Chapter

6

Lymphatic System

"Lives of great men all remind us, we can make our lives subline. And departing leave behind us, foot prints on the sands of time." ***—William Wordsworth***

Lymphatic system is essentially a drainage system which is accessory to the venous system (Fig. 6.1).

Most of the tissue fluid formed at the arterial end of capillaries is absorbed back into the blood by the venous ends of the capillaries and the postcapillary venules. The rest of the tissue fluid (10–20%) is absorbed by the lymphatics which begin blindly in the tissue spaces.

It is important to know that the larger particles (proteins and particulate matter) can be removed from the tissue fluid only by the

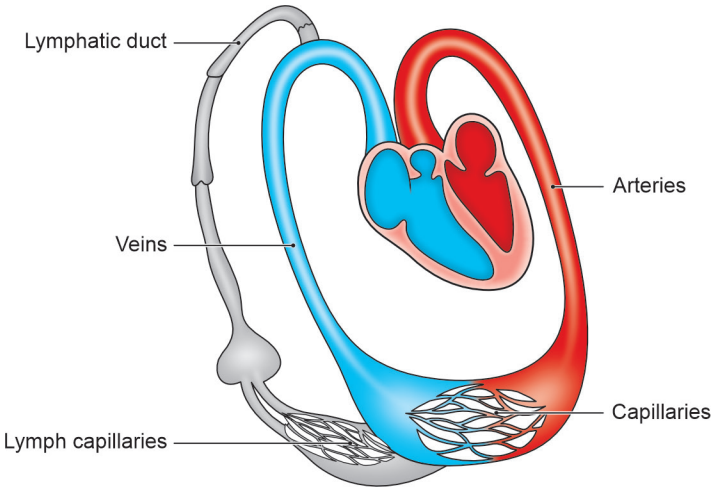

Fig. 6.1: Beginning and termination of lymph vessels

lymphatics. Therefore, the lymphatic system may be regarded as 'drainage system of coarse type' and the venous system as 'drainage system of fine type'.

Certain parts of the lymphatic system (lymphoreticular organs), however, are chiefly involved in phagocytosis, raising immune responses, and contributing to cell populations of the blood and lymph.

The tissue fluid flowing in the lymphatics is called lymph. It passes through filters (lymph nodes) placed in the course of lymphatics, and finally drains into the venous blood.

Lymph from most of the tissues is clear and colourless, but the lymph from small intestine is milky-white due to absorption of fat. The intestinal milky lymph is called chyle, and lymph vessels, the *lacteals*.

Competency achievement: The student should be able to:
AN 6.1 List the components and functions of the lymphatic system
AN 6.2 Describe structure of lymph capillaries and mechanism of lymph circulation

COMPONENTS

The lymphatic system comprises:

1. Lymph capillaries and lymph vessels
2. Central lymphoid tissues
3. Peripheral lymphoid organs
4. Circulating lymphocytes
5. Epithelio-lymphoid system
6. Mononuclear phagocyte system

1. Lymph Capillaries and Lymph Vessels

The lymph capillaries begin blindly in the tissue spaces and form intricate networks. Their calibre is greater and less regular than that of blood capillaries, and their endothelial wall is permeable to substances of much greater molecular size.

Lymph capillaries are absent from the cellular structures like brain, spinal cord, splenic pulp, bone marrow, articular cartilage, epidermis, hair, nail and cornea.

Lymph capillaries have been compared to blood capillaries in Table 6.1.

Table 6.1: Comparison of lymph and blood capillaries	
Lymph capillaries	*Blood capillaries*
1. Colourless, difficult to observe	Reddish, easy to observe
2. Blind (closed at the tip)	Joined to arterioles at one end and to venules at another end
3. Wider than blood capillaries	Narrower than lymph capillaries
4. Wall consists of thin endothelium and poorly developed basement membrane	Wall consist of normal endothelium and basement membrane
5. Contain colourless lymph	Contain red blood
6. Have relatively low pressure	Have relatively high pressure
7. Absorb tissue fluid from intercellular spaces	Add tissue fluid to intercellular spaces

Lymph capillaries start from portal radicle around hepatic lobule. These join together and drain into thoracic duct which ends in the large vein near the heart (Fig. 6.2).

The lymph capillaries join to form lymphatics, which are superficial and deep lymphatics. The superficial lymphatics accompany veins, while the deep lymphatics accompany arteries.

The lymph passes through filters or barriers of the regional lymph nodes which trap the particulate matter.

