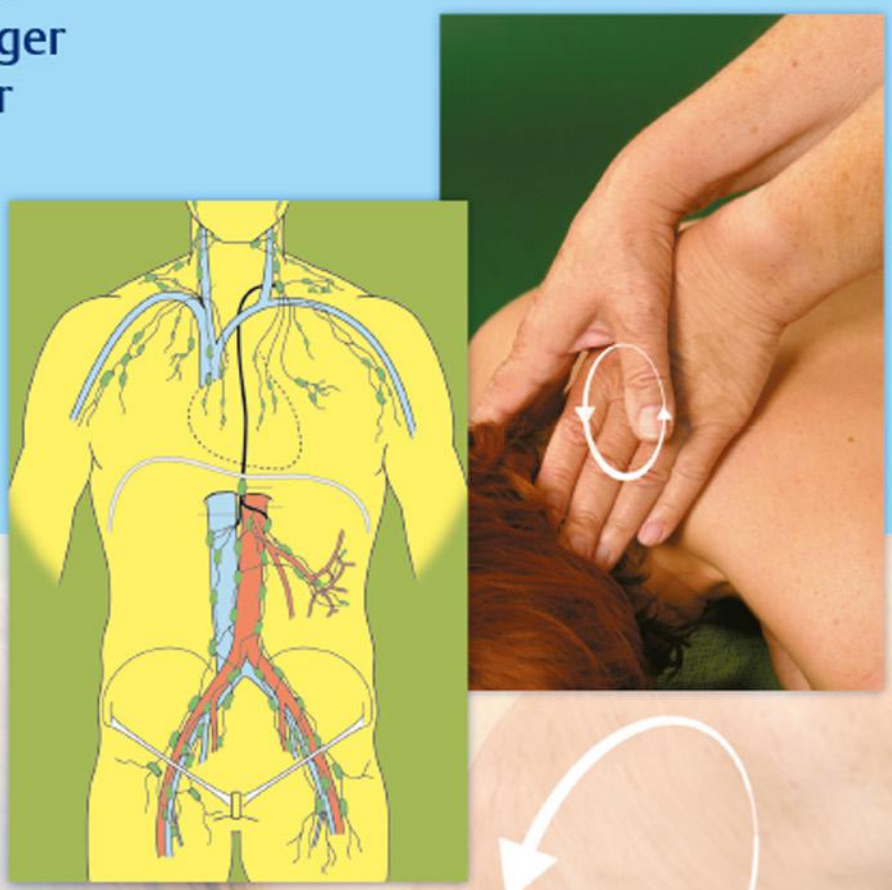
Dr. Vodder's Manual Lymph Drainage

A Practical Guide

Second Edition

Hildegard Wittlinger
Dieter Wittlinger
Andreas Wittlinger
Maria Wittlinger



Thieme

Dr. Vodder's Manual Lymph Drainage

A Practical Guide

Second Edition

Professor Hildegard Wittlinger
Founder, Lymphedema Clinic Wittlinger
Director, Dr. Vodder Academy
Walchsee, Austria

Dieter Wittlinger, PT
CEO, Wittlinger Therapy Center
Lymphedema Clinic Wittlinger
Dr. Vodder Academy
Walchsee, Austria

Andreas Wittlinger, PT
Director of Therapy Department
Lymphedema Clinic Wittlinger
Director, Dr. Vodder Academy
CEO, Dr. Vodder Academy International
Walchsee, Austria

Maria Wittlinger, MT
Director, Lymphedema Clinic Wittlinger
Director, Dr. Vodder Academy
Walchsee, Austria

204 illustrations

Thieme
Stuttgart • New York • Delhi • Rio de Janeiro

Library of Congress Cataloging-in-Publication Data
Names: Wittlinger, Hildegard, author. | Wittlinger, Dieter, author. | Wittlinger, Andreas, author. | Wittlinger, Maria, author.
Title: Dr. Vodder's manual lymph drainage: a practical guide / Hildegard Wittlinger, Dieter Wittlinger, Andreas Wittlinger, Maria Wittlinger.

