See 122, 126

LYMPHOCYTE CIRCULATION

CN: Use blue for H, red for I, purple for L, and green for M. (1) Color over the light lines representing peripheral (superficial) lymph vessels (A). (2) Color each large step numeral in the diagram below with the related titles. In the bottom diagram, do not color the lymphocytes circulating in and between the blood and lymph capillaries.

SUPERFICIAL DRAINAGE

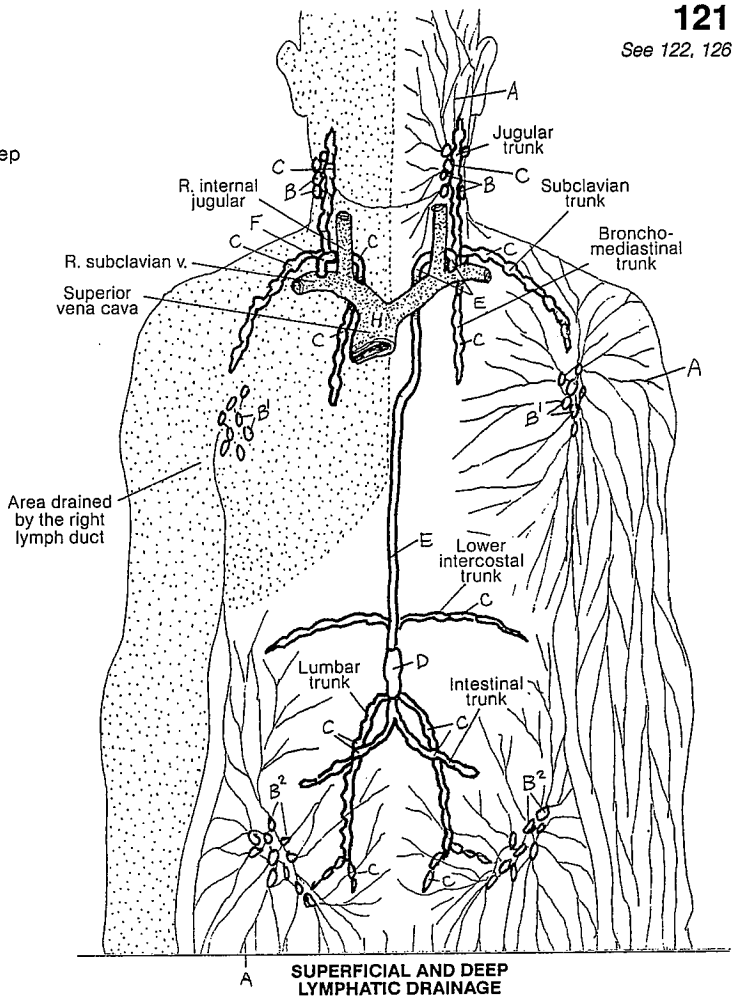
- PERIPHERAL LYMPH VESSELS A
- CERVICAL NODE B
- AXILLARY NODE B'
- INGUINAL NODE B²

DEEP DRAINAGE

- LYMPHATIC TRUNK C
- CYSTERNA CHYLI D
- THORACIC DUCT E
- RIGHT LYMPH DUCT F

The body is about 60% fluid (by volume), which fills cells, vessels, and spaces. Fluid requires circulation. Some of the fluid of the blood and some lymphocytes leave the circulatory system and enter the tissue spaces. Some of this fluid (lipids) and lymphocytes (lymph) are recovered by thin-walled vessels (*lymphatic capillaries*) that form in the loose connective tissue spaces. Unlike the closed-loop blood capillary networks, these tiny vessels are closed at one end. They merge to form progressively larger lymphatic vessels that drain into large veins in the neck. These vessels constitute the lymphatic system. Certain lymphatic vessels enter and leave lymph-filtering stations called *lymph nodes*.