The filtered lymph passes through larger lymphatics and is eventually collected into two large trunks, the *thoracic duct* and *right*

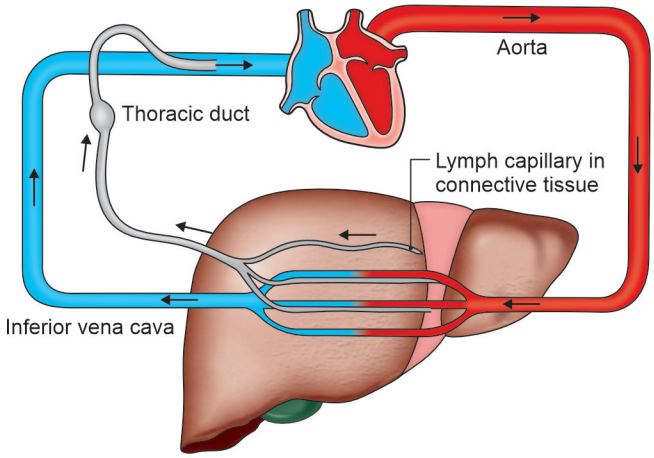

Fig. 6.2: Lymph vessels from the liver

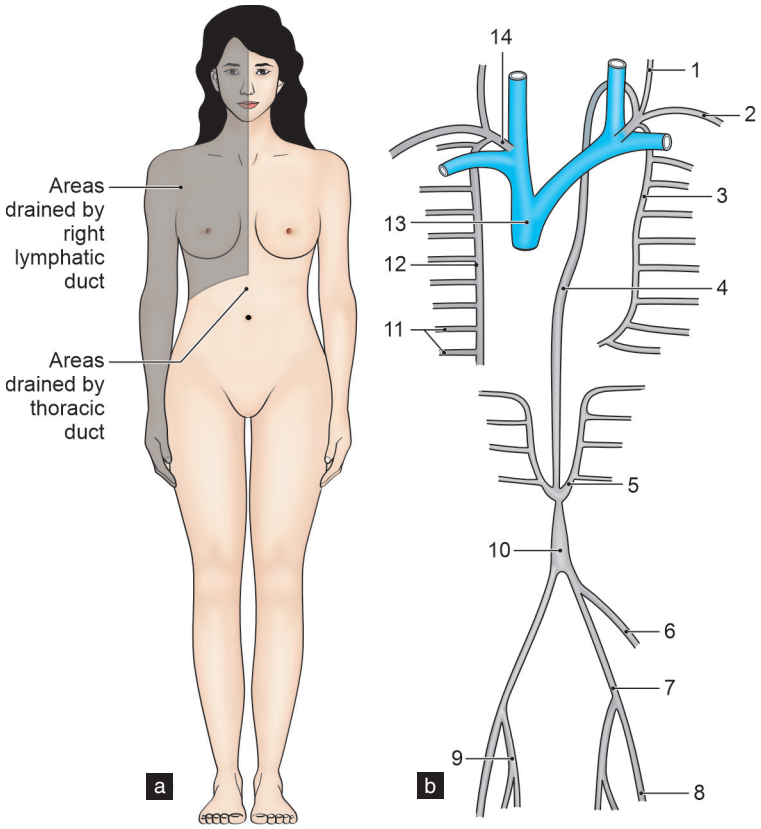

Fig. 6.3: (a) Areas drained by thoracic duct and (b) right lymphatic duct

1. Jugular lymph trunk
2. Subclavian lymph trunk
3. Broncho-mediastinal lymph trunk
4. Thoracic duct
5. Descending thoracic lymph trunk
6. Intestinal lymph trunk
7. Left lumbar lymph trunk
8. External iliac lymph trunk
9. Internal iliac lymph trunk
10. Cisterna chyli
11. Intercostal lymph vessels
12. Right broncho-mediastinal lymph trunk
13. Superior vena cava
14. Right lymphatic duct

lymphatic duct, which pour their lymph into the brachiocephalic veins (Fig. 6.3). Thoracic duct drains both lower limbs, abdomen, left half of thorax, head and neck and left upper limb. Right lymphatic duct drains right half of thorax, head and neck and right upper limb.

The lymphatics anastomose freely with their neighbours of the same side as well as of the *opposite side*. Larger lymphatics are

supplied with their vasa vasorum and are accompanied by a plexus of fine blood vessels which form red streaks seen in lymphangitis.

2. Central Lymphoid Tissues

Central lymphoid tissues comprise bone marrow and thymus.

Bone Marrow

All 'pluripotent' lymphoid stem cells are initially produced by bone marrow, except during early fetal life when these are produced by liver and spleen. The stem cells undergo differentiation in the central lymphoid tissues, so that the lymphocytes become competent defensive elements of the immune system.

Bone marrow helps differentiation of the (committed) B-lymphocytes which are capable of synthesizing antibodies after getting transformed into plasma cells.

Thymus

The thymus is an important lymphoid organ, situated in the anterior and superior mediastina of the thorax, extending above into the lower part of the neck. It is well developed at birth, continues to grow up to puberty, and thereafter undergoes gradual atrophy and replacement by fat. It is the only lymphoid organ well developed at birth.

The thymus is a bilobed structure, made up of two pyramidal lobes of unequal size which are connected together by areolar tissue (Fig. 6.4).

Functions

1. The thymus controls lymphopoiesis, and maintains an effective pool of circulating lymphocytes, competent to react to innumerable antigenic stimuli.

