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Klose Training
MLD Certification

Anatomy

of the Lymphatic System

Manual Lymph Drainage Certification

Klose Training
MLD Certification

Table of Contents

ANATOMY OF THE LYMPHATIC SYSTEM

Anatomy of the Lymphatic System

Components of the Lymphatic System[1]

The lymphatic system is one of the organs that is present throughout the human body and consists of lymph vessels and a number of organs, all of which contain lymphatic tissue[3].

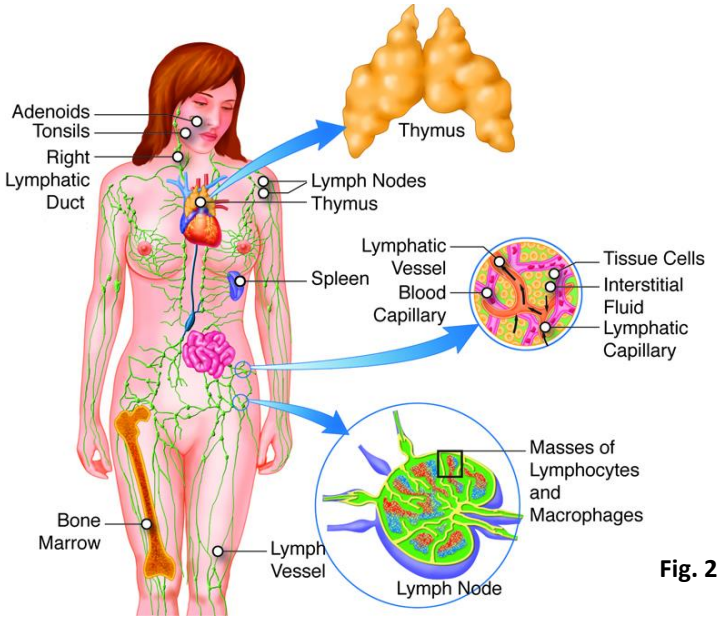

Fig. 2 Components of the lymphatic system. *savingstudentsmoney.org/OLI/AnPpost.html*

The lymphatic structures in the body are:

- **Lymph vessels (collectors) -** collect and transport protein-rich fluid (lymph) from the interstium to the central venous system.
- **Lymph nodes** - are filtering stations for the lymph fluid and serve as a storage place for white blood cells (lymphocytes).
- **Spleen** – is used to dispose of aged red blood cells (erythrocytes) and serves as a storage place for blood (plasma).
- **Thymus** – serves very important immunological functions in the early years of life; also referred to as "thymus gland" because of its secretion of hormones, making it also part of the endocrine system.
- **Tonsils** – serve immunological functions.
- **Lymphocytes** – are white blood cells which the body uses to fight off infections, bacteria and foreign matter.
- **Peyer's patches** – are aggregations of lymphoid tissue (aggregated lymphoid nodules) found in the lowest part of the intestine. Because the lumen of the gastrointestinal tract is exposed to the external environment, much of it is populated with potentially pathogenic microorganisms. Peyer's patches are important for the immune surveillance of the intestinal lumen.

Function of the Lymphatic System[4-6]

- Returns protein and water from the interstitium to the cardiovascular system.
- Absorbs protein, fat and fat-soluble vitamins (chyle) through the intestinal lymph vessels.
- Recognizes and responds to foreign cells, microbes, and cancer cells (serves important immunological functions).

Lymph vessels absorb interstitial fluid, mainly from the skin and subcutaneous tissues, and transport it into the venous circulation. From the intestines, the lymph vessels absorb nutritional fatty acids. This intestinal lymph is called chyle. In addition, the lymphatic organs have very important immunological functions. Lymphocytes (white blood cells) are stored in lymph nodes. These lymphocytes have the ability to recognize foreign cells, substances, microbes, and cancer cells and respond to them, i.e. destroy and eliminate them from the body.

Below is a drawing of the superficial lymph nodes of the axilla and inguinal region with the collecting lymphatics and lymph trunks leading to them.

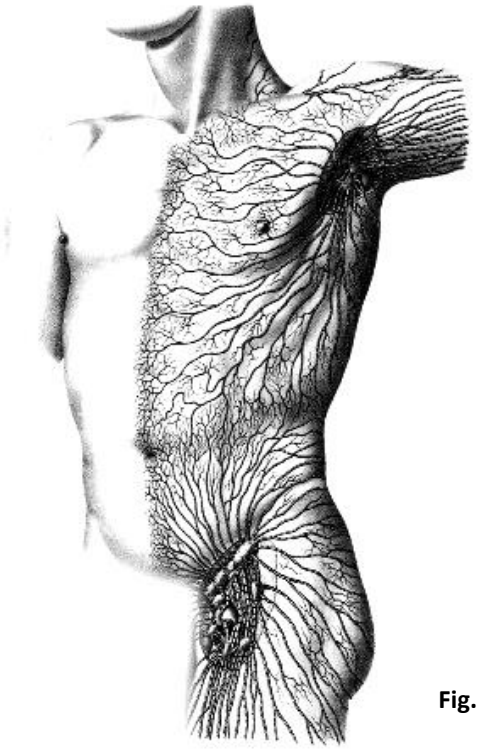

Fig. 3 Marie Philibert Constant Sappey
French anatomist, 1810-1896

Fig. 4 Drawing of lymphatic vessels by Sappey.
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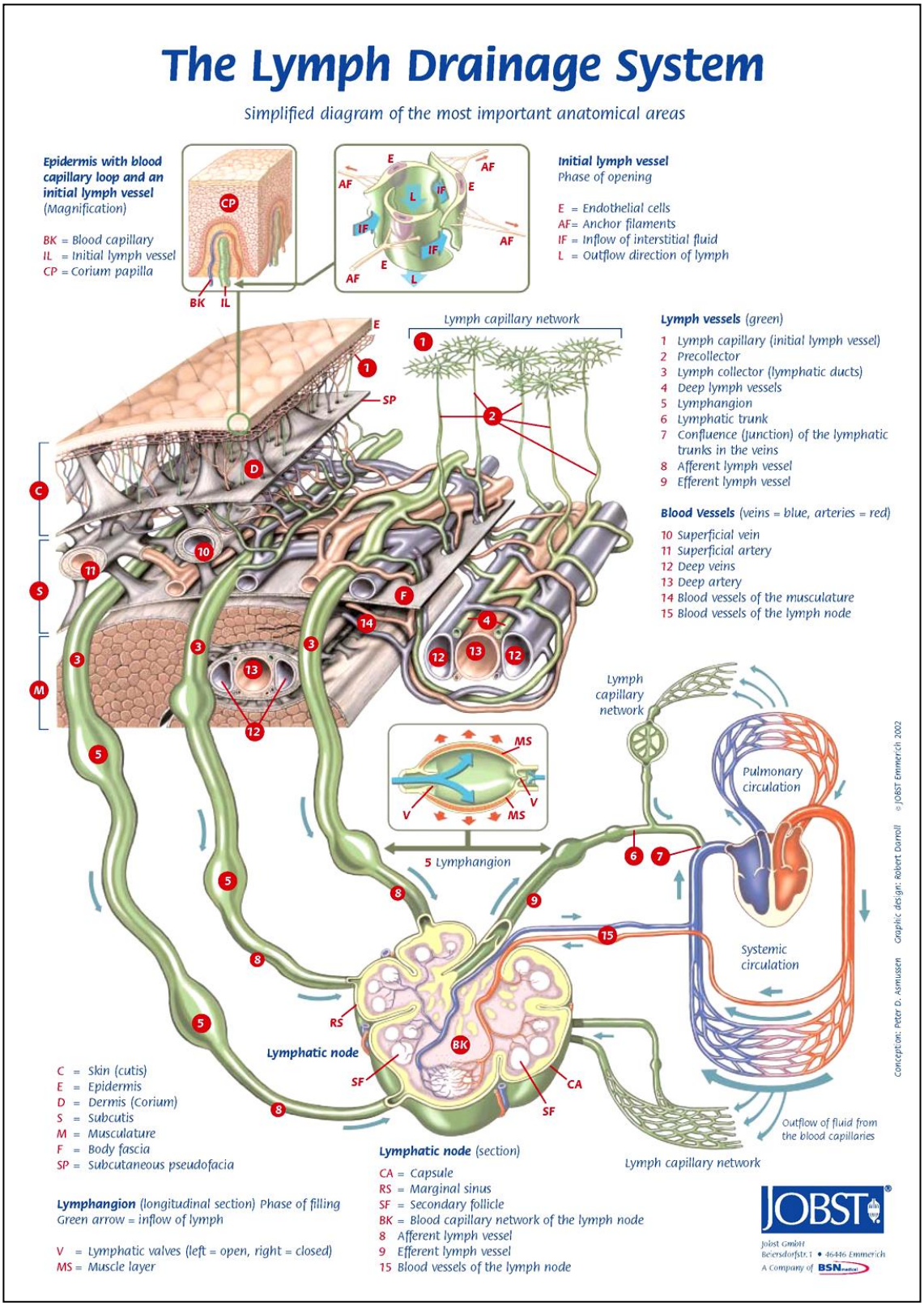

