Chapter 11
Keeping Up Your Defenses: The Lymphatic System

In This Chapter

- Delving into lymphatic ducts
- Noodling around with nodes
- Exploring the lymphatic organs

You see it every rainy day — water, water everywhere, rushing along gutters and down storm drains into a complex underground system that most would rather not give a second thought. Well, it’s time to give hidden drainage systems a second thought: Your body has one. You already know that the body is made up mostly of fluid. Interstitial or extracellular fluid moves in and around the body’s tissues and cells constantly. It leaks out of blood capillaries at the rate of nearly 51 pints a day, carrying various substances to and away from the smallest nooks and crannies. Most of that fluid gets reabsorbed into blood capillaries. But the one or two liters of extra fluid that remain around the tissues become a substance called lymph that needs to be managed to maintain fluid balance in the internal environment. That’s where the lymphatic system steps in, forming an alternative route for the return of tissue fluid to the bloodstream.

But the lymphatic system is more than a drainage network. It’s a body-wide filter that traps and destroys invading microorganisms as part of the body’s immune response network. It can remove impurities from the body, help absorb and digest excess fats, and maintain a stable blood volume despite varying environmental stresses. Without it, the cardiovascular system would grind to a halt.

We bet that you won’t take your little lymph nodes for granted anymore after you’re done with this chapter.

Duct, Duct, Lymph

The story of the lymphatic system (shown in Figure 11-1) begins deep within the body’s tissues at the farthest reaches of blood capillaries, where nutrients, plasma, and plasma proteins move out into cells, while waste products like carbon dioxide and the fluid carrying those molecules move back in through a process known as diffusion. Roughly 10 percent of the fluid that leaves the capillaries remains deep within the tissues as part of the interstitial (meaning “between the tissues”) fluid. But in order for the body to maintain sufficient volume of water within in the circulatory system, eventually this plasma and its protein must get back into the blood. So the lymphatic vessels act as a recycling system to gather, transport, cleanse, and return this fluid to the bloodstream.
To collect the fluid, minute vessels called lymph capillaries are woven throughout the body, with a few caveats and exceptions. There are no lymph capillaries in the central nervous system, teeth, outermost layer of the skin, certain types of cartilage, any other avascular tissue, and bones. And because bone marrow makes lymphocytes, which we explain in the next section, it’s considered part of the lymphatic system. Plus, lacteals (lymphatic capillaries found in the villi of the intestines) absorb fats to mix with lymph, forming a milky fluid called chyle. (See Chapter 9 for details on lacteals.) Unlike blood capillaries, lymph capillaries dead-end (terminate) within tissue. Made up of loosely overlapping endothelial cells anchored by fine filaments, lymph capillaries behave as if their walls are made of cellular one-way valves. When the pressure outside the capillary is
greater than it is inside, the filaments anchoring the cells allow them to open, permitting interstitial fluid to seep in. Rising differential pressure across the capillary walls eventually forces the cell junctions to close. Once in the capillaries, the trapped fluid is known as lymph, and it moves into larger, vein-like lymphatic vessels. The lymph moves slowly and without any kind of central pump through a combination of peristalsis, the action of semilunar valves, and the squeezing influence of surrounding skeletal muscles, much like occurs in veins.

In the skin, lymph vessels form networks around veins, but in the trunk of the body and around internal organs, they form networks around arteries. Lymph vessels have thinner walls than veins, are wider, have more valves, and — most important — regularly bulge with bean-shaped sacs called lymph nodes (more on those in the later section “Poking at the Nodes”). Just as small tree branches merge into larger ones and then into the trunk, lymphatics eventually merge into the nine largest lymphatic vessels called lymphatic trunks. The biggest of these at nearly 1 1/2 feet in length is the thoracic duct; nearly all the body’s lymph vessels empty into it. Only those vessels in the right half of the head, neck, and thorax empty into its smaller mate, the right lymphatic duct. Lymph returns to the bloodstream when both ducts connect with the subclavian (under the collarbone) veins.