Region-draining *lymph trunks* converge into a dilated lymph sac (*cysterna chyli*) lying deep to the abdominal aorta on the first lumbar vertebra. The *thoracic duct* begins at the upper end of the sac, ascends the anterior surface of the vertebral column, and drains into the left subclavian vein at its junction with the internal jugular vein. The *right lymph duct* terminates similarly on the opposite side. It drains the dotted area.



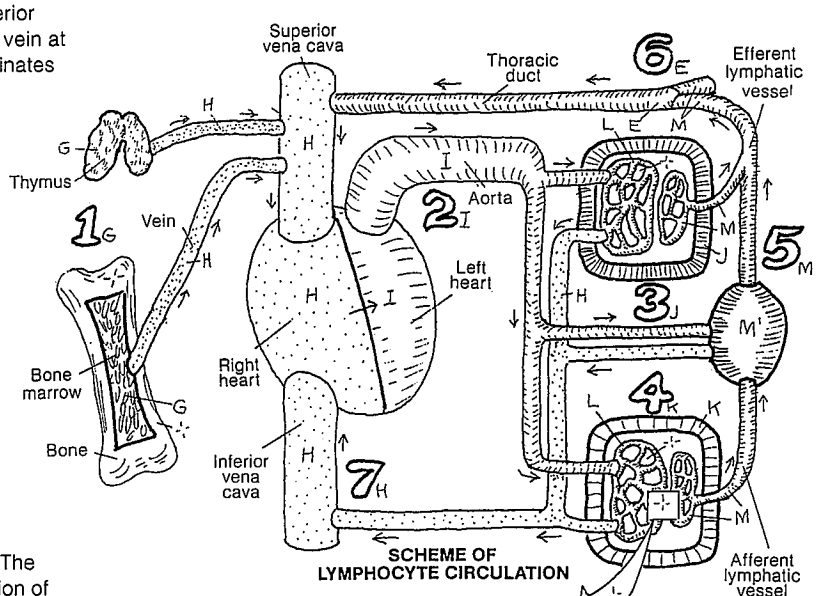
SUPERFICIAL AND DEEP LYMPHATIC DRAINAGE

LYMPHOCYTE CIRCULATION

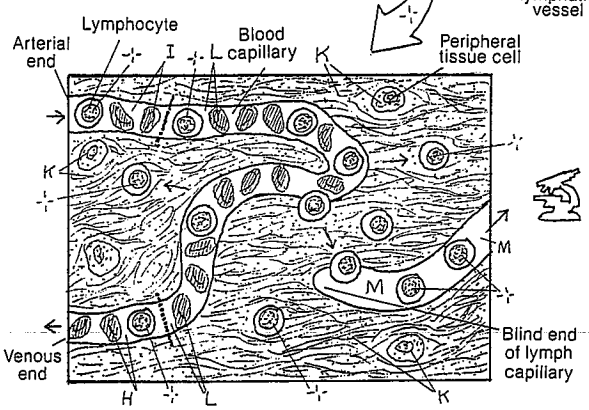
- GENERATIVE ORGAN G
- VENOUS BLOOD H
- ARTERIAL BLOOD I
- LYMPHOID TISSUE J
- PERIPHERAL TISSUE K
- CAPILLARY NETWORK L
- LYMPH VESSEL M
- LYMPH NODE M'

Lymphocytes are among the principal cells of the immune system. The circulation scheme reveals the primary pathway for the dissemination of lymphocytes from their *generative organs* (*bone marrow, thymus*) into the *lymphoid tissues* and organs as well as organs and tissues in general (*peripheral tissues*). Such a circulation pattern provides for maximum exposure of lymphocytes to microorganisms and subsequent body defense operations (immune responses).