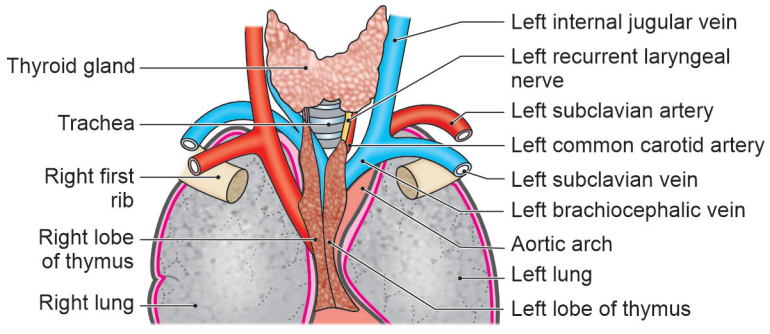

Fig. 6.4: Thymus in a child

2. It controls development of the peripheral lymphoid tissues of the body during the neonatal period. By puberty, the main lymphoid tissues are fully developed.
3. The cortical lymphocytes of the thymus arise from stem cells of bone marrow origin. Most (95%) of the lymphocytes (T lymphocytes) produced are autoallergic (act against the host or 'self antigens'), short-lived (3–5 days) and never move out of the organ. They are destroyed and their remnants are seen in Hassall's corpuscles. The remaining 5% of the T lymphocytes are longer living and join the circulating pool of lymphocytes where they act as immunologically competent but uncommitted cells. On the other hand, the other circulating lymphocytes (from lymph nodes, spleen, etc.) are committed only when exposed to a particular antigen. The process of involution are all intrinsically controlled.
4. The medullary epithelial cells of the thymus are thought to secrete:
   a. *Lymphopoietin*, which stimulates lymphocyte production, both in the cortex of the thymus and in peripheral lymphoid organs.
   b. The *competence-inducing* factor, which may be responsible for making new lymphocytes competent to react to antigenic stimuli.
5. Normally, there are no germinal centres in the thymic cortex. Such centres appear in autoimmune diseases. This may indicate a defect in the normal function of the thymus.

3. Peripheral Lymphoid Organs

Peripheral lymphoid organs comprise lymph nodes, spleen. Any part of this may become overactive on appropriate stimulation.

The progenies of B- and T-lymphocytes reach these organs where the cells may proliferate and mature into competent cells. The mature lymphocytes join the circulating pool of lymphocytes.

Lymphatic Follicle (Nodule)

Collections of lymphocytes occur at many places in the body. Everywhere there is a basic pattern, the *lymphatic follicle*. The follicle is a spherical collection of lymphocytes with a pale centre known as *germinal centre*, where the lymphocytes are more loosely packed.

The central cells are larger in size, stain less deeply, and divide more rapidly, than the peripheral cells.

LYMPH NODES

Lymph nodes are small nodules of lymphoid tissue found in the course of smaller lymphatics.

The lymph passes through one or more lymph nodes before reaching the larger lymph trunks.

The nodes are oval or reniform in shape, 1–25 mm long, and light brown, black (pulmonary), or creamy white (intestinal) in colour.

Usually they occur in groups (cervical, axillary, inguinal, mesenteric, mediastinal, etc.), but at times there may be a solitary lymph node.

Superficial nodes are arranged along the veins, and the deep nodes along the arteries.

Cervical lymph nodes form a ring at the junction of head and neck and vertical chains in the neck (Fig. 6.5). These drain whole of head and neck. On right side jugular lymph trunk drains into right lymphatic duct, while on left side it drains into thoracic duct. Lymph vessels of abdominal wall above a line passing horizontally through umbilicus drain into respective sides of axillary lymph nodes. Lymph vessels below this line drain into