The thoracic duct, which also sometimes is called the left lymphatic duct, arises from a triangular sac called the chyle cistern (or cisterna chyli) into which one intestinal trunk and two lumbar lymphatic trunks (which drain the lower limbs) flow. Both the thoracic duct and the much smaller right lymphatic duct drain into the subclavian (behind the collarbone) veins. The remaining four trunks are a pair serving the jugular region (sides of the throat) and a pair serving the bronchomediastinal region (the central part of the chest).

To see how much of this information is seeping in, answer the following questions:

1. The lymphatic system plays an important role in regulating
   a. Intracellular energy function
   b. Interstitial fluid protein
   c. Metabolizing unused fats from the small intestine
   d. Intercellular transportation of oxygen
   e. None of these

2. Terminated vessels that return plasma proteins to the blood are
   a. Blood capillaries
   b. Venules
   c. Lymph capillaries
   d. Arterioles
   e. Cardiac ducts

3. The thoracic duct does not drain lymph from the
   a. Right lower extremity
   b. Right side of the head
   c. Digestive tract
   d. Left axilla
   e. Posterior abdominal wall
4. The largest lymphatic vessel in the body is the
   a. Right lymphatic duct
   b. Spleen
   c. Thoracic duct
   d. Chyle cistern

5. The lymphatic system does not function to
   a. Return interstitial fluid to the blood
   b. Destroy bacteria
   c. Remove old erythrocytes
   d. Produce erythrocytes
   e. Produce lymphocytes

**Poking at the Nodes**

Lymph nodes (see Figure 11-2) are the site of filtration of the lymphatic system. Also sometimes incorrectly referred to as lymph glands — they don’t secrete anything, so technically they’re not glands — these kidney-shaped sacs are surrounded by connective tissue (and therefore are tough to spot). Lymph nodes contain macrophages, which destroy bacteria, cancer cells, and other matter in the lymph fluid. Lymphocytes, which produce an immune response to microorganisms, also are found in lymph nodes. Like the kidneys, the indented part of each node is referred to as the hilus. The stroma (body) of each node is surrounded by a fibrous capsule that dips into the node to form trabeculae, or septa (thin dividing walls) that divide the node into compartments. Reticular (net-like) fibers are attached to the trabeculae and form a framework for the lymphoid tissue and lymphocytes (white blood cells) in clusters called lymphatic nodules.

Inside the node is a cortex where most of the lymphocytes gather, and at the center is a medulla, which is less dense than the cortex but also contains lymphocytes. The outer cortex consists of lymphocytes arranged in masses called lymphatic nodules, which have central areas called germinal centers that produce the lymphocytes. Lymph fluid enters the node on its convex side through afferent (inbound) vessels that have valves opening only toward the node. Lymph circulates through the node, where it’s filtered and then allowed to depart through efferent (outbound) vessels in the hilus with valves pointing exclusively away from the node. (If you have trouble remembering your afferent from your efferent, think of the “a” as standing for “access” and the “e” as standing for “exit.”)

Although some lymph nodes are isolated from others, most nodes occur in groups, or clusters, particularly in the inguinal (groin), axillary (armpit), and mammary gland areas. The following are the primary lymph node regions:

- Head
- Neck
- Upper extremities
- Lower extremities
Nodes in the head drain lymph from the scalp, upper neck, ear, parts of the eye, nose, and cheek. Lymph vessels from the head and the neck carry lymph to the nodes in the neck. Axillary nodes found in the armpit receive lymph from the upper arm, while the lymphatic vessels on the radial side of the arm supply nodes in the clavicle region. Lymph nodes in the chest region process lymph from the thoracic wall. Lymph nodes in the abdominal and pelvic region filter fluid from the lower body regions, reproductive organs, and thighs. Viscera nodes or gastric lymph nodes function in the drainage of the digestive organs. The inguinal nodes function to drain the lower extremities.