Fig. 5 Lymph Drainage System

Poster available for download at: jobstcompressioninstitute.com/Resources/Literature

Lymph Vessels[1]

Lymph vessels are subdivided into:

- Capillaries (8)
- Pre-collectors (9)
- Collectors (11)
- Trunks (not shown)

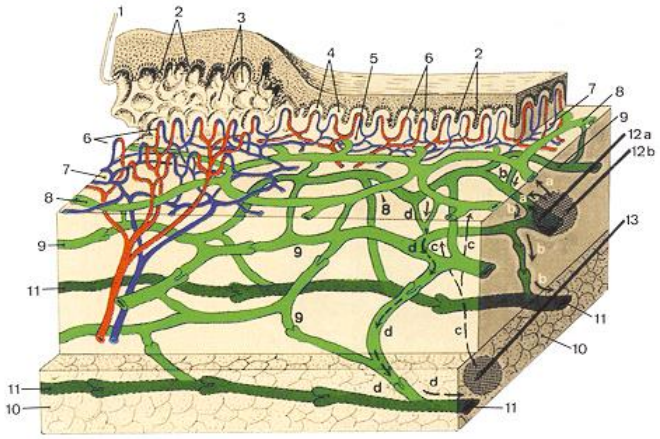

Fig. 6 Lymphatic vessels of the skin.
Foeldi's Textbook of Lymphology

Lymph Capillaries[1,3-6]

Lymph capillaries are larger than blood capillaries and are structurally adapted to ensure the absorption of large molecules, i.e. proteins from the interstitium (Fig. 7). The lymph capillaries originate in tissue spaces and form an extensive plexus throughout the body. In the soft connective tissue of the skin and mucous membranes, lymph capillaries are located close to the blood capillaries. Their wall is made of flat endothelial cells that overlap each other. Because the overlapping ends of the endothelial cells open and close as needed for the absorption of fluid, they are sometimes referred to as "swinging flaps." Anchoring filaments attach to the endothelial cells of the lymph capillary and the surrounding tissues. Any increase of interstitial fluid produces a pull on the anchoring filaments that opens the pores even more, allowing a passive influx of fluid into the small vessel. (Fig. 8)

The important characteristics of the lymph capillaries:

- They are flat endothelium cells with anchoring filaments.
- They form an extensive network just below the epidermis.
- They have a larger diameter than blood capillaries.
- They are able to absorb interstitial fluid (protein and water) as necessary.
- There are no valves inside the lymph capillaries.

The Lymph Capillary and Blood Capillary Loop[1]

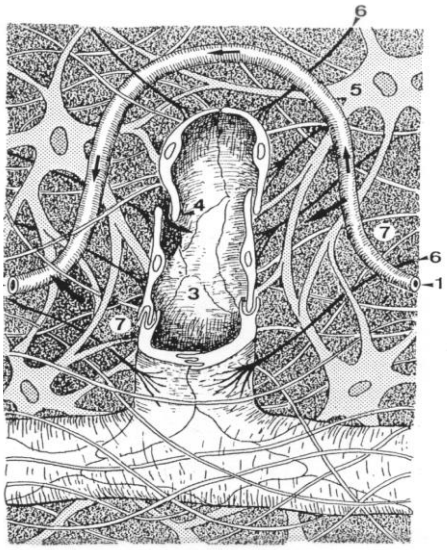

Fig. 7 Lymphatic Capillary

1. Arterial side of the blood capillary
2. Venous side of the blood capillary
3. Lymph capillary
4. Open junction "swinging flap"
5. Fibrocyte
6. Anchoring filaments
7. Interstitial space

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The Opening Mechanism of the Lymph Capillary[1]

Lymph Formation (Fig. 8)

A. The initial lymph vessel is empty and collapsed. The subsequent precollector is filled with lymph. The anchoring filaments and the fiber network are relaxed as a result of low interstitial pressure.

B. Filling phase: The interstitium is filled with fluid and thus the interstitial pressure exceeds the pressure in the initial lymph vessel. The interstitial fiber network and the anchoring filaments are tense, causing the outer swinging flaps of the lymph vessel to be pulled outward. At the same time, the fluid flowing inside the lymph vessel pushes the inner flaps inward causing the inlet valves to open.

C. The initial lymph vessel is filled with lymph.* The pressure in the initial lymph vessel exceeds the interstitial pressure and thus the inlet valves are closed.

D. The pressure inside the initial lymph vessel opens the valve to the precollector and thus the lymph flows towards the precollector.

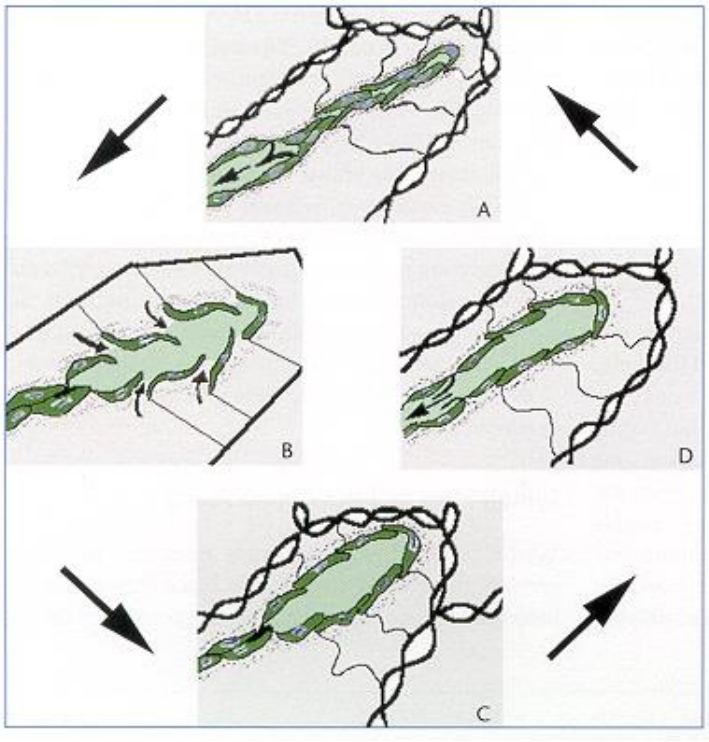

Fig. 8 Opening mechanism of a lymph capillary.
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* Interstitial fluid travels through pre-lymphatic channels from the blood capillary to the lymph capillary. Once interstitial fluid has entered into the lymph capillary, it has become lymph. On its way to the central venous system, lymph fluid will be filtered by lymph nodes and becomes more concentrated with protein. Therefore, interstitial fluid differs from lymph fluid.

Pre-collectors[1]

The pre-collectors channel the lymph fluid into the larger transporting vessels. Pre-collectors possess absorbing functions for fluid like the capillaries but in some areas resemble transporting vessels containing smooth-muscle cells and valves.

Lymph Collectors[1]

In structure, the collectors resemble veins (Fig. 9) but have thinner walls and valves in shorter intervals. The valves are passive and determine the direction of flow. They prevent the return of fluid and guarantee transport from distal to proximal or to the regional lymph nodes.

Depending on the diameter of the vessel, valves are evident every 0.6 - 2 cm in the collectors and every 6 - 10 cm in the thoracic duct. The section of the collector between a distal and a proximal valve is called a lymphangion.

Like veins, lymph collectors also consist of a three-layer wall and bicuspid valves. The three layers are:

- **Tunica intima** (inner layer) - composed of endothelial cells and a basal membrane
- **Tunica media** (middle layer)- composed of smooth muscle cells
- **Tunica externa** (outer layer) - made of soft collagenous connective tissue

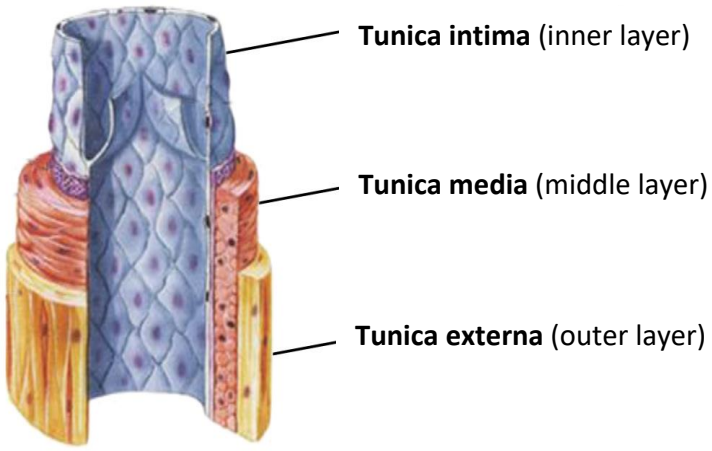

Fig. 9 Diagram of the wall structure of a vein.
Modified from Fox, Stuart I, Human Physiology 4th Edition, Brown Publishers