Formed and developed in the bone marrow and thymus (1), lymphocytes leave with the *venous blood* to enter the circulation. By way of *arterial blood* (2), lymphocytes enter the *capillary networks* of the lymphoid tissues (3) and other peripheral tissues (4). The lymphocytes may remain in or migrate from the lymphoid organs/peripheral tissues, entering blood capillaries or lymph vessels. From lymph capillaries, the lymphocytes flow with the lymph fluid into regional lymph nodes (5). Here they may become resident or they may depart the node and merge with other lymph vessels to join the lymph ducts (6) that connect with the blood circulatory system.



SCHEME OF LYMPHOCYTE CIRCULATION



See 101, 121

INTRODUCTION

CN: Use green for D, the same colors for bone marrow (A) and thymus (B) used on Plate 121. (1) Structures depicting mucosal-associated lymphoid tissue (E) are generalizations; more accurate representations can be seen on Plate 127. (2) The three lymphocyte types have identifying letters drawn into their nuclei. Color over the entire cell in all cases. (3) The various types of cells appearing in this section will generally be identified by more descriptive letters/labels (e.g., PC = plasma cell). Try to use the same light color for each type wherever it appears on plates 122–128.

PRIMARY ORGANS

BONE MARROW A

THYMUS B

The lymphoid system, the anatomical component of the immune system, functions in defense against microorganisms entering the body as well as the destruction of cells or cell parts no longer recognizable as "self." Lymphoid tissues and organs are predominantly collections of lymphocytes and related cells (see below), often supported by a meshwork of reticular fibers and cells.

The red bone marrow and thymus are primary lymphoid organs. The *bone marrow* contains the precursors of all lymphocytes and disburses lymphocytes into the circulation. It consists largely of great varieties of blood cells in various stages of maturation, phagocytes, reticular cells and fibers, and fat cells. Some of the lymphocytes mature and undergo structural and biochemical revision (differentiation) in the bone marrow to become B lymphocytes. Large lymphocytes enter the circulation from the bone marrow and function as natural killer cells. Some partly differentiated lymphocytes migrate via the blood to the thymus. There they become T cells and differentiate further. Those cells then re-enter the circulation and migrate to secondary lymphoid organs.

The thymus is located in the superior and anterior (inferior) mediastinum. It receives uncommitted lymphocytes from the bone marrow The thymus is actively engaged in T lymphocyte proliferation and differentiation during embryonic and fetal life as well as the first decade of extrauterine life. The thymus begins to undergo degeneration (involution) after puberty.

