing production of antibody from an antigenic stimulus.
Figure 13-24. Follicular lymphoid hyperplasia, conjunctiva, lymphoid nodules, cow. The diffuse lymphoid tissue has increased in size, and there are two follicles with germinal centers (arrows). This reaction is a frequent response to conjunctivitis from irritants and bacteria. H&E stain
Figure 13-25A. Aplastic anemia, canine bone marrow. **A,** Bone marrow aspirate from a dog 8 days after ingestion of a toxic dose of 5-fluorouracil showing stromal cells but a lack of developing blood cells. **B,** Bone marrow aspirate from the same dog one week later, after resumption of hematopoiesis. *Inset,* Higher magnification of Fig. 13-25, *B* shows early- and late-stage erythroid and granulocytic precursors. Wright’s stain.
Figure 13-25B. Aplastic anemia, canine bone marrow. **A,** Bone marrow aspirate from a dog 8 days after ingestion of a toxic dose of 5-fluorouracil showing stromal cells but a lack of developing blood cells. **B,** Bone marrow aspirate from the same dog one week later, after resumption of hematopoiesis. **Inset,** Higher magnification of Fig. 13-25, **B** shows early- and late-stage erythroid and granulocytic precursors. Wright’s stain
Figure 13-26. **Neonatal isoerythrolysis, foal.** Note the enlarged spleen (also liver) and icterus. The newborn foal had colostrum-derived maternal antibodies, which reacted against its own erythrocytes. Macrophages in the splenic red pulp remove erythrocytes whose membranes have bound antibody.
Figure 13-28A. *Cytauxzoonosis, cat.* **A,** Lymph node aspirate. A large macrophage is laden with schizonts of *Cytauxzoon felis.* Wright’s stain. **B,** Splenic macrophages are filled with *Cytauxzoon* organisms. H&E stain
Figure 13-28B.  **Cytauxzoonosis, cat. A**, Lymph node aspirate. A large macrophage is laden with schizonts of *Cytauxzoon felis*. Wright's stain. **B**, Splenic macrophages are filled with *Cytauxzoon* organisms. H&E stain
Figure 13-29A. Hemotropic parasites, bovine blood smear. A, Trypanosomiasis. Trypanosomes are flagellated protozoa characterized by an undulating membrane, kinetoplast, and nucleus. They may be identified in a wet mount made from the buffy coat portion of the packed cells.
Figure 13-29B. Hemotropic parasites, bovine blood smear. B, Anaplasmosis, *Anaplasma marginale*. Note the darkly stained organism, most of which are located on the edges of the erythrocytes. Anaplasmosis causes anemia mainly by immune-mediated extravascular hemolysis.
Figure 13-31. *Mycoplasma haemofelis, cat.* Note the splenomegaly, hepatomegaly, and icterus caused by infection of erythrocytes with this hemotropic parasite. Splenomegaly and icterus are the result of increased destruction (extravascular hemolysis) of infected erythrocytes
Figure 13-32.  Granulocytic ehrlichiosis, *Anaplasma phagocytophila*, canine blood smear. The top neutrophil contains an inclusion consistent with an *Anaplasma phagocytophila* morula. Wright’s stain.
Figure 13-33A. Pelger-Huët anomaly, feline blood smear. Eosinophil (A) and neutrophil (B) have hyposegmented nuclei with mature, condensed chromatin. Wright’s stain
Figure 13-36. Lymphoma (lymphosarcoma), vertebral canal, epidural space, cow. Bilateral ventrally located soft pink masses compress the spinal cord. In addition to lymph nodes, lymphoma in cattle often involves other locations, such as abomasum, vertebral canal, kidney, heart, retro-orbital space, and uterus.
Figure 13-37.  Alimentary lymphoma (lymphosarcoma), stomach, cat. Note the notable thickening of the stomach, which occurred because of infiltration with neoplastic cells. Although uncommon, the mucosal epithelium is focally ulcerated.
Figure 13-38A.  Multiple myeloma and monoclonal gammopathy.  A, Canine bone marrow aspirate. Many of the neoplastic plasma cells in the bone marrow aspirate have pink-tinged cytoplasm, the result of a high concentration of immunoglobulin. Wright’s stain.