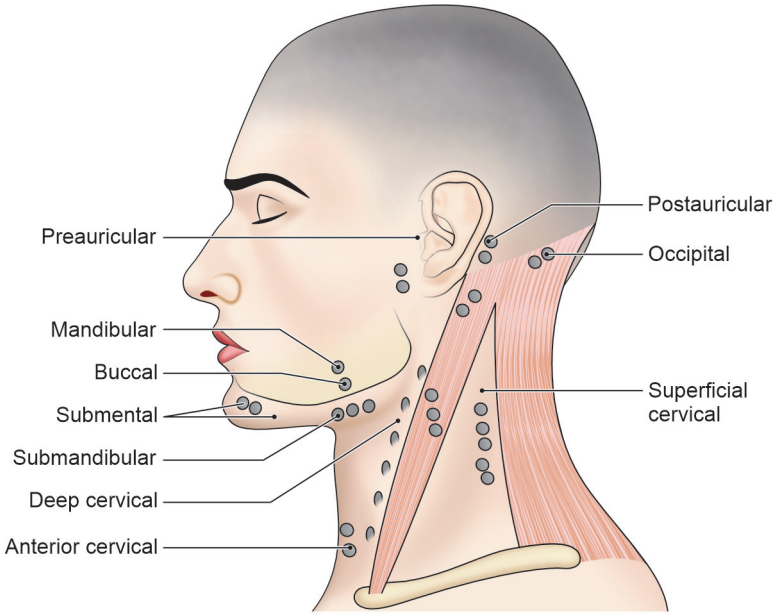

Fig. 6.5: Some lymph nodes of the neck

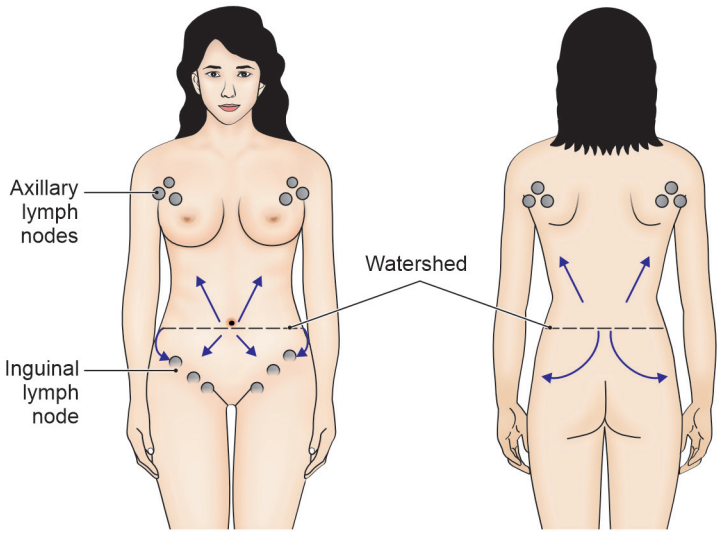

Fig. 6.6: Areas drained by axillary and inguinal lymph nodes

inguinal group of lymph nodes. This line is called "watershed" (Fig. 6.6).

Each lymph node has a slight depression on one side, called hilum. The artery enters the node, and the vein with efferent lymphatic comes out of it, at the hilum.

The afferent lymphatics enter the node at different parts of its periphery.

Structurally, a lymph node is made up of the following parts (Fig. 6.7).

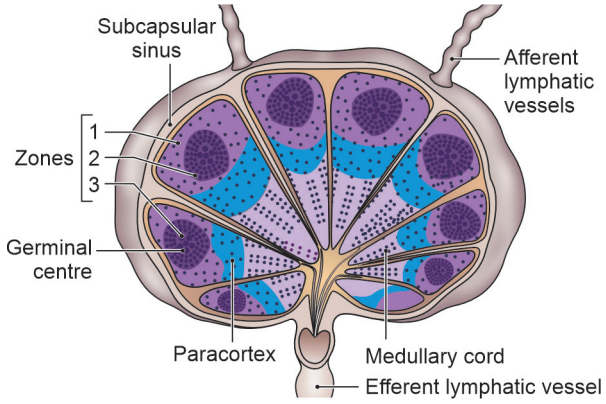

Fig. 6.7: Structure of a lymph node

a. ***Fibrous and reticular framework:*** The lymph node is covered by a capsule. From the deep surface of the capsule a number of trabeculae extend radially into the interior of the node, where they are continuous with the fine reticulum which forms the supporting framework for the lymphoid tissue.

b. ***Lymphatic channels:*** The *subcapsular sinus* lies beneath the capsule and surrounds the node except at the hilum. Many afferent lymphatics of the node open into the subcapsular sinus. Lymph filters through reticulin fibres and leaves the node by only *one* efferent lymphatic vessel.

c. ***Cortex:*** It is the outer part of the lymph node situated beneath the subcapsular sinus, being absent at the hilum.

It is made up of lymphatic follicles and is traversed by fibrous trabeculae.

The cortex is far more densely cellular than the medulla.

It is divided into:

Zone 1: Containing loosely packed small lymphocytes, macrophages and occasional plasma cells at the periphery of the follicle and extending into the medullary cords.

Zone 2: Containing more densely packed small lymphocytes and macrophages, and limited to cortical and paracortical (inner cortex) areas.

Zone 3: Including the germinal centre which contains large lymphocytes and macrophages.

The maturing lymphocytes pass from zone 3 to zone 2 to zone 1 and to the subcapsular sinus (Fig. 6.7).

According to the distribution of B- and T-lymphocytes, the cortex is divided into:

1. An outer part which contains immature B-lymphocytes.
2. An inner part, between the germinal centre and the medulla, which contains T-lymphocytes. This part is known as *paracortex* or *thymus dependent zone*.

   The mature B-lymphocytes (plasma cells) are found in the medulla.

d. ***Medulla:*** It is the central part of the lymph node, containing loosely packed lymphocytes (forming irregular branching medullary cords), the plasma cells, and macrophages.

e. ***Blood channels:*** The artery enters at the hilum and divides into straight branches which run in the trabeculae. In the cortex