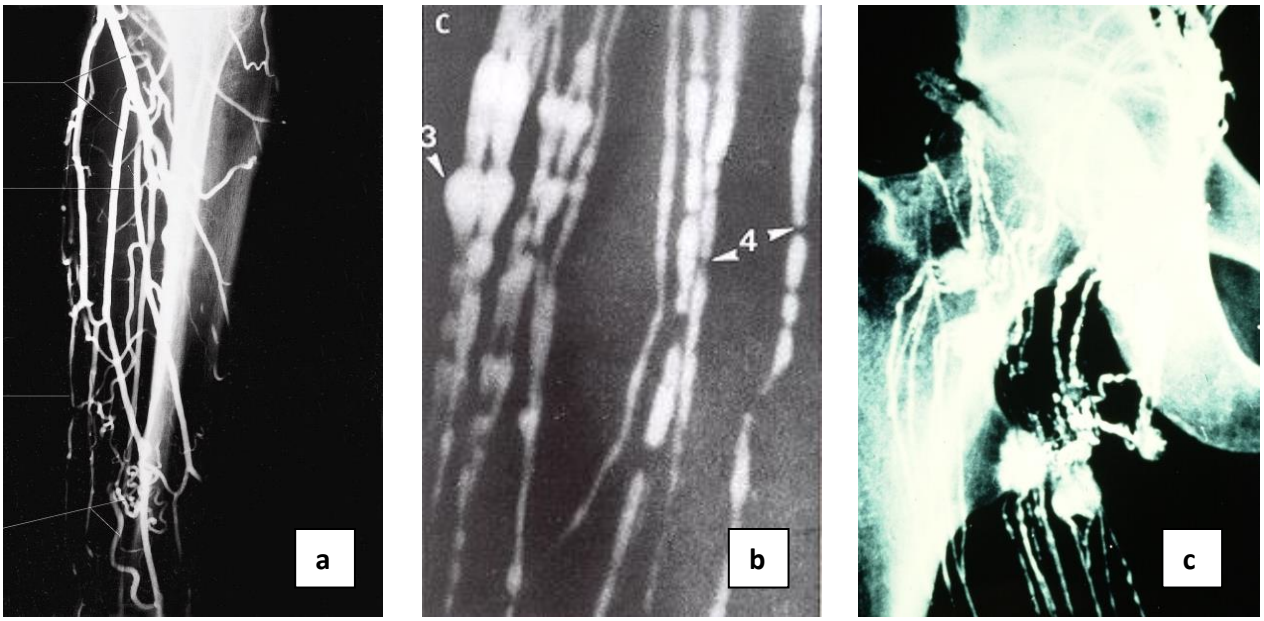

Fig. 10 Comparison of a venogram of the lower extremity veins (a) vs. a lymph-angiogram (aka lymphography) of the lower extremity collectors (b) and lymph nodes (c).

In contrast to circulation of the blood where the heart is acting as a pump, lymph is transported by the intrinsic contractions of the lymphangia, a process referred to as lymphangioactivity. The frequency of contractions is determined by autonomous regulation through the sympathetic nervous system and the lymph volume. When lymph volume stretches the vessel wall, its smooth muscle responds with a contraction. The frequency of contractions amounts to 6-10 x/min at rest but may increase to 10 times that amount during exercise. An increase of lymph fluid due to physical activity, heat, or inflammation results in an increase in lymph time volume due to increased pulsation frequency and higher filling amplitude of the lymphangia. In addition, lymph transport is supported by extrinsic factors such as the contraction of the skeletal muscle (muscle and joint pump), arterial pulsation, respiratory pressure changes, negative pressure in central veins, and external pressure such as with Manual Lymph Drainage (MLD).

Collectors are differentiated as either superficial or deep, based on location. The superficial collectors are located in the subcutaneous fat tissue and drain the skin and the subcutis. The individual collectors run relatively straight and are connected with each other through numerous anastomoses. The deep collectors are located sub-fascially at the extremities and the trunk. They are usually larger in diameter than the superficial collectors and they drain related muscle, joints, and ligaments. As a rule, they run within a sheath along with the deep arteries and veins. Like the veins, superficial and deep collectors are networked via so-called perforators (cross connections).

Lymphangion[1]

The lymphangion is the smallest functional unit of the lymph collector. It is bordered by a distal and proximal valve. The lymphangion is characterized by:

- Muscle tissue and bicuspid valves
- Autonomic NS innervation
- Intrinsic contractions (6-10 x/min)

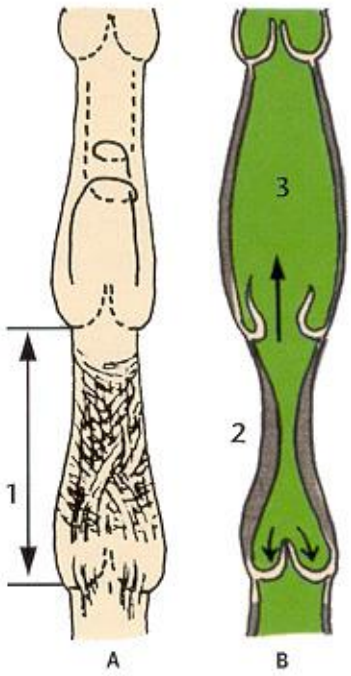

Fig. 11 Structure and function of lymphangion:
A - Arrangement of musculature
B - Normal function

1 – Lymphangion
2 - Contracted segment (emptying phase)
3 - Relaxed segment (filling phase)

NOTE: Arrows indicate direction of flow.

Modified from Foeldi's Textbook of Lymphology

Lymphatic Watersheds and Anastomoses[1]

Lymphatic watersheds delineate (separate) lymphatic tributary regions (Fig. 12). Important watersheds on the trunk are the:

1. Median-sagittal (vertical) WS
2. Transverse (horizontal) WS
3. Clavicle WS
4. Spine of scapula WS
5. Chaps (gluteal) WS

A. Right upper trunk quadrant
B. Left upper trunk quadrant
C. Right lower trunk quadrant
D. Left lower trunk quadrant

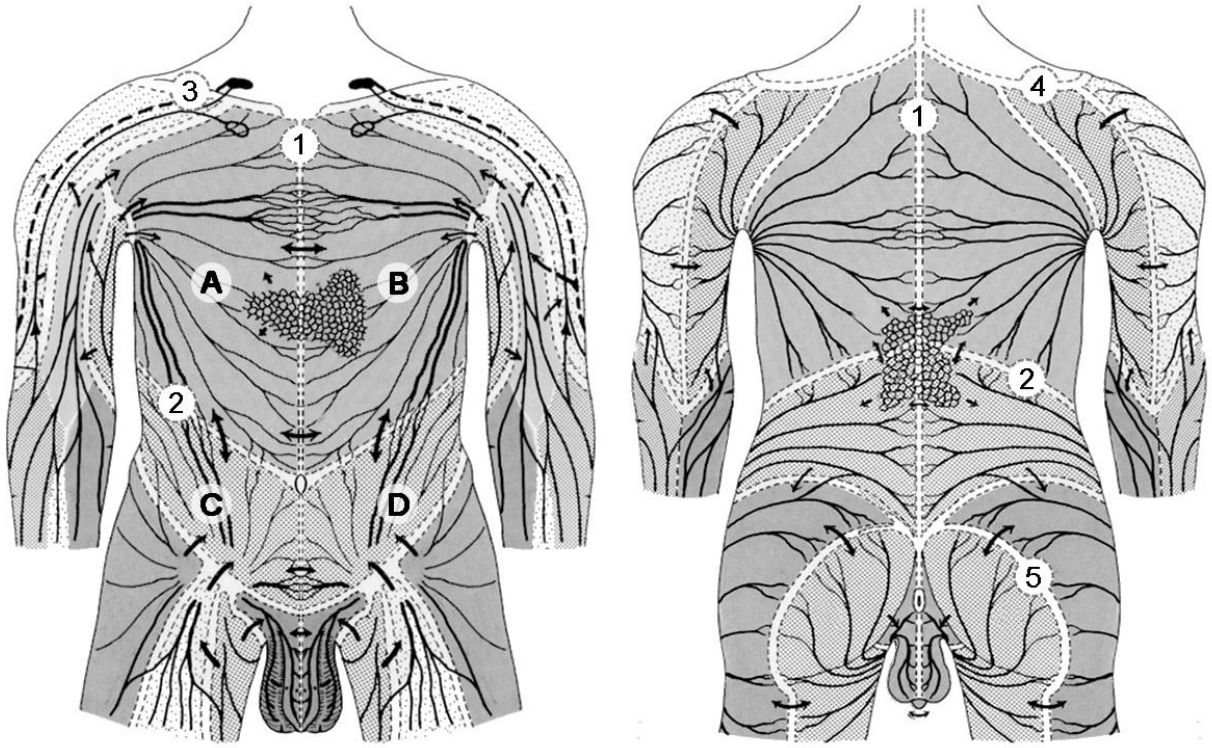

Fig. 12 Lymphatic Watersheds
Modified from Foeldi's Textbook of Lymphology

Lymphatic regions may be referred to as the "tributary regions" or "root areas," e.g. root areas for the axillary lymph nodes are the upper extremities, the upper trunk quadrants, and the mammary glands (breasts). Alternately, it can be said that the axillary lymph nodes are the "regional" lymph nodes for the upper extremities, upper trunk quadrants, and the breasts. See Tables 1-3 later in the Anatomy section for the tributary regions of lymph nodes.