Other titles: Manuelle Lymphdrainage nach Dr. Vodder. English. | Manual lymph drainage

Description: Second edition. | Stuttgart; New York : Thieme, [2019] | Preceded by Dr. Vodder's manual lymph drainage/Hildegard Wittlinger... [et al. ; translator, Ruth Gutberlet; illustrator, Emil Wolfgang Hanns]. 2011. | Translation of: Manuelle Lymphdrainage nach Dr. Vodder. 2. Aufl. 2016. | Includes bibliographical references and index. |
Identifiers: LCCN 2018038902 (print) | LCCN 2018041066 (ebook) | ISBN 9783132411470 ( ) | ISBN 9783132411449 (softcover) | ISBN 9783132411470 (e-book)
Subjects: | MESH: Lymphedema--therapy | Manual Lymphatic Drainage--methods | Lymphatic System-physiology | Atlases

Classification: LCC RM723.L96 (ebook) | LCC RM723.L96 (print) | NLM WH 17 | DDC 616.4/20622--dc23

LC record available at https://lccn.loc.gov/2018038902

This book is an authorized translation of the 2nd German edition published and copyrighted 2016 by Georg Thieme Verlag, Stuttgart.
Title of the German edition: Manuelle Lymphdrainage nach Dr. Vodder

Translator: Ruth Gutberlet

Illustrators: Emil Wolfgang Hanns, Schriesheim, Germany; Karin Baum, Paphos, Cyprus;
Helmut Holtermann, Dannenberg, Germany

1st Czech 2013

1st Japanese 2012

1st Portuguese (Brazil) 2013

1st Spanish 2012

Thieme Publishers Stuttgart
Rüdigerstrasse 14, 70469 Stuttgart, Germany
+49 [0]711 8931 421, customerservice@thieme.de

Thieme Publishers New York
333 Seventh Avenue, New York, NY 10001, USA
+1-800-782-3488, customerservice@thieme.com

Thieme Publishers Delhi
A-12, Second Floor, Sector-2, Noida-201301
Uttar Pradesh, India
+91 120 45 566 00, customerservice@thieme.in

Thieme Publishers Rio, Thieme Publicações Ltda.
Edifício Rodolpho de Paoli, 25º andar
Av. Nilo Peçanha, 50 – Sala 2508
Rio de Janeiro 20020-906 Brasil
+55 21 3172 2297 / +55 21 3172 1896

Cover design: Thieme Publishing Group
Typesetting by DiTech Process Solutions, India

Printed in Germany by CPI Books

5 4 3 2 1

ISBN 978-3-13-241144-9

Also available as an e-book:
eISBN 978-3-13-241147-0

Important note: Medicine is an ever-changing science undergoing continual development. Research and clinical experience are continually expanding our knowledge, in particular our knowledge of proper treatment and drug therapy. Insofar as this book mentions any dosage or application, readers may rest assured that the authors, editors, and publishers have made every effort to ensure that such references are in accordance with **the state of knowledge at the time of production of the book**.

Nevertheless, this does not involve, imply, or express any guarantee or responsibility on the part of the publishers in respect to any dosage instructions and forms of applications stated in the book. **Every user is requested to examine carefully** the manufacturers' leaflets accompanying each drug and to check, if necessary in consultation with a physician or specialist, whether the dosage schedules mentioned therein or the contraindications stated by the manufacturers differ from the statements made in the present book. Such examination is particularly important with drugs that are either rarely used or have been newly released on the market. Every dosage schedule or every form of application used is entirely at the user's own risk and responsibility. The authors and publishers request every user to report to the publishers any discrepancies or inaccuracies noticed. If errors in this work are found after publication, errata will be posted at www.thieme.com on the product description page.

Some of the product names, patents, and registered designs referred to in this book are in fact registered trademarks or proprietary names even though specific reference to this fact is not always made in the text. Therefore, the appearance of a name without designation as proprietary is not to be construed as a representation by the publisher that it is in the public domain.

Contents

Preface

The content of this second edition was revised. The latest scientific findings of fundamental research in lymphology were implemented, for example, the evidence of lymph vessels in the meninges of mice.

As practitioners of this method, we must ask ourselves what clinical relevance these little steps that are made in fundamental research provide.