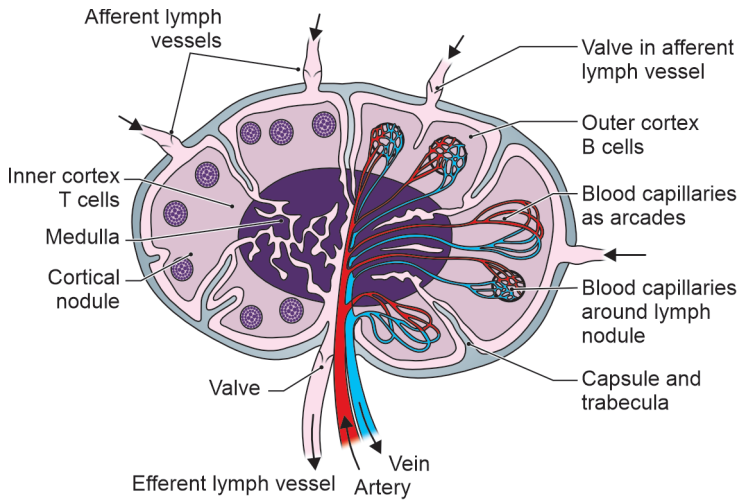

Fig. 6.8: Artery, vein and lymph vessels of the lymph node

the arteries further divide to form arcades of arterioles and capillaries with many anastomosing loops (Fig. 6.8).

The capillaries give rise to venules and veins, which run back to the hilum. The capillaries are more profuse around the follicles, and the postcapillary venules are more abundant in the paracortical zones for lymphatic migration.

Haemal Nodes and Spleen

These are small lymphatic bodies resembling lymph nodes in their structure, which are found in the course of blood vessels.

The afferent and efferent lymphatics are absent. Their sinuses are filled with blood rather than lymph.

These are found in some animals in relation to their abdominal and thoracic viscera.

Haemal nodes may represent an intermediate stage between a lymph node and the spleen. In man, the spleen is a large haemal node.

Spleen

Spleen is the largest lymphoid organ and is covered by a dense connective tissue *capsule* (Fig. 6.9). *Trabeculae* extend inwards from capsule. Cellular material of spleen is divided into *white pulp* and

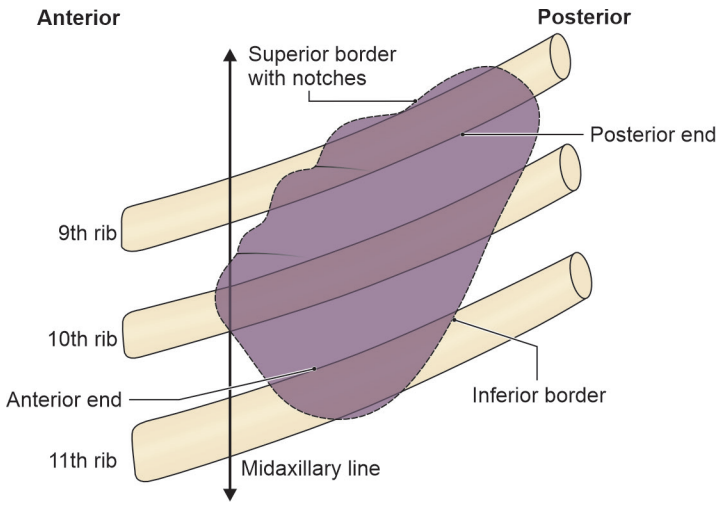

Fig. 6.9: Spleen with its extent, ends and borders (previous view)

red pulp. Red pulp consists of blood filled venous sinuses and white pulp comprises lymphatic tissue, consisting of lymphocytes and macrophages. (*Reference: Gray's Anatomy*, 42nd edition, spleen lies along 10th–12th ribs.)

Spleen is part of the lymphatic system and its functions are:

1. ***Phagocytosis:*** Leukocytes, platelets are phagocytosed in spleen. Old and abnormal RBCs are destroyed in spleen and break down products (bilirubin and iron) are passed to the liver.
2. ***Storage of blood:*** Spleen contains up to 350 ml blood. In shock, sympathetic stimulation can return a large part of this volume to circulation.
3. ***Immunity:*** Spleen contains B- and T-lymphocytes which are important in immune response to infections.
4. ***Erythropoiesis:*** RBC production occurs in spleen and liver in fetal life.
5. Storage of platelets.

4. Circulating Pool of Lymphocytes

The pool contains mature progenies of B- and T-lymphocytes which may be called upon during antigenic emergencies (Roitt, 1977).

Table 6.2 shows the differences between T- and B-lymphocytes.

Table 6.3 shows the approximate percentage of lymphocytes in lymphoid organs.

Table 6.2: Differences between T- and B-lymphocytes		
	T-lymphocytes	*B-lymphocytes*
Origin	Bone marrow → Thymus → lymphoid tissue	Bone marrow → Bursa-equivalent → lymphoid tissue
Life span	Months to years	Less than one month
Location Lymph nodes Spleen Peyer's patches	 Perifollicular Perifollicular Perifollicular	 Germinal centre Germinal centre Central follicles
Number in blood	80%	20%
Function	i. Cell-mediated immunity via Tc cells (cytotoxic) ii. Immunoregulation of T and B-lymphocytes via TH cells (helper) iii. Memory T cells	i. Humoral immunity IgG (most abundant). It is via immunoglobulins produced by plasma cells ii. Formed by enlargement and modification of B-lymphocytes iii. Memory B cells

Table 6.3: Approximate percentage of lymphocytes in lymphoid organs		
Lymphoid organ	*T-lymphocytes*	*B-lymphocytes*
Thymus	100%	0%
Lymph node	60%	40%
Spleen	45%	55%
Bone marrow	10%	90%
Blood	80%	20%

5. Epithelio-lymphoid System

Epithelio-lymphoid system comprises Mucosa Associated Lymphoid Tissue (MALT) in digestive system and Bronchus Associated Lymphoid Tissue (BALT) in respiratory system.