Lymphatic Anastomoses[1]

Lymph collectors connect across lymphatic watersheds! These connections are referred to as anastomoses and are utilized in Manual Lymph Drainage for moving fluid from a congested to a healthy part of the body. The most prominent areas where lymphatic vessels connect are across the sternum (chest), the upper thoracic spine (back), supra-pubic area (front), sacrum (back) and on the flank (between the anterior and posterior axillary lines).

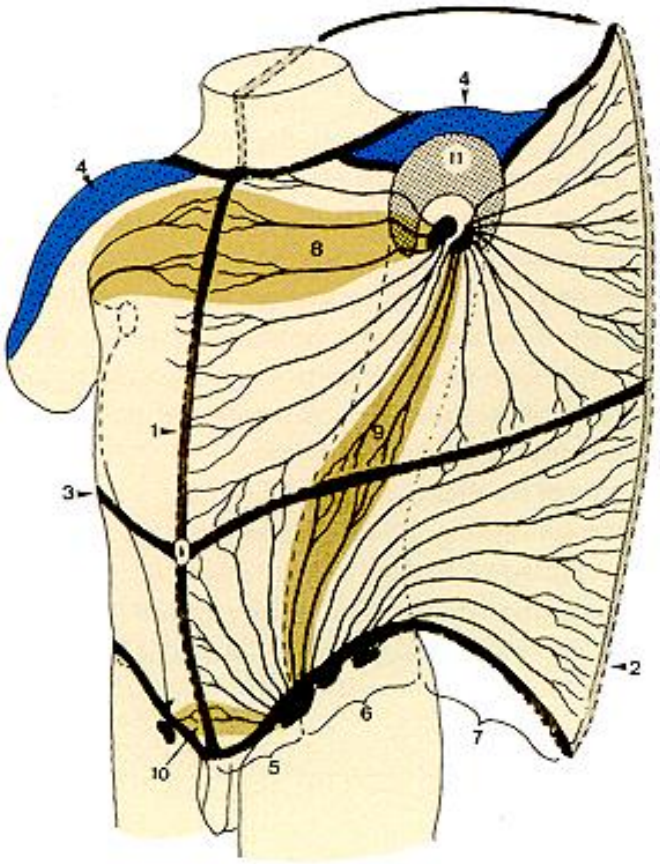

Fig. 13 Lymphatic Anastomoses Pathways

1. Median-sagittal (vertical) WS
2. Posterior sagittal WS
3. Transversal (horizontal) WS
4. Drainage area of the lateral upper arm bundle
5. Anterior thoracic and abdominal walls
6. Lateral thoracic and abdominal walls
7. Posterior thoracic and abdominal walls
8. Axillo-axillary (interaxillary) anastomoses
9. Axillo-inguinal anastomoses
10. Interinguinal anastomoses
11. Amputation plane of the shoulder

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Lymph Trunks and Ducts[1,8]

The largest lymph vessels are called trunks and ducts. The trunks collect fluid from the organs, the extremities and the related quadrants of the trunk. The ducts eventually transport approximately 4 liters of lymph into the venous circulation (Fig. 14).

The largest lymphatic vessel in the human body is the thoracic duct. It is approx. 2 – 5 mm in diameter and 40 cm long. Deep in the trunk, it parallels the spine from L2 to the venous angle (juncture between the left internal jugular and left subclavian veins). Because it penetrates the diaphragm and runs through the chest into the root of the neck, it can be subdivided into an abdominal, thoracic, and cervical part. The abdominal portion of the thoracic duct is a sack-like enlargement which is called the cisterna chyli.

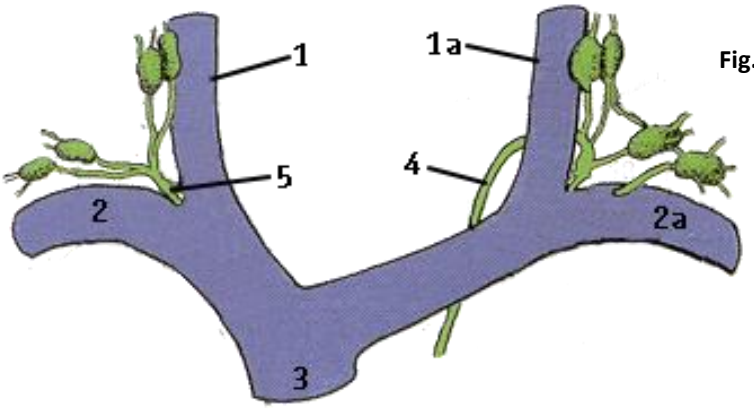


Fig. 14 Right and left venous angles:
1, 1a - Internal jugular veins
2, 2a - Subclavian veins
3 - Superior vena cava
4 - Thoracic duct
5 - Right lymphatic duct
Modified from Foeldi's Textbook of Lymphology

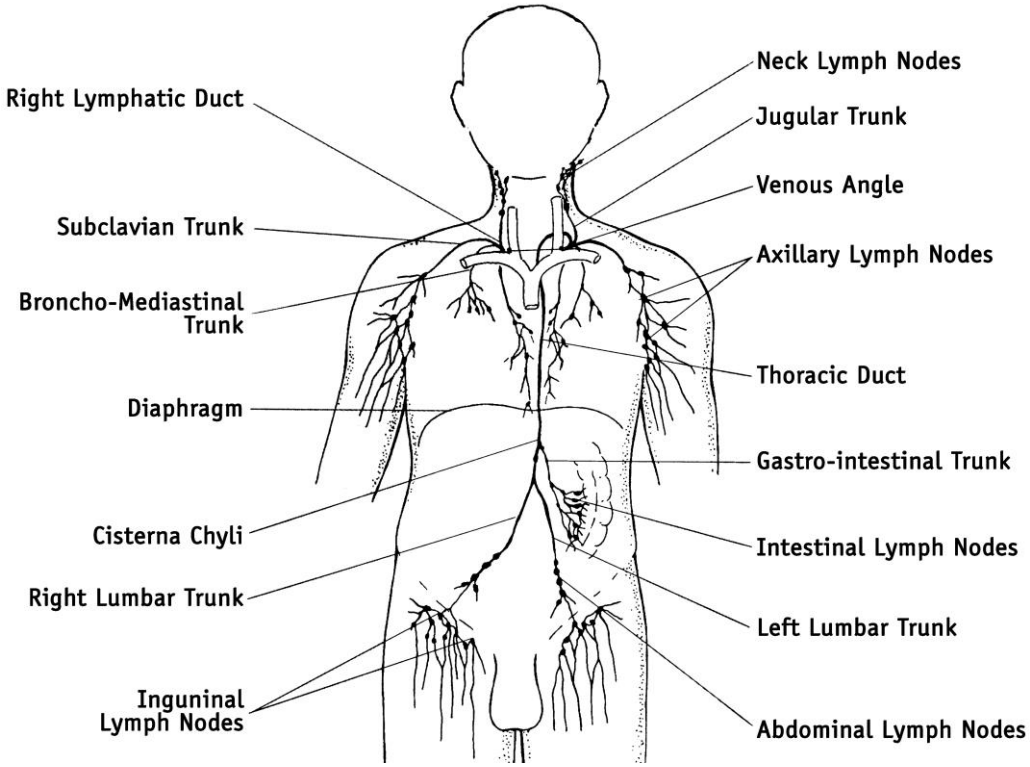


Fig. 15 Major lymphatic trunks and ducts of the human body.

From the lower extremities and the adjacent trunk quadrants, lymph is transported into the inguinal lymph nodes and from there, via the right and left lumbar trunks, to the cisterna chyli, the beginning of the thoracic duct. The intestinal trunk also transports fluid to the cisterna chyli from the small intestines. After a meal, due to the absorption of fat into the intestinal trunk, the contents of the intestinal lymph vessels appear cloudy (milky white) in color. Because of its milky-white appearance, the intestinal lymph is referred to as chyle.

The **lymphatic trunks of the lower body** are:

- **Right and left lumbar trunks** - from the inguinal lymph nodes to the cisterna chyli
- **Intestinal trunk** - from the small intestines to the cisterna chyli

From the upper extremities and the adjacent trunk quadrants, the fluid is transported into the axillary lymph nodes, and from there, via the bilateral subclavian trunks, into the thoracic duct on the left side and the right lymphatic duct on the right. The cervical lymph nodes drain lymph via the bilateral jugular trunks into the thoracic and right lymphatic ducts. From the bronchi, lungs, and the mediastinum, the lymph fluid reaches the ducts via the broncho-mediastinal trunks.