Each node acts like a filter bag filled with a network of thin, perforated sheets of tissue — a bit like cheesecloth — through which lymph must pass before moving on. White blood cells line the sheets of tissue, including several types that play critical roles in the body's immune defenses. This filtering action explains why, when infection first starts, lymph nodes often swell with the cellular activity of the immune system launching into battle with the invading microorganisms.

The cortex of each lymph node contains monocytes and two types of lymphocytes: B cells and T cells.

- Monocytes within the lymph nodes develop into large invader-eaters called *macrophages* that are capable of destroying a variety of microorganisms and sometimes even cancer cells.

- B cells don’t attack pathogens directly but instead may produce molecules called *antibodies* that do the dirty work. Or they may instruct other cells called *phagocytes* (literally “cells that eat”) to attack the invaders.

- T cells are lymphocytes that started out in the bone marrow but matured in the *thymus gland* (hence the name T cells) before moving on to the lymph nodes and spleen.
Think you have a node-tion (sorry!) about what’s happening here? Test your knowledge:

6. An encapsulated mass of lymph tissue connected to lymph vessels is a
   a. Tonsil
   b. Spleen
   c. Peyer’s patch
   d. Thymus
   e. Lymph node

7. The lymph organ that has afferent and efferent lymph vessels is the
   a. Lymph node
   b. Tonsil
   c. Peyer’s patches
   d. Spleen
   e. Thymus

8. Cells attached to the reticular fibers in a lymph node are
   a. Macrophages
   b. Monocytes
   c. Neutrophils
   d. Lymphocytes
   e. Basophils

9. A function of the lymph nodes is to
   a. Remove dead erythrocytes
   b. Produce bilirubin
   c. Produce lymphocytes
   d. Conserve iron
   e. Remove erythrocytes

A. The correct answer is the central nervous system (brain and spinal cord).
10. The stroma of the lymph node does not consist of
   a. Capsule
   b. Hilus
   c. Cortex
   d. Trabeculae
   e. Villi

11. Lymphocytes are produced in the lymph nodules in the region called the
   a. Medulla
   b. Germinal center
   c. Lymphatic reservoir
   d. Trabeculae
   e. Hilus

12. The connective tissue fiber that forms the framework of the lymphoid tissue is
   a. Cartilaginous
   b. Collagenous
   c. Bone
   d. Elastic
   e. Reticular

13. When infection first starts, the lymph nodes tend to
   a. Recede
   b. Swell
   c. Multiply
   d. Divide
   e. Fade

14. T cells get their name because they start out in the bone marrow and mature in the
   a. Thigh
   b. Thyroid
   c. Thymus
   d. Tongue
   e. Tailbone

Having a Spleen-ded Time with the Lymphatic Organs

While the lymph nodes are the most numerous lymphatic organs, several other vital organs exist in the lymphatic system, including the spleen, thymus gland, and tonsils.
The spleen

The spleen, the largest lymphatic organ in the body, is a 5-inch, roughly egg-shaped structure to the left of and slightly behind the stomach. Like lymph nodes, it has a hilus through which the splenic artery, splenic vein, and efferent (remember “e” for “exit”) vessels pass. Also like lymph nodes, the spleen’s surrounded by a fibrous capsule that folds inward to section it off. Arterioles leading into each section are surrounded by masses of developing lymphocytes that give those areas of so-called white pulp their appearance. On the outer edges of each compartment, tissue called red pulp consists of blood-filled cavities. Unlike lymph nodes, the spleen doesn’t have any afferent (access) lymph vessels, which means that it doesn’t filter lymph, only blood.

Blood flows slowly through the spleen to allow it to remove microorganisms, exhausted erythrocytes (red blood cells), and any foreign material that may be in the stream. Among its various functions, the spleen can be a blood reservoir. When blood circulation drops while the body is at rest, the spleen’s vessels can dilate to store any excess volume. Later, during exercise or if oxygen concentrations in the blood begin to drop, the spleen’s blood vessels constrict and push any stored blood back into circulation.