As a matter of fact—at least in Austria—the governing body of social security compiles metastudies, which keep questioning the clinical efficiency of manual lymph drainage and combined decongestive therapy. These metastudies keep talking about the small amount of evidence of the efficiency of manual lymph drainage. Further studies need to focus on proving and substantiating that manual lymph drainage therapy is an effective therapy. Only then medicine would be open to recognizing the importance of the method and accepting its effectiveness. Therapists could then count on continuous prescriptions for manual lymph drainage and would be able to provide proof of its effectiveness. The therapists' problem is that MDs know little about the lymph pathways of the skin vessel system and how Vodder's manual lymph drainage achieves its results by influencing the lymph vessel system of the skin.

Nothing has changed in regard to the practical aspects and execution of Dr. Vodder's manual lymph drainage as a whole-body treatment or in combination with physical decongestion therapy. Vodder's techniques are explained to perfection and must be executed precisely in order to achieve the established and desired results.

For the past 50 years, it has been a well-known fact (based on scientific research and proof) that a hastened execution of the techniques or an increased pressure will cause spasms in the lymph vessels. Vodder too emphasized this in his teachings and I vividly remember his lectures. I hope the therapists, who will use this book complementary to their studies, will truly enjoy this technique and recognize manual lymph drainage as a valuable addition to their therapeutic options.

I dedicate this book to my sons Dieter and Andreas as well as to Dieter's wife Maria. They truthfully carry on Vodder's life's work and the enthusiasm that their father had for this method.

Hildegard Wittlinger
Walchsee, Austria

Spring 2019

Part I

Theoretical Basics of Manual Lymph Drainage

1 Anatomy and Physiology of the Circulation of Blood

1.1 Blood

Blood can be regarded as a liquid tissue. It circulates in the body, driven by a pump, the heart. Our blood accounts for 7 to 8% of our body weight, which in a person of 70 kg (154 lb) body weight amounts to about 4.5 to 6 L of blood. Blood is made up of **blood plasma** and **blood cells** (erythrocytes, leukocytes, and thrombocytes; ▶**Fig. 1.1**).

Red blood cells (erythrocytes) develop like all other blood cells from pluripotent stem cells in the bone marrow (▶**Fig. 1.2**). Erythrocytes contain hemoglobin, which transports oxygen. They are not motile (i.e., they cannot move on their own), but are carried along in the bloodstream.

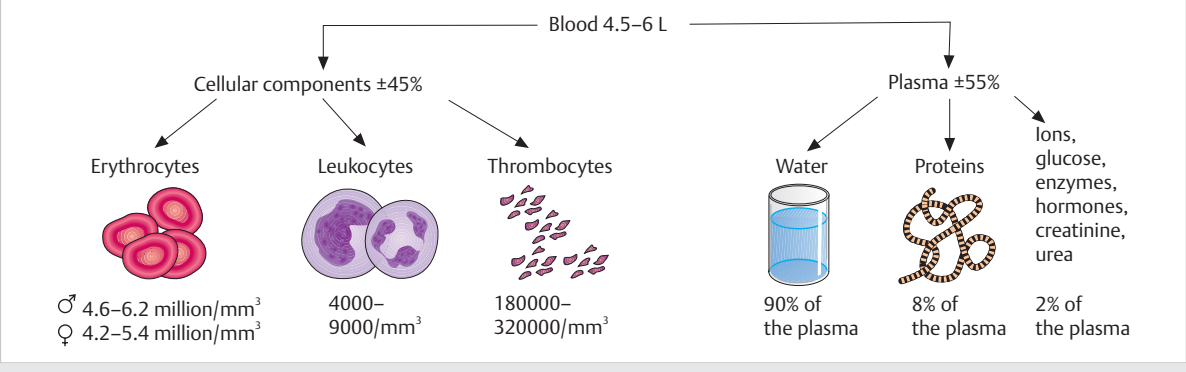


Fig. 1.1 Solid and liquid blood components.