The **lymphatic trunks of the upper body** are:

- **Right and left jugular trunk** - from the cervical lymph nodes to the thoracic duct (left side of body) and the right lymphatic duct (right)
- **Right and left subclavian trunk -** from the axillary lymph nodes to the thoracic duct (left) and the right lymphatic duct (right)
- **Right and left broncho-mediastinal trunk** - from the bronchi, lungs and mediastinum to the thoracic duct (left) and the right lymphatic duct (right)

Since the central (deep) lymphatic trunks and ducts are arranged asymmetrically, the lymph fluid of the lower body (everything below the diaphragm), as well as the left upper body, is carried via the thoracic duct to the left venous angle. The right upper body is eventually drained via the right lymphatic trunk into the right venous angle (Fig. 16).

The thoracic duct drains approx. ¾ of the body's lymph into the left venous angle (subclavian vein). The right lymphatic duct drains approx. ¼ of the body's lymph into the right venous angle (subclavian vein).

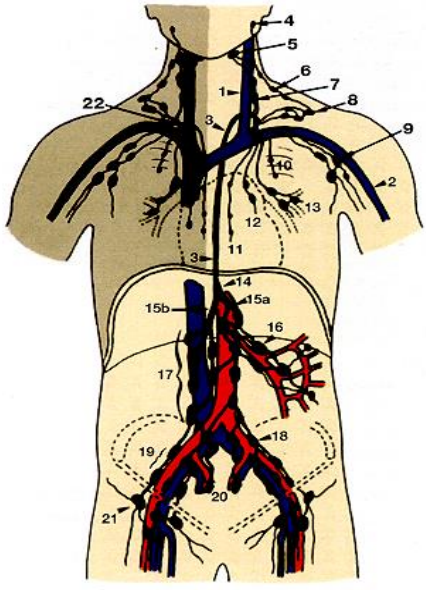


Fig. 16 Three-quarters of the body empties into the left venous angle. *Foeldi's Textbook of Lymphology*

Lymph Fluid and Lymph Nodes[1]

Lymph fluid (lymphatic load) consists of:

- Proteins
- Water
- Cells (RBCs, WBCs, lymphocytes)
- Waste products and other foreign substances
- Fat (intestinal lymph, chyle)

75-100 grams of protein are transported by the lymph vessels per day. This equals approximately ½ the amount of proteins circulating in the systemic circulation. In addition, the lymphatic system is able to carry foreign protein, lymphocytes, cancer cells, cell debris, and bacteria. From the interstitium, water is also absorbed and transported through the lymphatic system. In the small intestines, long-chain triglycerides, cholesterol, and the fat-soluble vitamins A, D, E and K are absorbed into the lymphatic system. The intestinal lymph is called chyle.

There are **600-700 lymph nodes** in the human body. The majority of lymph nodes are found in the abdomen (intestines), but the head and neck region also contains a large quantity. Other lymph node stations are found in the axilla and inguinal areas. Lymph nodes vary in size and shape. They are 2 – 30 mm long and are oval, round, bean, or kidney-shaped. A strong connective-tissue capsule protects a dense filter-like network inside.

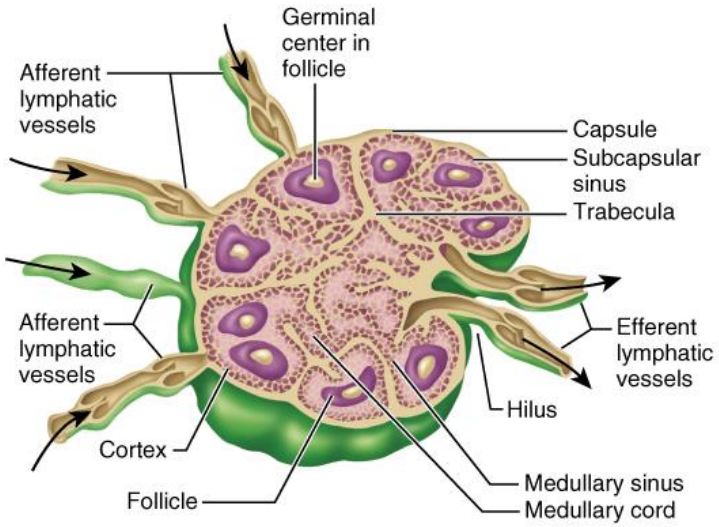


Fig. 17 Lymph node with afferent and efferent lymph vessels.
hypervibe.com

The **functions of the lymph nodes** are:

- **Filtration of noxious matter** such as bacteria, toxins and dead cells. Due to the branched sinus system, the lymph flow is slowed, allowing macrophages to better catch and phagocytize harmful substances.
- **Storage of lymphocytes** (white blood cells). Lymphocytes are important in fighting infections and enhancing the body's immune capabilities.
- **Regulation of the concentration of protein in the lymph.** As the lymph flows through the node, excess water is reabsorbed into blood capillaries.

Lymph nodes are generally located in adipose tissue and are therefore not palpable. Enlarged, easily-palpable nodes are always suspicious. Frequently, infections in the drainage areas of the nodes will cause enlargement and pressure-sensitivity. However, enlarged lymph nodes can also be indicative of malignant disease (cancer). In slender, athletic people, inguinal lymph nodes are easily palpable because the upper-thigh fascia forms a firm backing so that the lymph nodes cannot move away under palpation.

Lymph nodes have more afferent than efferent lymph vessels. Numerous afferent lymph vessels carry lymph into the node(s), whereas a small number of efferent lymph vessels leave the nodes at the "hilus." The lymph-node hilus is also the place where arteries and veins enter and exit.

Each lymph node and lymph node group receives lymph from a specific region of the body. In regard to the superficial lymph system, these regions are delineated by "lymphatic watersheds." On the trunk, the direction of flow changes at the lymphatic watersheds. Lymph vessels on either side of the watershed transport lymph fluid to the left/right side of the trunk and to the upper (axillary)/lower (inguinal) lymph nodes, respectively.

Lymph Nodes and their Tributary Regions

Table 1 Lymphatic tributary regions of the head and neck region

Lymph Node Group	Location	Tributary Areas	Drainage
Submental LN	2-3 nodes below the chin	Lower lip, gums, tip of tongue, chin	Deep cervical lymph nodes
Submandibular LN	5-8 nodes in the area of the submandibular glands	Lips, external cheeks, medial eye lids, teeth, gums, tongue, floor of mouth, cheek mucosa	Deep cervical lymph nodes
Preauricular LN	2-4 nodes in front of the ear at the parotid gland	Front of the auricle, nasal root, lateral eye lids, parotid	Deep cervical lymph nodes
Retroauricular LN	1-2 nodes behind the ear	Auricle (chiefly posterior surface), neighboring scalp, middle ear	Deep cervical lymph nodes
Occipital LN	2-3 nodes above insertion of the trapezius muscle	Skin of posterior head, base of head	Deep cervical lymph nodes
Cervical LN	Along the sternocleidomastoid muscle and the internal jugular vein, in the supraclavicular fossa	Ear, parotid gland, jaw angle, neck, back of head, tonsils	Deep cervical lymph nodes and jugular trunk
Supraclavicular LN	Supraclavicular fossa	Lymph fluid from cervical LN, skin between clavicle and spine at scapula WS's	Jugular trunk

Table 2 Lymphatic tributary regions of the upper body

Lymph Node Group	Location	Tributary Areas	Drainage
Axillary LN	25-30 nodes prefascial in the armpit, grouped around the large vessels	Upper extremities, upper trunk quadrants and breasts	Deep axillary lymph nodes, infra and supraclavicular nodes, subclavian trunk
Pectoral LN	Next to the major pectoral muscle, in the area of the third serratus digitation	Breasts, especially lateral quadrants	Deep axillary lymph nodes
Cubital LN	Cubital fossa	Ulnar skin of forearm, bones, muscle and connective tissue of forearm and hand	Deep axillary lymph nodes

Table 3 Lymphatic tributary regions of the lower body

Lymph Node Group	Location	Tributary Areas	Drainage
Lumbar LN	Lumbar area	Testicles/ovaries, uterus, kidneys,adrenal glands	Lumbar trunks
Iliac LN	Pelvis	Inguinal lymph nodes, bladder, prostate, seminal vesticles, uterus, upper portion of vagina	Lumbar trunks
Superficial Inguinal LN	Approx. 10 nodes prefascial in the groin	Trunk wall below navel line, lumbar and gluteal region, perineum, external genitals, lower extremities	Deep inguinal lymph nodes
Popliteal LN	Popliteal fossa	Skin, deep parts of the lower leg	Deep inguinal lymph nodes

Lymph Flow versus Blood Flow[1,3,4,6,8,9]