Figure 13-39. **Plasmacytoma, oral mucosa, dog.** Note the moderately well-differentiated plasma cells arranged in small clusters separated by a fibrovascular stroma. H&E stain
Figure 13-40B. Histiocytic sarcoma, canine mesenteric lymph node. The neoplastic cells are round cells with abundant gray-blue cytoplasm. Note the following features of malignancy: A, The low-magnification image shows notable variation in cell and nuclear sizes. B, The high-magnification image shows multinucleation, prominent nucleoli, and mitotic figures, as well as a background population of lymphocytes. Wright’s stain
Figure 13-43. Combined immunodeficiency disease, spleen, foal. The large pale pink areas are splenic trabeculae. Note the almost total absence of white pulp. H&E stain.
Figure 13-44. *Equine herpesvirus 1, spleen, aborted foal.* Most of the splenic follicle is occupied by nuclear debris, the result of lymphocytolysis. The splenic follicle is surrounded by a small rim of red pulp. H&E stain.
Figure 13-45A. Effect of ionizing radiation, atrophy of the thymus, cortex and medulla. A, Normal thymus. The cortex is heavily populated with numerous thymocytes. The medulla (bottom right) contains fewer of these cells. H&E stain. B, Thymus exposed to ionizing radiation. Note the depletion of lymphocytes in both cortex and medulla and the preservation of Hassell’s corpuscles (pink, concentric layers). H&E stain.
Figure 13-45B.  Effect of ionizing radiation, atrophy of the thymus, cortex and medulla.  

**A**, Normal thymus. The cortex is heavily populated with numerous thymocytes. The medulla (*bottom right*) contains fewer of these cells. H&E stain.  

**B**, Thymus exposed to ionizing radiation. Note the depletion of lymphocytes in both cortex and medulla and the preservation of Hassell’s corpuscles (pink, concentric layers). H&E stain
Figure 13-46. Lymphoma (lymphosarcoma), thymus, dog. The large pale mass in the cranial mediastinum is a thymic lymphosarcoma that has displaced the lungs caudad.
Figure 13-47A. **Uniform splenomegaly.** A, Congested bloody spleen. This condition occurs secondary to compromises in vascular flow into and out of the spleen (e.g., torsion), from intravenous barbiturates (e.g., euthanasia or anesthesia), and from acute hyperemia from septicemia. B, Meaty spleen. This condition most commonly results from proliferation of cells, most frequently macrophages in the red pulp and increased splenic phagocytosis in, for example, septicemias and bacteremias.
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Figure 13-48. Splenic congestion from barbiturate euthanasia, horse. The spleen is enlarged and congested from storage of blood.
Figure 13-49. Splenic congestion from barbiturate euthanasia, dog. The red pulp vascular spaces are markedly distended by blood. One focus of white pulp—a splenic follicle with a pale germinal center—is present in the lower right. H&E stain.
Figure 13-50A. Histoplasmosis, spleen, dog. A, There is uniform splenomegaly and the surface of the spleen is mottled from the diffuse granulomatous infiltrate. B, Cross section of spleen. The red pulp has been almost completely replaced by diffuse noncaseous granulomatous inflammation.
Figure 13-50B. Histoplasmosis, spleen, dog. A, There is uniform splenomegaly and the surface of the spleen is mottled from the diffuse granulomatous infiltrate. B, Cross section of spleen. The red pulp has been almost completely replaced by diffuse noncaseous granulomatous inflammation.
Figure 13-51. **Lymphoid hyperplasia, cross section of spleen, dog.** Each of the 1- to 3-mm pale foci consists of hyperplastic periarteriolar lymphoid sheaths and splenic follicles. These structures are not visible in the normal spleen but become enlarged and visible from marked lymphoid hyperplasia or from lymphoma.
Figure 13-52A. Lymphoma (lymphosarcoma). A, Spleen and liver, dog. The spleen is grossly enlarged with pale subcapsular nodules. The mottled appearance of the liver is caused by infiltration of malignant lymphocytes into the portal areas. B, Spleen, cow. The pale horizontal band on the upper right is a trabeculum. The remainder of the spleen is diffusely infiltrated by malignant lymphocytes, which have completely obliterated all normal architecture. Note the absence of any normal red or white pulp. H&E stain.