But the spleen’s primary role is as a biological recycling unit, capturing and breaking down defective and aged blood cells to reuse their components later. Iron stored by the spleen’s macrophages goes to the bone marrow where it’s turned into hemoglobin in new blood cells. By the same token, bilirubin for the liver is generated during breakdown of hemoglobin. The spleen produces red blood cells during embryonic development but shuts down that process after birth; in cases of severe anemia, the spleen sometimes starts up production of red blood cells again.

Fortunately, the spleen isn’t considered a vital organ; if it’s damaged or has to be surgically removed, the liver and bone marrow can pick up where the spleen leaves off.

T cell central: The thymus gland

Tucked just behind the breastbone and between the lungs in the upper chest, the thymus gland was a medical mystery until recent decades. Its two oblong lobes are largest at puberty when they weigh around 40 grams (somewhat less than an adult mouse). Through a process called involution, however, the gland atrophies and shrinks to roughly 6 grams by the time an adult is 65. (You can remember that term as the inverse of evolution.)

The thymus gland serves its most critical role — as a nursery for immature T lymphocytes, or T cells — during fetal development and the first few years of a human’s life. Prior to birth, fetal bone marrow produces lymphoblasts (early stage lymphocytes) that migrate to the thymus. Shortly after birth and continuing until adolescence, the thymus secretes several hormones, collectively called thymosin, that prompt the early cells to mature into full-grown T cells that are immunocompetent, ready to go forth and conquer invading microorganisms. (These hormones are the reason the thymus is considered part of the endocrine system, too.)

As with other lymphatic structures, the thymus is surrounded by a fibrous capsule that dips inside to create chambers called lobules. Within each lobule is a cortex made of T cells held in place by reticular fibers and a central medulla of unusually onion-like layered epithelial cells called thymic corpuscles, or Hassall’s corpuscles, as well as scattered lymphocytes.
**Opening wide and moving along: The tonsils and Peyer’s patches**

Like the thymus gland, the tonsils, which are misunderstood masses of lymphoid tissue, are largest around puberty and tend to atrophy as an adult ages. Unlike the thymus, however, the tonsils don’t secrete hormones but do produce lymphocytes and antibodies to protect against microorganisms that are inhaled or eaten. Although only two are visible on either side of the pharynx, there are actually six tonsils: the two you can identify, which are called *palatine tonsils*; two more called *adenoids* or pharyngeal tonsils in the wall of the pharynx; and two in the posterior one-third of the tongue called *lingual tonsils*. *Invaginations* (ridges) in the tonsils form pockets called *crypts*, which trap bacteria and other foreign matter.

*Peyer’s patches*, also called *aggregate glands* or *agminate glands*, are masses of lymph tissue just below the surface of the ileum, the lowest section of the small intestine. When harmful microorganisms get into the intestine, Peyer’s patches can mobilize an army of B cells and macrophages to fight off infection.

You’ve absorbed a lot in this section. See how much of it is getting caught in your filters:

15. Cells that remove foreign matter from the lymph in the lymph nodes are the
   a. Endothelial cells
   b. Erythrocytes
   c. Neutrophils
   d. Lymphocytes
   e. Macrophages

16. Which of the following is not a lymphatic organ?
   a. Tonsil
   b. Thymus
   c. Liver
   d. Spleen

17. The lymphatic organ that stops growth during adolescence and atrophies with aging is the
   a. Thymus
   b. Lymph nodes
   c. Tonsil
   d. Adenoids
   e. Spleen

18. Lymphoid tissue located in the pharynx that protects against inhaled or ingested pathogens and foreign substances is called the
   a. Thymus
   b. Tonsils
   c. Peyer’s patches
   d. Spleen
   e. Lymph nodes
19. Lymphatic nodules found in the ileum of the small intestines are
   a. Tonsils
   b. Lymph nodes
   c. Thymus
   d. Macrophages
   e. Peyer’s patches

20. The spleen is in close relation with the
   a. Stomach
   b. Liver
   c. Colon
   d. Kidney
   e. Duodenum

21. The lymphatic organ found in the superior mediastinum is the
   a. Tonsil
   b. Spleen
   c. Thymus
   d. Reticular formation
   e. Germinal center