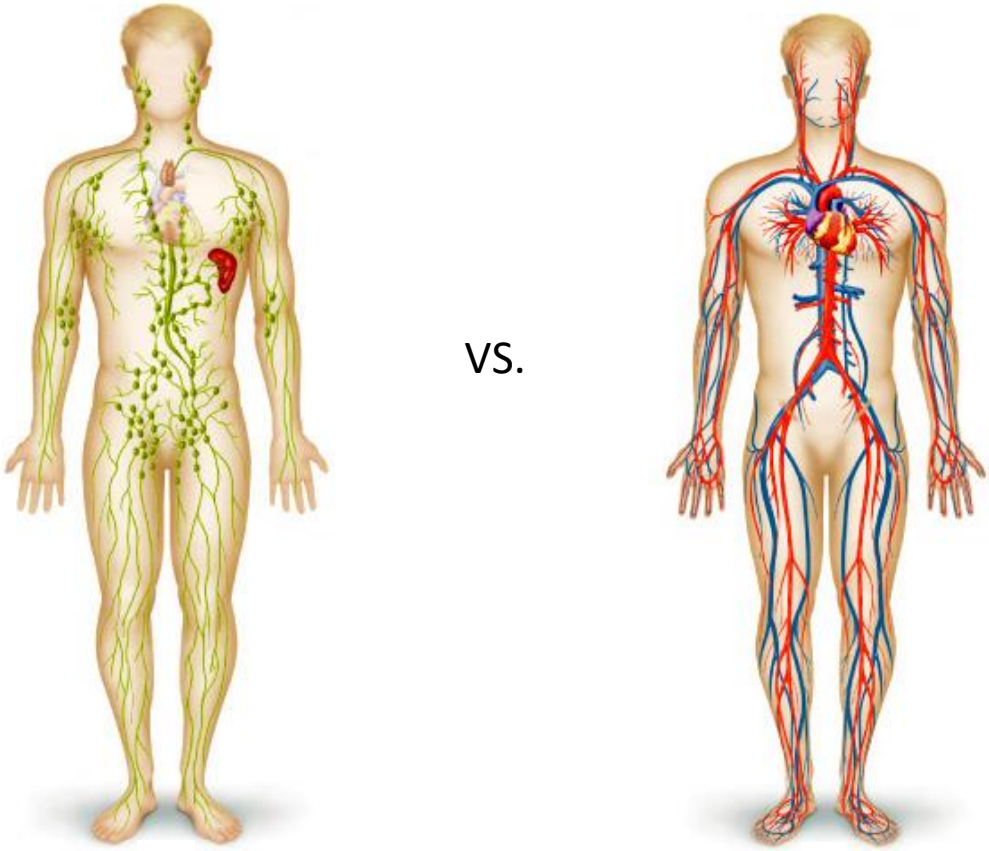
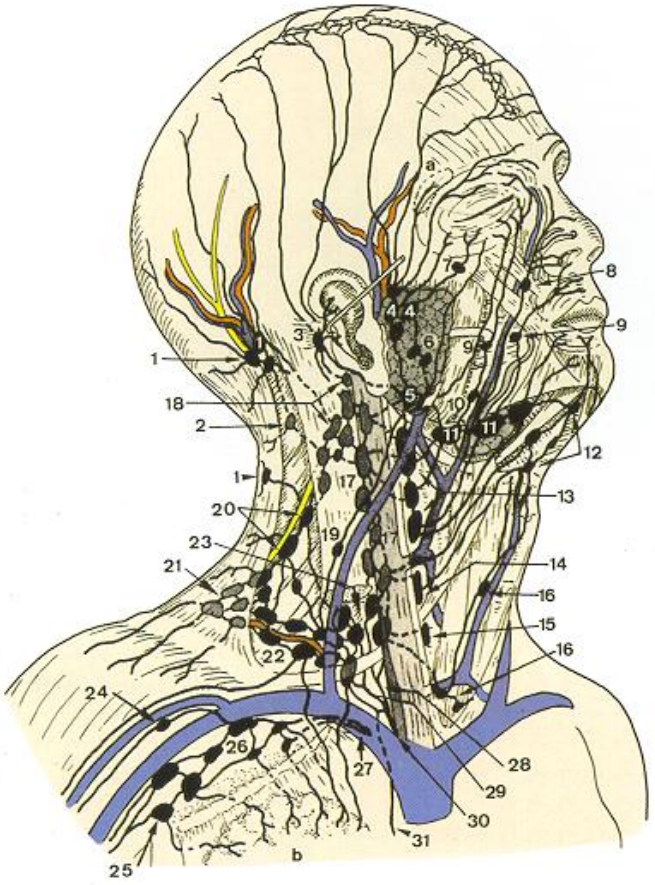


Fig. 18 Diagram of the lymphatic system (A) and the blood circulatory system (B).

Table 4 Lymph system versus blood circulatory system

LYMPH SYSTEM	**BLOOD CIRCULATORY SYSTEM**
One way	Circular
Approx. 4 liters/day	Approx. 7200 liters/day (5 liters/minute)
Fluid moved by intrinsic contractions of lymph collectors	Fluid moved by central pump (heart) and calf muscle pump
No continuous column of fluid	Continuous column of fluid
Peripheral lymphatic pressure is unaffected by dependency	Dependency significantly increases venous pressure
Obstruction leads to collection of *high* protein fluid (>1.5gm/dl)	Obstruction leads to collection of *low* protein fluid (<1.0 gm/dl)
Long latency period between injury and clinical appearance	Long latency period between injury and clinical appearance
Lymph is filtered by lymph nodes	Blood is filtered by the kidneys, liver, and spleen

Illustrations of Important Lymph Node Locations[1]



Cervical (Head & Neck) Lymph Nodes

Fig. 19 Lymph nodes of the head and neck.

1. Occipital lymph nodes - Occipital region and upper part of the skin of the neck.
3. Retroauricular lymph nodes - Parietal area (posterior auricle)
4. Preauricular/parotid lymph nodes - Forehead, upper eye lid, and lateral part of the lower eye lid (auricle)
11. Submandibular lymph nodes - Nose, upper and lower lip, medial part of the lower lid, cheek
12. Submental lymph nodes - Chin, medial part of lower lip

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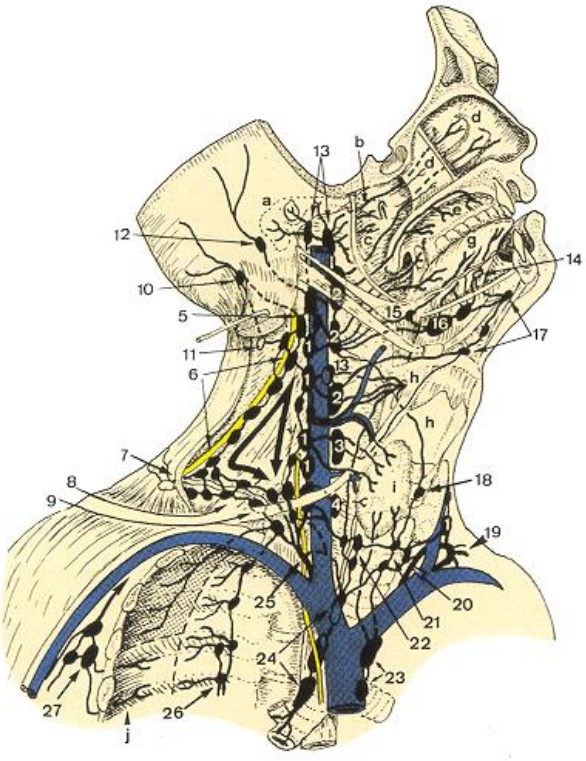

Deep Cervical Lymph Nodes

Fig. 20 Deep cervical lymph nodes.

1. Internal jugular lymph nodes
6. Lymph nodes accompanying the accessory nerve
8. Supraclavicular lymph nodes

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Axillary & Parasternal Lymph Nodes

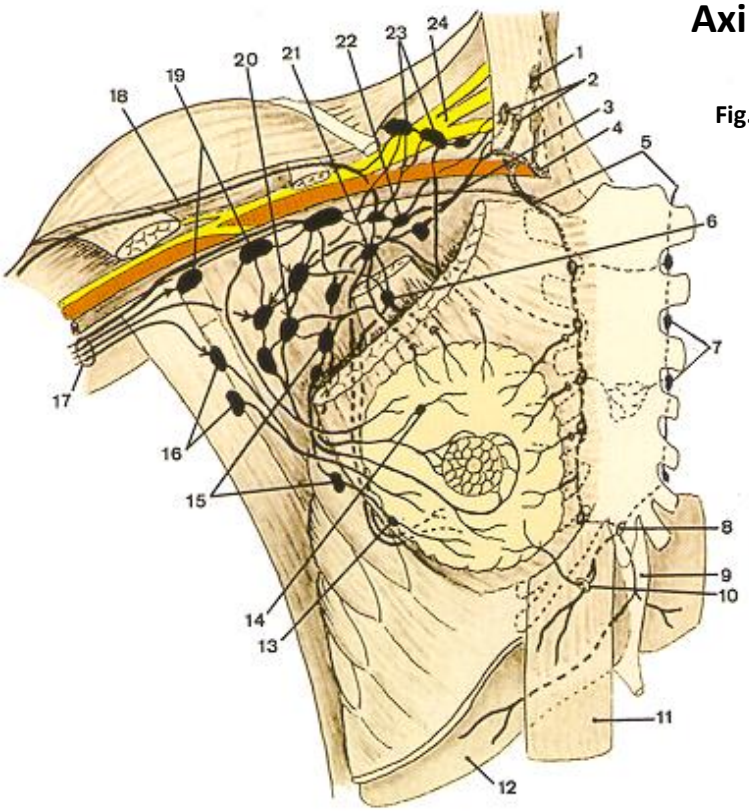

Fig. 21 Axillary lymph nodes.