Figure 13-52B. Lymphoma (lymphosarcoma). A, Spleen and liver, dog. The spleen is grossly enlarged with pale subcapsular nodules. The mottled appearance of the liver is caused by infiltration of malignant lymphocytes into the portal areas. B, Spleen, cow. The pale horizontal band on the upper right is a trabeculum. The remainder of the spleen is diffusely infiltrated by malignant lymphocytes, which have completely obliterated all normal architecture. Note the absence of any normal red or white pulp. H&E stain.
Figure 13-53. **Amyloid spleen, dog.** The spleen is pale beige, firm and waxy, and uniformly distended in this advanced case of amyloidosis.
Figure 13-54. Hematoma, spleen, dog. The ventral extremity of the spleen has a large hematoma on its visceral surface. Note the two nodules of splenic hyperplasia (dorsal extremity), a common site for hematomas to occur (Fig. 13-59).
Figure 13-55A. **Subcapsular hematoma, spleen, dog.** A, Note the separation of the splenic capsule from the underlying parenchyma by a mass of blood. B, The yellow material is bilirubin, resulting from the breakdown of erythrocytes in a subcapsular hemorrhage.
Figure 13-55B.  **Subcapsular hematoma, spleen, dog.**  

A, Note the separation of the splenic capsule from the underlying parenchyma by a mass of blood.  

B, The yellow material is bilirubin, resulting from the breakdown of erythrocytes in a subcapsular hemorrhage.
Figure 13-56A. Hemangiosarcoma, spleen, dog. A, There are multiple nodules on the dorsal extremity and a large nodule on the ventral extremity of the spleen.
**Figure 13-56B. Hemangiosarcoma, spleen, dog.** B, The ventral mass has been incised to reveal the stroma of the hemangiosarcoma.
Figure 13-57. **Hemangiosarcoma, spleen, dog.** Note the haphazardly arranged vascular channels lined by anaplastic endothelial cells. H&E stain
Figure 13-58. **Chronic splenic infarct, spleen, dog.** Note the characteristic pale, wedge-shaped area with its base against the capsule of the spleen.
Figure 13-59A. Nodular hyperplasia, spleen, dog. A, A hemispherical 4-cm diameter nodule is protruding from the capsular surface. B, Cross section of the nodular mass showing intermixed red and white areas composed of proliferating erythroid cells and proliferating leukocytes.
Figure 13-59B.  Nodular hyperplasia, spleen, dog. A, A hemispherical 4-cm diameter nodule is protruding from the capsular surface. B, Cross section of the nodular mass showing intermixed red and white areas composed of proliferating erythroid cells and proliferating leukocytes.
Figure 13-60. **Metastatic carcinoma, spleen, ox.** The white mass is an undifferentiated carcinoma, which has metastasized to the spleen. Note the lobular texture of the mass and how it bulges from the cut surface.
Figure 13-61. Subcapsular splenic abscesses, *Rhodococcus equi*, spleen, horse
Figure 13-62. Chronic multifocal suppurative splenitis, splenic abscesses, *Arcanobacterium pyogenes*, spleen, cow. Multiple encapsulated abscesses are present throughout the parenchyma of the spleen, the result of a previous bacteremia.
Figure 13-63A. Sidero-calcific plaque, spleen, dog. A, Multiple, sometimes confluent raised yellow-white plaquelike foci (sidero-calcific plaques) are present on the capsular surface of the body of the spleen. Note the nodular hyperplasia (incised). B, The sidero-calcific plaque lies in the fibrous connective tissue of the capsule and consists chiefly of calcium (blue) and hemosiderin (brown) in fibrous connective tissue. The yellow material is bilirubin, resulting from the breakdown of erythrocytes in a capsular hemorrhage. H&E stain
Figure 13-63B. Sidero-calcific plaque, spleen, dog. A, Multiple, sometimes confluent raised yellow-white plaquelike foci (sidero-calcific plaques) are present on the capsular surface of the body of the spleen. Note the nodular hyperplasia (incised). B, The sidero-calcific plaque lies in the fibrous connective tissue of the capsule and consists chiefly of calcium (blue) and hemosiderin (brown) in fibrous connective tissue. The yellow material is bilirubin, resulting from the breakdown of erythrocytes in a capsular hemorrhage. H&E stain
Figure 13-64. Acute splenic rupture and hemorrhage, spleen, dog. The spleen has been almost transected by trauma. Because of the loss of blood, the spleen has contracted, the surface is crinkled, and the exposed surface of the parenchyma is dry.