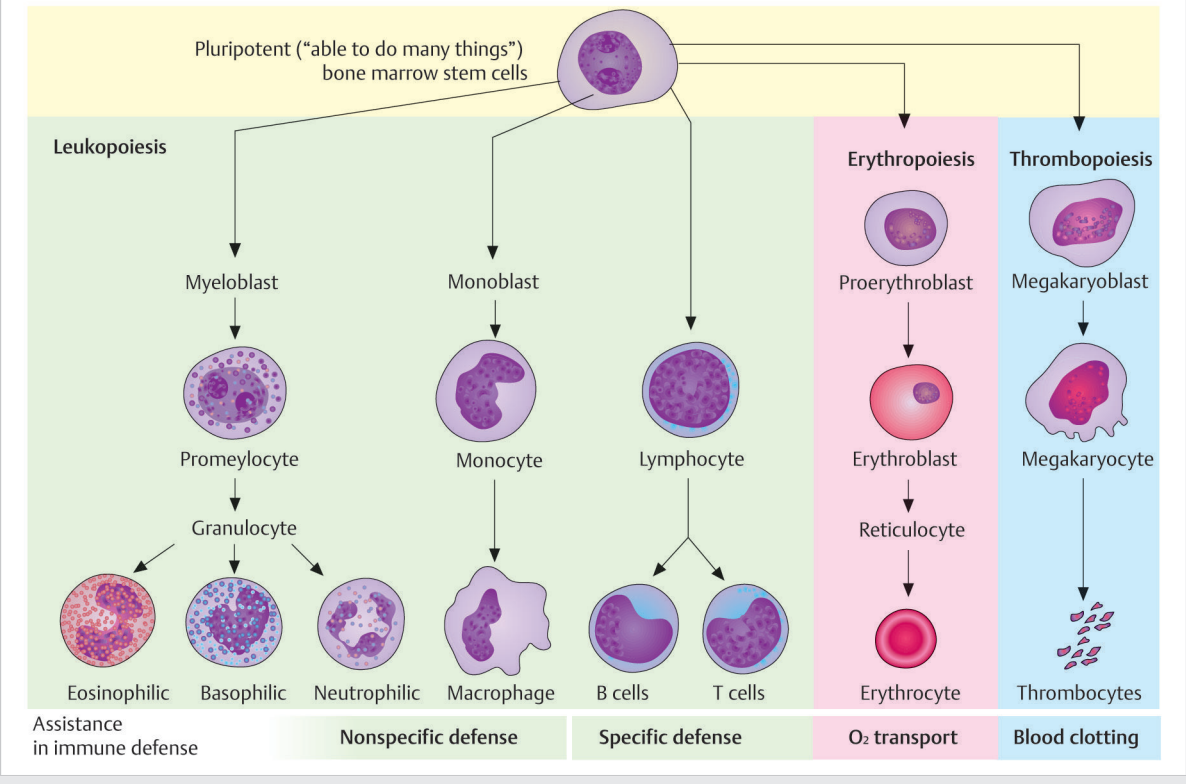


Fig. 1.2 Family tree of blood cells.

White blood cells (leukocytes) include granulocytes (neutrophilic, basophilic, and eosinophilic), lymphocytes, plasma cells, and monocytes.

Thrombocytes are blood platelets, which play an important part in blood coagulation.

Blood plasma contains dissolved organic and inorganic molecules. Albumins make up the majority of **plasma proteins**. They are metabolized in the liver and have a role as transporters, for example, of hormones. Like all plasma proteins, albumins are water soluble and are thus responsible for the colloid osmotic pressure. The immunoglobulins (also called antibodies) are the molecular front of the body's defense system. They are released into the blood by certain lymphocytes, called plasma cells.

Both blood and lymph contain **fibrinogen**, which has a role in coagulation. Examples of organic substances found in blood are lipids, lipid–protein compounds (lipoproteins), hormones, vitamins, amino acids, and bile pigments. "Organic substances" is the name given collectively to all molecules containing the carbon atom C, except for CO (carbon monoxide) and CO_2 (carbon dioxide).

Examples of inorganic substances are phosphate, iodine (I), iron (Fe), potassium (K), and sodium (Na).

The main task of blood is as a transporter. Oxygen is carried from the lungs directly to all tissues via the red blood corpuscles (erythrocytes), and carbon dioxide is carried back from the tissues to the lungs. The only structures excluded from this direct exchange are joint cartilage, a small section of the bone–tendon connection, and parts of the intervertebral disk. In addition, as a liquid medium, the bloodstream transports nutrients from the intestines to the tissues and metabolic waste to the organs of excretion.