1.+2. Jugular lymph nodes
3. Subclavian trunk
4. Right lymphatic duct
5. Parasternal trunk
6. lymph node (interpectoral LN)
7. Parasternal lymph nodes
8. Prepericardic l.n.
9. Falciform ligament
10. Epigastric pathway
11. Rectus abdominis muscle
12. Liver
13. Paramammary lymph node
14. Premammary lymph node
15. Pectoral lymph nodes
16. Subscapular lymph nodes
17. Medial upper arm bundle
18. Deltoid bundle
19. Lateral axillary lymph nodes
20. Central axillary lymph nodes
21. Subpectoral lymph nodes
22. Infraclavicular lymph nodes
23. Supraclavicular lymph nodes
24. Brachial nerve plexus

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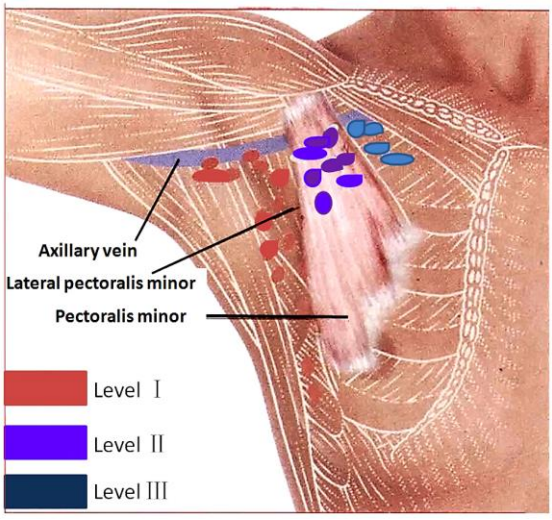

Level 1-3 Axillary Lymph Nodes

Fig. 22 Three levels of axillary lymph nodes.
figshare.com

Intercostal Lymph Nodes and Collectors

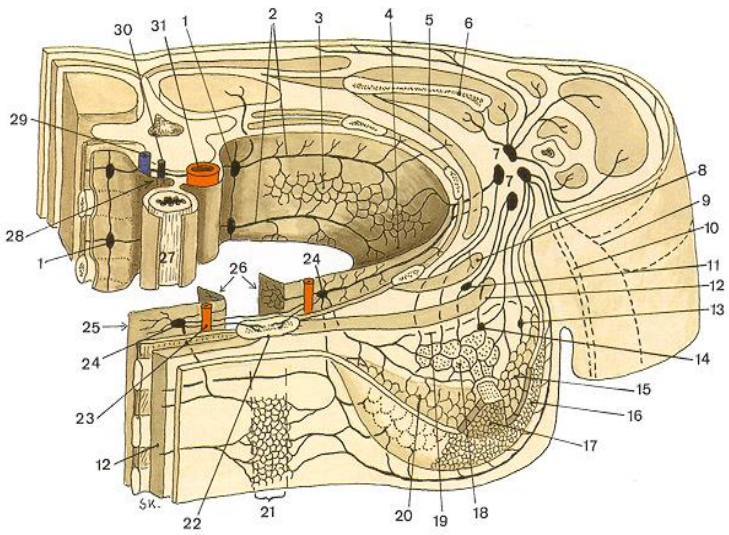

Fig. 23 Intercostal lymph nodes and collectors

1. Intercostal (paravertebral) lymph node
2. Intercostal collector
3. Lymph vessel plexus of the pleura
7. Axillary lymph nodes
10. Medial upper arm bundle
21. Sagittal (median) watershed
22. Parasternal lymph nodes
24. Thoracic duct

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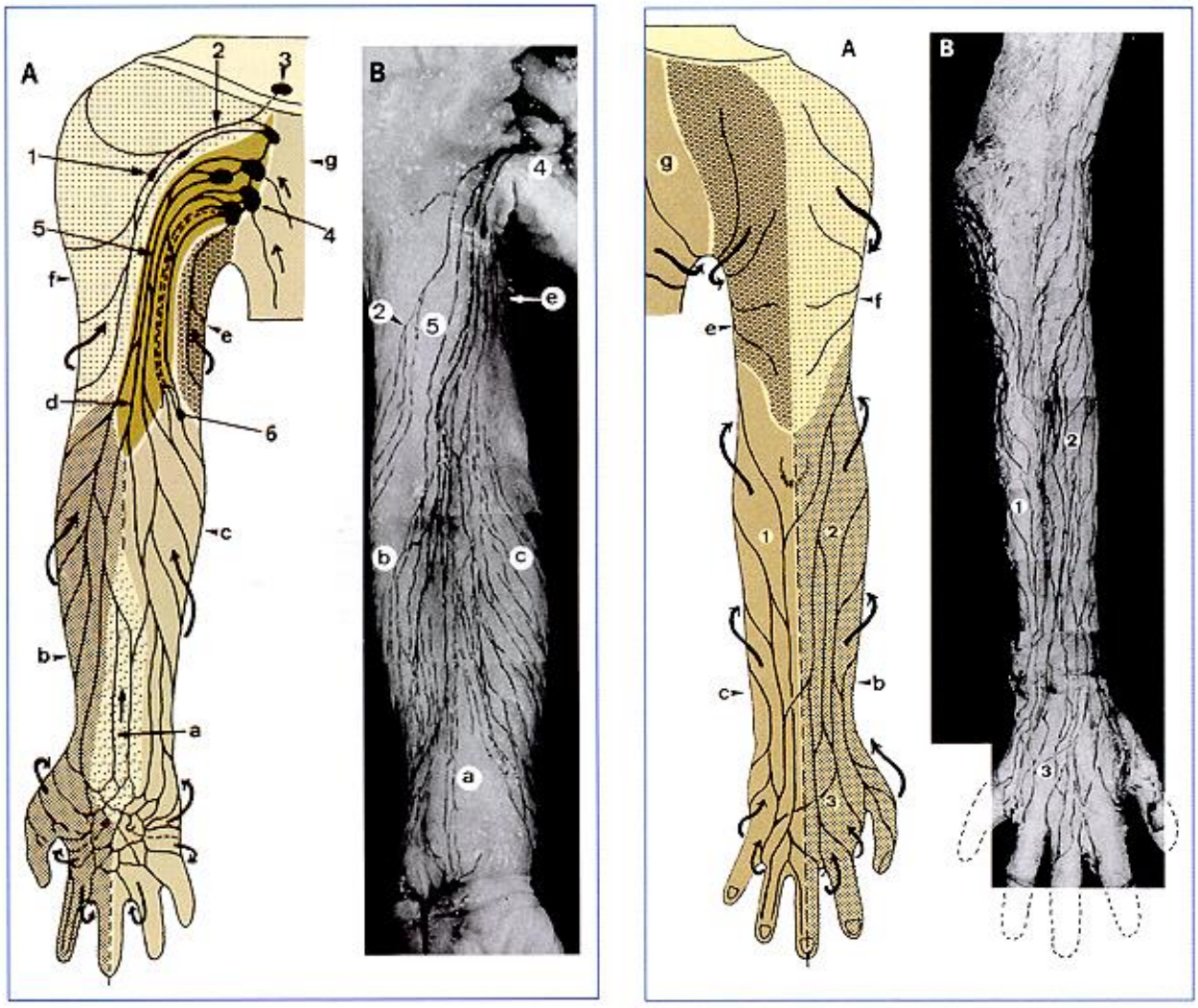

Lymph Vessels and Drainage Areas of the Upper Extremity

Fig. 24 and 25 Lymph vessels of the upper extremity.

a. Medial forearm bundle
b. Radial forearm bundle
c. Ulnar forearm bundle
d. Medial upper arm bundle
e. Dorso-medial upper arm bundle
f. Lateral upper arm bundle
g. Upper trunk quadrant