22. Lymphocytes are the predominant cells in the
   a. Bone tissue
   b. Cartilage
   c. White pulp of the spleen
   d. Red pulp of the spleen
   e. Elastic connective tissue

23. The lymphatic organ responsible for removal of aged and defective blood cells is the
   a. Tonsil
   b. Spleen
   c. Peyer’s patches
   d. Lymph nodes
   e. Thymus

24. The lymphatic organ that secretes hormones to make T lymphocytes immunocompetent is the
   a. Lymph node
   b. Tonsil
   c. Peyer’s patch
   d. Spleen
   e. Thymus
25. Which of the following is not a true tonsil?
   a. Pharyngeal tonsil
   b. Palatine tonsils
   c. Adenoids
   d. Sublingual tonsil
   e. Lingual tonsil

26–35. Mark the statement with a T if it’s true or an F if it’s false:
26. _____ The lymph system offers an alternative route for the return of the tissue fluid to the bloodstream.
27. _____ The fluid surrounding the cells that will enter the lymph capillaries is called interstitial fluid.
28. _____ Lymph from the lymph vessels flows into the right thoracic duct and the left thoracic duct.
29. _____ The lymph capillaries are composed of loosely overlapping reticular fiber.
30. _____ The spleen filters both lymph and blood.
31. _____ The thymus gland is functional in the early years of life and is most active in old age.
32. _____ Tonsils function to protect against pathogens and foreign substances that are inhaled or ingested.
33. _____ The spleen functions in the removal of aged and defective blood cells and platelets from the blood.
34. _____ The gastric lymph nodes drain the lymphatic vessels on the radial side of the arm.
35. _____ The thoracic duct originates from a triangular sac called the chyle cistern (or cisterna chyli).

36–41. Fill in the blanks:
36. The bilobular thymus gland is located in the ______________________________.
37. Once in the lymphatic system, interstitial fluid becomes known as ________________.
38. ________________ are masses of lymphatic nodules found in the distal portion of the small intestines.
39. The largest lymphatic organ in the body is the ________________.
40. The lymph nodes of the lower extremities drain the ________________, ________________, and ________________.
41. In the center of the nodules of the lymph node are areas called ______________________________.
Answers to Questions on the Lymphatic System

The following are answers to the practice questions presented in this chapter.

1. The lymphatic system plays an important role in regulating **b. interstitial fluid protein**. By keeping the interstitial fluid volume between tissue cells in balance, the lymphatic system also keeps the body in homeostasis.

2. Terminated vessels that return plasma proteins to the blood are **c. lymph capillaries**. “Terminated vessels” is a technical way of saying they’re a one-way path straight back to the source.

3. The thoracic duct does **not** drain lymph from the **b. right side of the head**. In fact, that’s one of the very few areas the thoracic duct doesn’t drain.

4. The largest lymphatic vessel in the body is the **c. thoracic duct**. Yes, this duct is the largest lymphatic vessel. “Spleen” isn’t the correct answer because that’s the largest lymphatic organ.

5. The lymphatic system does **not** function to **d. produce erythrocytes**. Those are red blood cells, which develop in the bone marrow.

6. An encapsulated mass of lymph tissue connected to lymph vessels is a **e. lymph node**. Don’t let a $5 word like “encapsulated” fool you. It just means that the mass is wrapped in connective tissue.

7. The lymph organ that has afferent and efferent lymph vessels is the **a. lymph node**. The thymus and spleen have no inbound (afferent) vessels, and Peyer’s patches and tonsils don’t have much to do with lymph circulation.

8. Cells attached to the reticular fibers in a lymph node are **d. lymphocytes**. The reticular fibers create a net on which these cells can cluster.

9. A function of the lymph nodes is to **c. produce lymphocytes**. That’s one of their two primary functions.

10. The stroma of the lymph node does **not** consist of **e. villi**. Nope, no finger-like projections here.

11. Lymphocytes are produced in the lymph nodules in the region called the **b. germinal center**. That’s the heart of lymphocyte production in a nodule.