Figure 13-65. **Multiple “spleens,” dog.** The spleen had been broken into several parts, and the rupture sites have healed. These small pieces of spleen, sometimes referred to as daughter spleens, are functional but not very effective in filtration because of their relatively paltry blood supply.
Figure 13-66. Follicular lymphoid hyperplasia, chronic demodicosis, caudal cervical (prescapular) lymph node, dog. The number of lymphoid follicles has increased (hyperplasia), and all of these have germinal centers (secondary follicles) indicating active proliferation of B lymphocytes to form plasma cells in response to an antigenic stimulus. H&E stain.
Figure 13-67.  Acute lymphadenitis, tracheobronchial lymph nodes, pig.
The nodes are enlarged and reddened from draining the pneumonic cranial lung lobes. Note the red consolidation of the dorsal portion of the cranial lung lobes.
Figure 13-69. **Jowl abscess, pig.** The submandibular swelling is caused by marked enlargement of the mandibular lymph nodes from a suppurative lymphadenitis caused by *Streptococcus porcinus*. 
Figure 13-70. Acute suppurative lymphadenitis, equine strangles (Streptococcus equi ssp. equi), dorsal view of larynx, left and right retropharyngeal lymph nodes, horse. The lymph nodes are grossly distended with pus.
Figure 13-71. Caseous lymphadenitis, *Corynebacterium pseudotuberculosis*, lymph node, sheep. The whole lymph node has been replaced by an abscess containing mostly semifluid yellowish pus. This is an early stage of caseous lymphadenitis, before the pus has become inspissated and caseous.
Figure 13-72. **Chronic caseous lymphadenitis, *Corynebacterium pseudotuberculosis*, lymph node, sheep.** The lymph node has been sliced longitudinally exposing three chronic abscesses enclosed by thick fibrous capsules and containing yellowish caseous pus.
Figure 13-73. **Tuberculosis (Mycobacterium bovis), lymph node, ox.** The normal architecture of the lymph node has been completely obliterated by multiple caseating granulomas, typical of *Mycobacterium bovis* lesions.
Figure 13-74. Johne’s disease (*Mycobacterium avium* ssp. *pseudotuberculosis*), lymph node, ox. Several noncaseating granulomas (*pale areas*) have replaced the normal lymphoid tissue (*blue*). Note the Langhans’ giant cell (*upper right*).
Figure 13-75. Cryptococciosis (*Cryptococcus neoformans*), right mandibular lymph node, cat. The lymph node is grossly enlarged and the incised surface is bulging and pale, and its normal architecture has been completely effaced.
Figure 13-76. **Cryptococciosis, right lymph node, cat.** The pale area in the upper center is occupied by *Cryptococcus neoformans*. In H&E stained sections, the capsule of the organism, which is thick, does not stain. The mass of cryptococci is bordered by the diffuse lymphoid tissue of the paracortex. Note the complete absence of any inflammation (usually granulomatous), which frequently occurs in feline cryptococciosis. H&E stain.
Figure 13-77. **Histoplasmosis, feline transtracheal wash.** A macrophage is laden with small, oval, encapsulated yeast forms. Wright's stain.
Figure 13-78. Histoplasmosis, lymph node, dog. Diffuse granulomatous lymphadenitis. Most of the field is occupied by macrophages, many of which have phagocytosed *Histoplasma capsulatum*. H&E stain.
Figure 13-79. Leishmaniasis, *Leishmania* spp., canine popliteal lymph node aspirate. A macrophage contains multiple amastigotes with oval nuclei and smaller bar-shaped kinetoplasts (arrow). Wright’s stain.
Figure 13-80. Lymphoma (lymphosarcoma), cranial mediastinal lymph nodes, cat. The cranial mediastinal lymph nodes are grossly enlarged, fill the cranial thoracic cavity, and have displaced the lungs and heart caudad.
Figure 13-81. **Lymphoma (lymphosarcoma), bovine lymph node.** Normal architecture of lymph node has been completely obliterated by proliferating lobules of neoplastic tissue composed of malignant lymphocytes.