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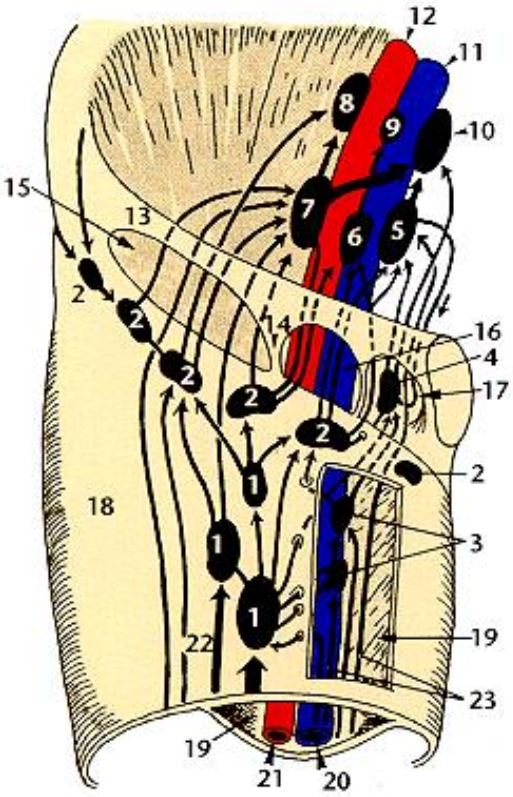

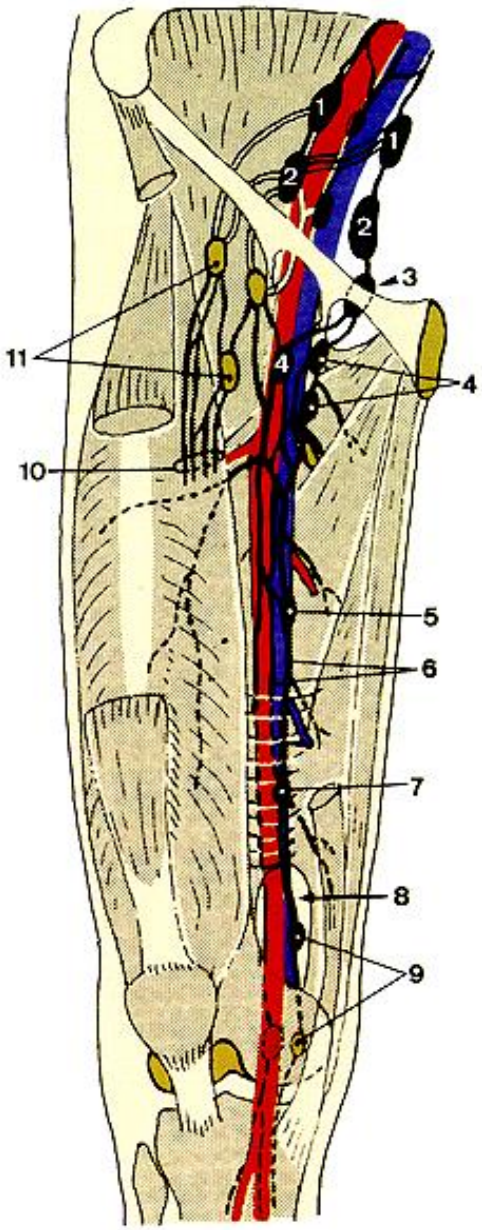

Inguinal Lymph Nodes

Fig. 26 and 27 Inguinal lymph nodes.
1-2. Superficial inguinal nodes
3. Deep inguinal nodes
4. Rosenmueller's node
5-10. Iliac (pelvic) nodes
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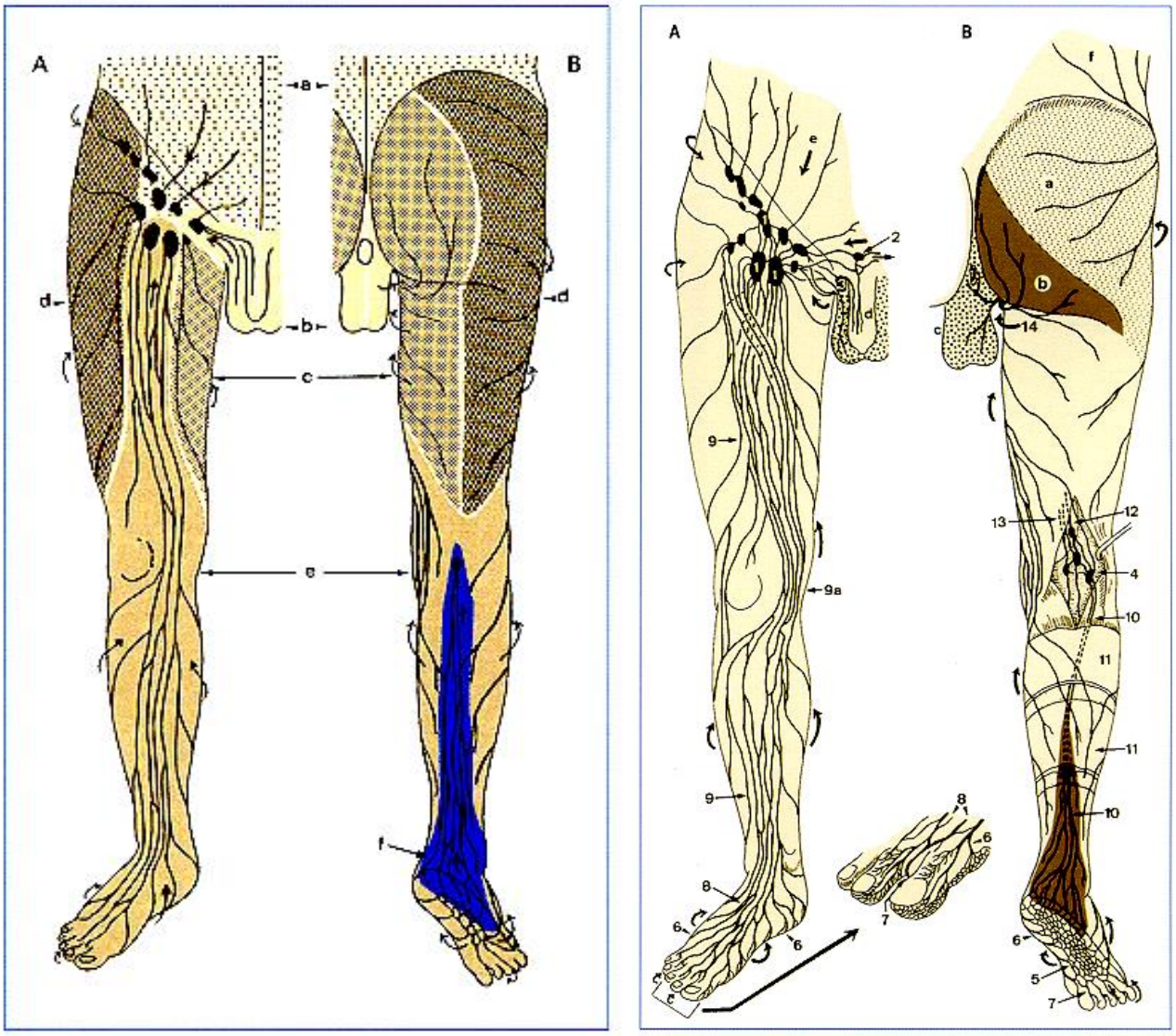

Lymph Vessels and Drainage Areas of the Lower Extremity

Fig. 28 and 29 Lymph vessels and drainage areas of the lower extremity.
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Bonus Pictures

Fig. 30 and 31 Lymph collectors of the lower extremity in a cadaver.
Anatomy Department of the University of Zurich, Switzerland

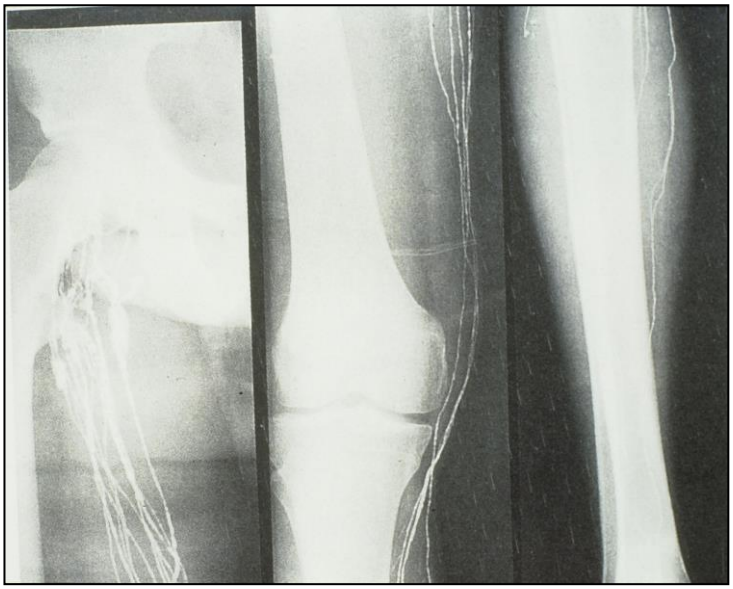

Fig. 32 and 33 Lymphanigiogram of the lower extremity. Healthy lymph collectors (left) and dilated lymph collectors in patient with primary lymphedema (right).
N. Browse, Reducing Operations for Lymphoedema of Lower Limb

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