In the region of posterior one-third of tongue, oropharynx, nasopharynx, there is a ring of lymphoid tissue under the mucous membrane. Its components are lingual tonsil, palatine tonsils, tubal tonsils and nasopharyngeal tonsil. This ring is called Waldeyer's ring

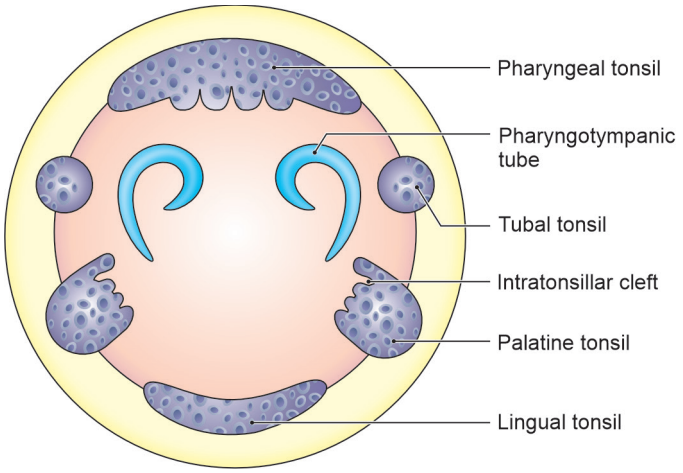

Fig. 6.10: Components of Waldeyer's ring

(Fig. 6.10). Peyer's patches of ileum of small intestine and lymphoid tissue of vermiform appendix belong to MALT.

6. Mononuclear Phagocyte System or Macrophage System (Reticuloendothelial System)

This system is not closely related to lymphatic system because the two are independent structurally and functionally. The macrophage system is made up of highly phagocytic cells which are widely distributed in the body. These cells include:

a. Macrophages of connective tissue, reticular tissue and lungs
b. Monocytes of blood
c. Kupffer's cells of liver
d. Meningocytes of meninges
e. Microglial cells of nervous tissue
f. Foreign body giant cells.

The endothelial cells, fibroblasts, and most leucocytes are not included in this system because of their poor power of phagocytosis.

Functions

1. The system forms first line of defence of the body against micro-organisms, because of the amoeboid and phagocytic properties of its cells.

2. The macrophages of lymphoid tissue are now considered to be intimately concerned with mounting specific immune responses by the neighbouring cells.
3. Many of the prominent sites of RES are also important sites of haemopoiesis.
4. Absorbs fat from intestines to be transported to blood.

Growth Pattern of Lymphoid Tissue

Lymphoid tissue of the body is prominent at birth, and grows rapidly during childhood. There are about 600 lymph nodes in an adult.

The growth ceases at about the time of puberty, and is followed by partial atrophy in the later years.

This growth pattern is shared by lymph nodes, thymus, tonsils, lymphoid tissue of the intestines, and the follicles of spleen.

However, the lymph nodes may enlarge again in response to inflammation (lymphadenitis) or tumour formation (Hodgkin's disease, lymphosarcoma, etc.).

Lymph nodes are commonly enlarged by metastases (spread) of malignant growths (carcinoma).

Functions of Lymphoid System

1. Lymph capillaries absorb and remove the large protein molecules and other particulate matter from the tissue spaces. Thus the cellular debris and foreign particles (dust particles inhaled into the lungs, bacteria and other micro-organisms) are conveyed to the regional lymph nodes. Lymphatics (lacteals) help in transportation of fat from the gut.
2. Lymph nodes serve a number of functions.
   a. They act as filters for the lymph which percolates slowly through the intricate network of its spaces. Thus the foreign particles are prevented from entering the blood stream.
   b. The foreign particles are engulfed by the macrophages in the sinuses.
   c. Antigens are also trapped by the phagocytes.
   d. The mature B-lymphocytes (plasma cells capable of producing antibodies) and mature T-lymphocytes are produced in the node.
   e. Both the cellular and humoral immune responses are mounted against the antigen-laden phagocytes.

f. The circulating lymphocytes can pass back into the lymphatic channels within the node.
g. Humoral antibodies are freely produced by the lymph nodes.

3. Production (proliferation) and maturation of B- and T-lymphocytes is the main function of lymphoid tissue.

Competency achievement: The student should be able to:
AN 6.3 Explain the concept of lymphoedema and spread of tumors via lymphatics and venous system

Clinical Anatomy of Lymphatic System

- Lymphatics are primarily meant for coarse drainage, from the tissue spaces to the regional lymph nodes.
- Here the foreign and noxious material is filtered off by the phagocytic activity of the macrophage cells. The cell debris is finally disposed by the appropriate immune responses within the node. Thus the lymphatic system forms the *first line of defence of the body*.