SECONDARY ORGANS

SPLEEN C

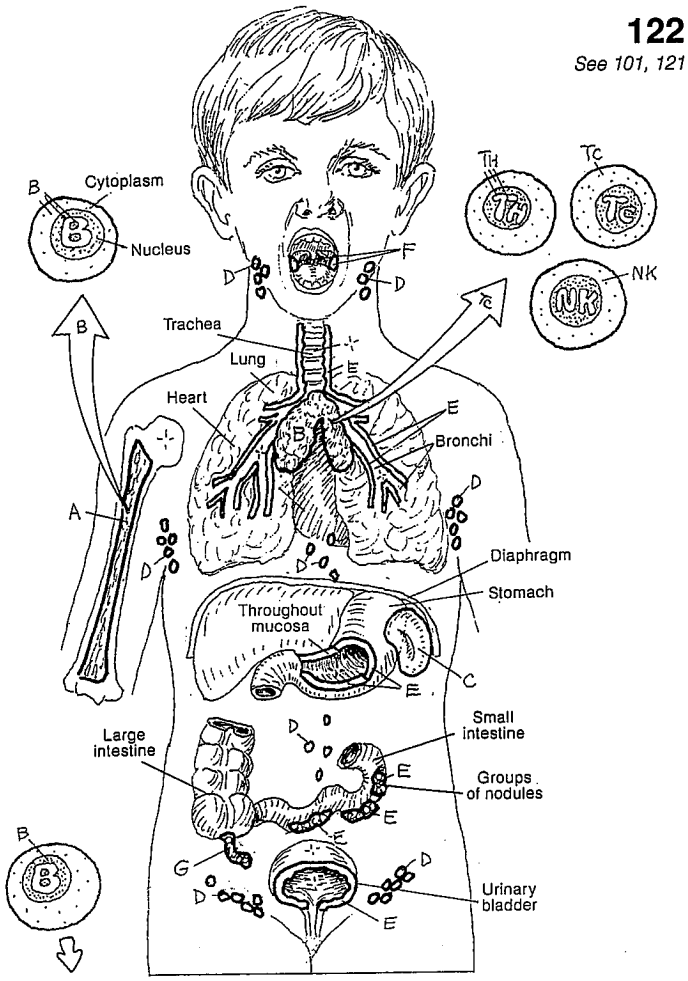
LYMPH NODE D

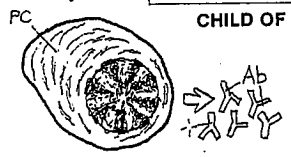
MUCOSAL ASSOCIATED LYMPHOID TISSUE (M.A.L.T.) E

TONSILS / ADENOIDS F

APPENDIX G

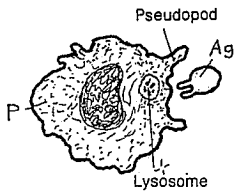
Secondary lymphoid organs are structures predominantly populated by lymphocytes that migrated from the primary lymphoid organs. The structural arrangement of these organs ranges from encapsulated, complex structures, like the *spleen* and *lymph nodes*, to a diffuse disposition of lymphocytes throughout the loose connective and epithelial tissues of the digestive system, if not all open cavities. These secondary organs represent satellite sites for lymphocytic activation when challenged by antigens. The *spleen* processes incoming blood. Its lymphocytes and phagocytes react rapidly to the presence of microorganisms and aged red blood corpuscles. *Lymph nodes* screen lymph from incoming (afferent) lymphatic vessels, much in the same manner as the spleen processes blood. Partly encapsulated, nodular masses of lymphoid tissue (tonsils and adenoids) guard the pharynx, marking incoming microorganisms for destruction. Unencapsulated, variably sized, nodular masses (follicles) of lymphocytes occur throughout the mucosal layers of open cavities (primarily the digestive tract), as do more diffuse distributions of lymphocytes. These unencapsulated follicles and lymphocyte collections constitute mucosal-associated lymphoid tissues (M.A.L.T.); in the intestines, they may be called "gut-associated lymphoid tissues" (G.A.L.T.). The vermiform appendix harbors multiple lymphoid follicles in its mucosa. The density of lymphocytes and follicles of lymphocytes in all these groups varies with the degree of immune responsivity required.





ANTIBODY Ab

ANTIGEN Ag



CELLS

B LYMPHOCYTE B

PLASMA CELL PC

T (HELPER) LYMPHOCYTE TH

T (CYTOTOXIC) CELL Tc

NATURAL KILLER CELL NK

PHAGOCYTE P

Activated B lymphocytes (B = bone marrow–derived) differentiate along specific lines, one of which becomes plasma cells. Plasma cells secrete protein molecules called antibodies into tissue fluids. Antibodies interact with and destroy antigens, a term restricted to those molecules (free or attached to/are part of cells and microorganisms) that elicit activation of the B cells.

Early T lymphocytes (T = thymus-derived) differentiate into one of a number of cells, including helper (TH), cytotoxic (Tc), and memory cells (not shown). Activated by antigen stimulation, TH cells stimulate and regulate specific and nonspecific immune operations against cells, without necessarily being assisted by B cells. Thus, they are concerned with cell-mediated immunity. Tc cells kill cells targeted by other T cells or lymphokines. Natural killer (NK) cells are neither B nor T cells. They are not activated by other cells or lymphokines (they kill naturally). In association with Tc cells, they destroy tumor cells and virus-infected cells primarily. Phagocytes are cells that destroy antigen by phagocytosis. They function as antigen-presenting cells (APC) for T cells; T cells, in turn, activate phagocytes.