1.1.1 Red Blood Cells (Erythrocytes)

Erythrocytes, which are non-nucleated, make up 99% of the corpuscular components of the blood. Their function is to transport oxygen, which bonds in the cell, to hemoglobin, the ferrous blood pigment.

Erythrocytes are formed in the bone marrow and have a life cycle of 120 days. They are broken down in the spleen. At maturity, they are 6 to 7 µm in size, which means they are larger than the diameter of the capillaries. Because they cannot move on their own, they have to be very pliable so that they can be pushed through the capillaries (▶ **Fig. 1.3**).

1.1.2 White Blood Cells (Leukocytes)

Leukocytes are not a uniform group of cells. Their three main groups comprise such differing cells as lymphocytes, granulocytes, and monocytes. Q 50

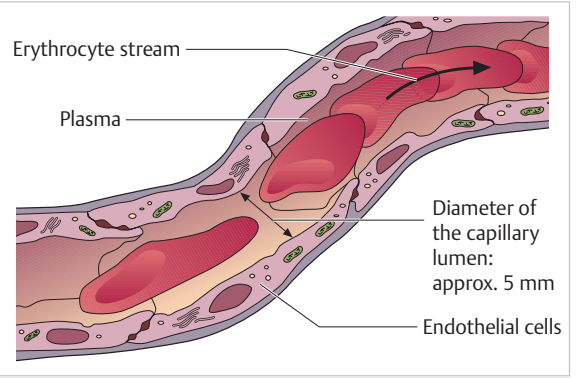


Fig. 1.3 Deformation of red blood cells as they pass through capillaries.

Granulocytes, which are nonspecific defense cells, make up 60% of leukocytes. They are divided into three groups (▶ **Fig. 1.4a–c**):

- Neutrophilic granulocytes (95%).
- Eosinophilic granulocytes (3%).
- Basophilic granulocytes (2%).

With a diameter of 10 to 17 µm, they are considerably larger than the erythrocytes. Granulocytes remain in the blood only for a short period of time, moving on from there to the tissues, especially the mucous membranes, where they fulfill their defense function by destroying bacteria through phagocytosis.

Approximately 30% of white blood cells are lymphocytes. They are 7 to 12 µm in diameter, between erythrocytes and granulocytes in size. Only 4% of lymphocytes circulate in the blood. Most of them are to be found in the lymphatic organs: spleen, thymus, lymphatic intestinal tissue, and lymph nodes.

Lymphocytes are subdivided into two groups: **T lymphocytes**, which are formed in the thymus, and **B lymphocytes**, formed in the bone marrow. These two groups have reciprocal effects. Certain T cells, the T helper cells, can stimulate B lymphocytes after an antigen has sensitized the latter. These B lymphocytes develop into plasma cells, which specialize in producing antibodies. T suppressor cells inhibit the immune response of B lymphocytes and other T cells. Specialized B lymphocytes represent the body's antigen memory. Q 39

Lymphocytes come in contact with an antigen in the lymph node. This contact sensitizes them and causes them to reproduce. They leave the lymph node through the efferent lymph vessels, enter the blood, enter the tissues, and then return to the lymph nodes. Lymphocytes spend most of their lifespan in lymph nodes or other lymphatic tissue and only hours (up to 24) in the blood. Q 11

Monocytes remain in the blood for a few days and travel from there to the tissues, where they reside as **macrophages** for months or even years. For this reason,