  While draining from an infected area, the lymphatics and lymph nodes carrying infected debris may become inflammed, resulting in *lymphangitis* (Fig. 6.11) and *lymphadenitis*. In acute cases the lymphatics are marked on the skin as painful red lines leading to the painful and tender swollen lymph nodes which may suppurate. Chronic infections (tuberculosis, syphilis, etc.) cause chronic lymphadenitis.

  Lymphoma is a malignant cancer comprising abnormal lymphocytes or stem lymphocytic cells.

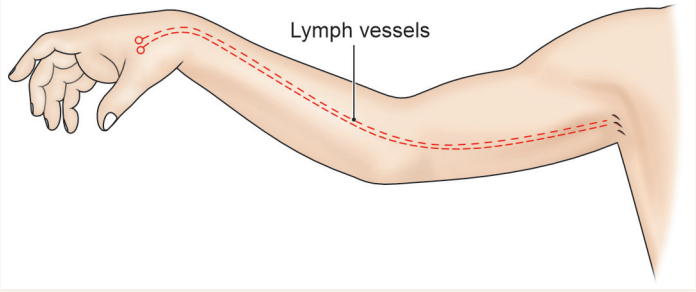

Fig. 6.11: Lymphangitis in upper limb

- The filarial parasite lives in the lymphatics, which may become blocked, giving rise to solid oedema (elephantiasis) in the peripheral area of drainage. *Elephantiasis* is characterized by enormous enlargement of the limb or scrotum (Fig. 6.12) due to the thickened skin. The microfilariae enter the blood stream only during night and, therefore, the blood for examination must be collected during night.

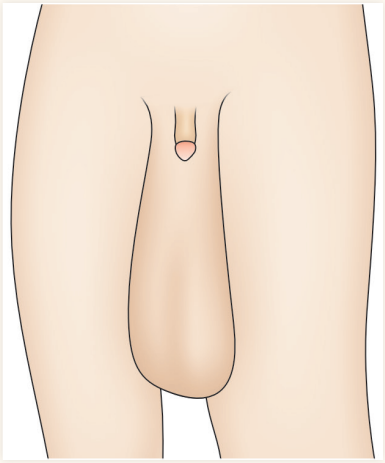

Fig. 6.12: Elephantiasis causing enlarged scrotum

- The lymphatics provide the most convenient *route of spread of the cancer cells* (Fig. 6.13). Therefore, the lymphatic drainage of those organs which are commonly involved in cancer should be studied in greater details. The reasons for detailed study are as follows:
  a. It is helpful in the diagnosis of the primary site of the cancer.
  b. It helps in predicting the prognosis and in classifying the stage of cancer.
  c. It helps the surgeon in doing the block dissections during operative removal of the cancer.

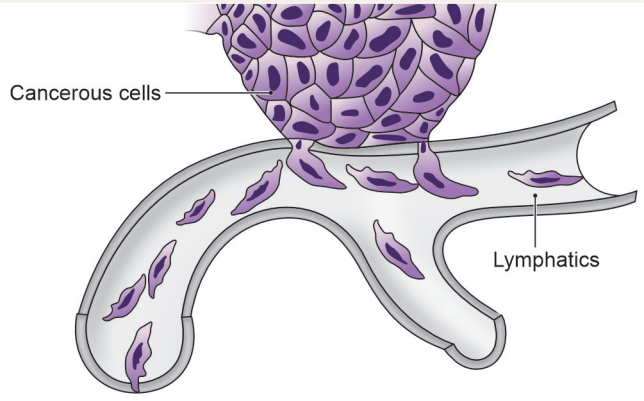

Fig. 6.13: Spread of cancer cells via the lymphatics

The spread of cancer causes enlargement of the regional lymph nodes, which become fixed and stony hard. Many a times the primary site of cancer is quite insignificant or even difficult to define, and the enormous enlargement of the draining lymph nodes due to secondary malignant deposits forms the most prominent part of the disease. A retrograde spread of cancer cells, after the blockage of lymphatics, may occur by a reversed flow of the lymph.

- Lymph node biopsy is a minor surgical procedure where lymph node is removed and is studied microscopically. It is done to see any infection or to grade stage of cancer.
- ***Splenomegaly*** is the enlargement of spleen mainly due to infections, circulatory disorders, blood diseases and malignant neoplasms. It causes excessive and premature haemolysis of red cells or phagocytosis of normal white cells and platelets leading to *anaemia, leukopenia* and *thrombocytopenia*. Spleen may also enlarge due to congestion of blood in portal venous system, in *right-sided heart failure* and in fibrosis caused due to *cirrhosis of liver*. Splenomegaly also occurs to meet the extra work load for removing damaged and abnormal blood cells. Commonest cause of splenomegaly is *malaria* (Fig. 6.14).