12. The connective tissue fiber that forms the framework of the lymphoid tissue is **e. reticular**. It provides both a tissue framework and a type of netting to hold clusters of lymphocytes.

13. When infection first starts, the lymph nodes tend to **b. swell**. This reaction occurs as the battle begins in your immune system at the cellular level.

14. T cells get their name because they start out in the bone marrow and mature in the **c. thymus**.

15. Cells that remove foreign matter from the lymph in the lymph nodes are the **e. macrophages**. These are the mature monocytes that can engulf a microorganism.

16. Which of the following is not a lymphatic organ? **c. Liver**. No lymph fluid here.
17. The lymphatic organ that stops growth during adolescence and atrophies with aging is the **a. thymus**.

Here’s a memory tool that only word-play students will love: “The thymus runs out of thyme.”

18. Lymphoid tissue located in the pharynx that protects against inhaled or ingested pathogens and foreign substances is called the **b. tonsils**. When you remember where the pharynx is — the back of the throat — this question becomes more obvious.

19. Lymphatic nodules found in the ileum of the small intestines are **e. Peyer’s patches**. It’s almost like they’re “patched” onto the ileum.

20. The spleen is in close relation with the **a. stomach**. It’s certainly nearest to the stomach.

21. The lymphatic organ found in the superior mediastinum is the **c. thymus**.

Break this question into parts and it becomes easier to locate which gland is being referenced: **Superior** means “upper,” **media–** means “middle” (or “midline”), and **–stinum** refers to the sternum, or breastbone.

22. Lymphocytes are the predominant cells in the **c. white pulp of the spleen**. They’re what give it its whitish color.

23. The lymphatic organ responsible for removal of aged and defective blood cells is the **b. spleen**. It recycles critical components from the spent blood cells and sends them to the bone marrow to be turned into fresh cells.

24. The lymphatic organ that secretes hormones to make T lymphocytes immunocompetent is the **e. thymus**. It’s where these cells get the “T” in their name.

25. Which of the following is not a true tonsil? **d. Sublingual tonsil**. If it’s not pharyngeal, palantine, or lingual, it’s not a real tonsil.

26. The lymph system offers an alternative route for the return of the tissue fluid to the bloodstream. **True**

27. The fluid surrounding the cells that will enter the lymph capillaries is called interstitial fluid. **True**

28. Lymph from the lymph vessels flows into the right thoracic duct and the left thoracic duct. **False**. There is no right thoracic duct, only a right lymphatic duct.

29. The lymph capillaries are composed of loosely overlapping reticular fiber. **False**. The lymph capillaries actually are composed of overlapping endothelial cells.

30. The spleen filters both lymph and blood. **False**

31. The thymus gland is functional in the early years of life and is most active in old age. **False**. The opposite is true; the thymus is practically nonexistent in old age.

32. Tonsils function to protect against pathogens and foreign substances that are inhaled or ingested. **True**

33. The spleen functions in the removal of aged and defective blood cells and platelets from the blood. **True**
The gastric lymph nodes drain the lymphatic vessels on the radial side of the arm. **False.** This statement doesn’t make much sense because “gastric” refers to the digestive system.

The thoracic duct originates from a triangular sac called the chyle cistern (or cisterna chyli). **True**

The bilobular thymus gland is located in the **superior mediastinum.**

Once in the lymphatic system, interstitial fluid becomes known as **lymph.** What else could it be called?

**Peyer’s patches** are masses of lymphatic nodules found in the distal portion of the small intestines. Don’t let that “distal” fool you; just think of it as “distant.”

The largest lymphatic organ in the body is the **spleen.** You may be tempted to write “thoracic duct” here, but that’s incorrect because the duct is the largest vessel, not the largest organ.

The lymph nodes of the lower extremities drain the **knee, leg, and foot.** It’s a dead giveaway seeing as how those are all part of the lower extremities.

In the center of the nodules of the lymph node are areas called **germinal centers.** When you read “germinal,” think of the word “germinate,” and then think of a place where lymphocytes can sprout and mature.