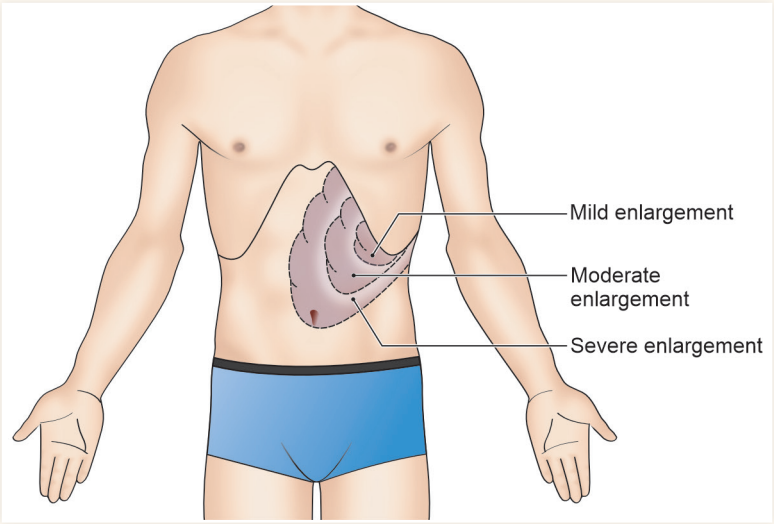

Fig. 6.14: Stages of enlargement of spleen

- Enlargement of thymus may cause *myasthenia gravis*, which produces extreme weakness of the skeletal muscles. It may be treated by removal of enlarged thymus, or by drug treatment.

Disorders of Immune System

Disorders of immune system covers:

1. Allergic reactions
2. Autoimmune disease in which body's immune system fails to recognise normal body cells and attacks the cells.
3. Immunodeficiency diseases, e.g. AIDS where the body's immune system becomes weak and is not able to protect itself, leading to diseases.

Let us discuss them in detail:

1. ***Allergic reactions:*** These can be simple reactions like papules, itching, burning of skin or these can be a major allergic reactions like reaction to intravenous drugs.
2. ***Autoimmune disease:*** It may appear as lupus erythematosus (LE). LE is of two types, discoid LE (DLE) and systemic LE (SLE). In both these cases the body's immune system attacks its own connective tissue.

   DLE affects the skin which becomes thickened with reddish patches on the face, forehead and cheeks.

   In SLE there is butterfly-shaped rash on the face. The joints of the upper limb are also affected.
3. ***Acquired Immunodeficiency Disease Syndrome (AIDS):*** AIDS is caused by HIV human immunodeficiency virus. This is a retrovirus where RNA is enveloped in a protein envelope. The mode of action of this virus is to attack T4 helper cells. These helper cells are vital to immune response and their inefficiency compromises the immune response. It results in minor infections taking on serious form.

   A person can be HIV positive for many years without showing symptoms of AIDS. AIDS is the last stage of HIV disease. Many opportunistic infections like TB invade AIDS patients and cause serious illness which can be fatal. They may also get AIDS, dementia, kaposis sarcoma.

   HIV is transmitted by needle sharing, multiple sexual contacts, multiple sex partners or from mother to the foetus. Public awareness and safe sex has reduced the cases of HIV/AIDS.

Points to Remember

- Lymph mostly consists of macromolecules not able to course through the blood capillaries. Lymph carries absorbed products of fats to the blood circulation.
- Lymph vessels also carry cancer cells from the original site of disease to nearby or distant regions.
- Lymph nodes/palatine tonsil/thymus, etc. are maximum in size till puberty. Then these start involuting/decreasing in size.
- Lymph nodes increase in size (lymphadenitis) during chronic infections like tuberculosis, syphilis, lymphomas.
- Lymphatic system forms the first line of defence of the body.
- Umbilical plane is the line of watershed of lymphatics.

Multiple Choice Questions

1. Components of lymphatic system are all *except*:

a. Lymph vessels
b. Central lymphoid tissues
c. Peripheral lymphoid organs
d. Circulating red blood cells

2. Lymphoid tissue enlarges in all conditions/stages *except*:

a. Childhood
b. At and after puberty
c. Lymphadenitis
d. Metastases of carcinoma

3. Splenomegaly commonly occurs in:

a. Malaria
b. Cirrhosis of liver
c. Anaemia
d. Elephantiasis

4. Lymph node enlargement draining an organ is useful in all *except*:

a. Diagnosis of primary site of the carcinoma
b. Classifying the stage of carcinoma
c. Surgeon in doing block dissection
d. Splenomegaly

5. Thoracic duct drains the following areas *except*:

a. Left upper limb
b. Left lower limb
c. Right lower limb
d. Right upper limb

6. Which lymphoid tissue contains red pulp and white pulp?

a. Lymph node
b. Palatine tonsil
c. Spleen
d. Thymus

7. Lymph capillaries are absent in all *except*:

a. Cornea
b. Epidermis
c. Spinal cord
d. Dermis

8. Thymus has the following features *except*:

a. Lies in superior and anterior mediastinum
b. T-lymphocytes are cytotoxic, helper and memory cells
c. Secretes thymosin
d. Filters blood to get rid of antigens

9. One of the following lymphoid tissues has both afferent and efferent lymphatics:

a. Thymus
b. Spleen
c. Tonsil
d. Lymph node

Answers

1. d **2.** b **3.** a **4.** d **5.** d **6.** c **7.** d **8.** d **9.** d