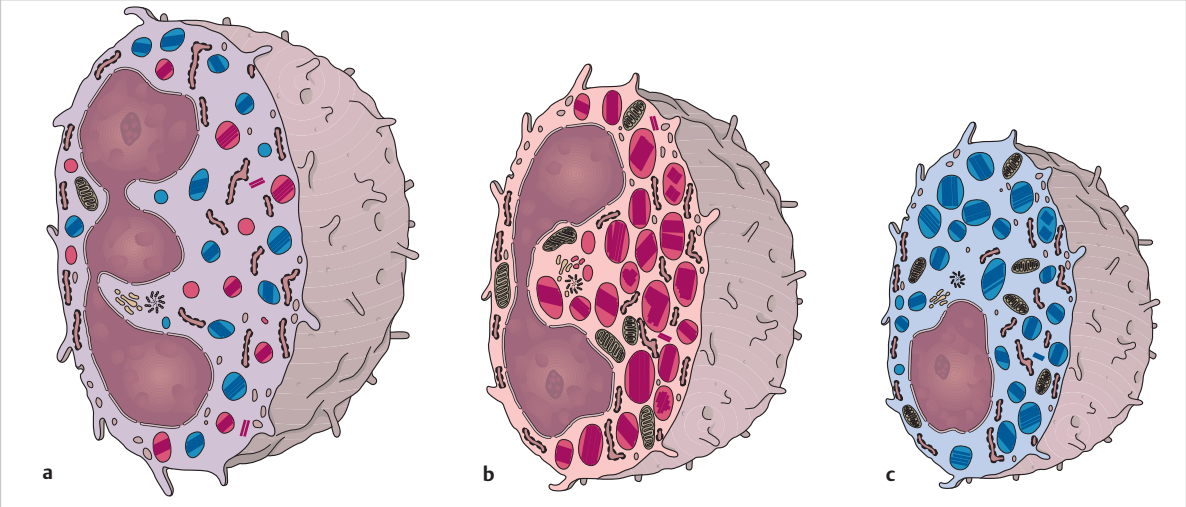


Fig. 1.4 Granulocytes: **(a)** neutrophilic; **(b)** eosinophilic; **(c)** basophilic.

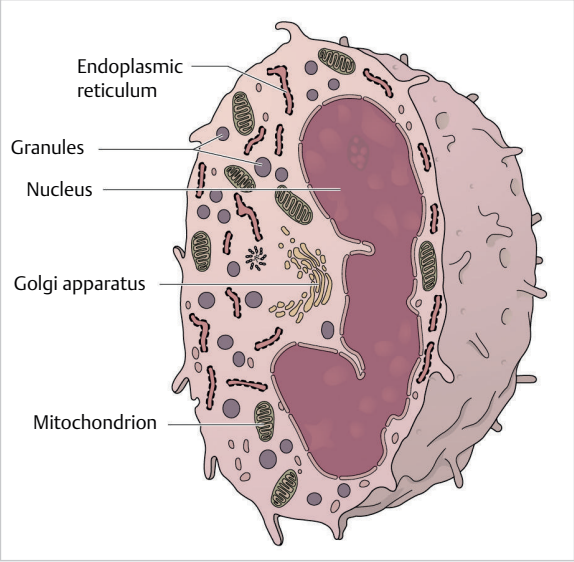


Fig. 1.5 Monocyte.

they are also called histiocytes (from the Greek *histion*, web, tissue). They have a nonspecific part in the defense system: they phagocytose cell debris and antigens. They are quite large (12–20 µm) and possess strong amoeboid motility (▶**Fig. 1.5**). Q 50

1.1.3 Blood Platelets (Thrombocytes)

Thrombocytes are small, flat, and round non-nucleated cells, 1 to 4 µm in diameter. Their lifespan is 9 to 12 days, during which time they remain in the blood. Their task is controlled coagulation of blood and wound sealing. If the endothelium of the inner vascular wall is damaged, platelets form a thrombus (clump) at the injury site.

Thrombocytes contain serotonin; serotonin causes vasoconstriction, which inhibits blood loss from the damaged vessel and promotes hemostasis.

1.2 Cardiovascular System

The cardiovascular system is made up of the heart and blood vessels. This system supplies oxygen and nutrients to all the cells in the body, and at the same time removes the waste products of metabolism, including carbon dioxide and substances excreted via the urinary system.

In the "greater" **circulatory system**, oxygen-rich blood coming from the lungs is pumped from the left cardiac ventricle, through the aorta, the arteries, the arterioles, and finally the capillaries into the periphery. Passing through the capillary system, the blood moves from the arterial into the venous system. From the venous part of the capillaries, the blood travels to the venules and veins. Propelled by various complementary mechanisms (valves that prevent the venous return), it travels to the right atrium of the heart, into the right ventricle (▶**Fig. 1.6**). The **muscle pump**, which is activated by any movement of the body, exerts pressure on the veins, particularly in the lower extremities.

The **venous valves** steer the blood in the desired direction. In addition, inspiration creates negative pressure in the thoracic cavity relative to the abdominal cavity, producing a suction that transports the venous blood toward

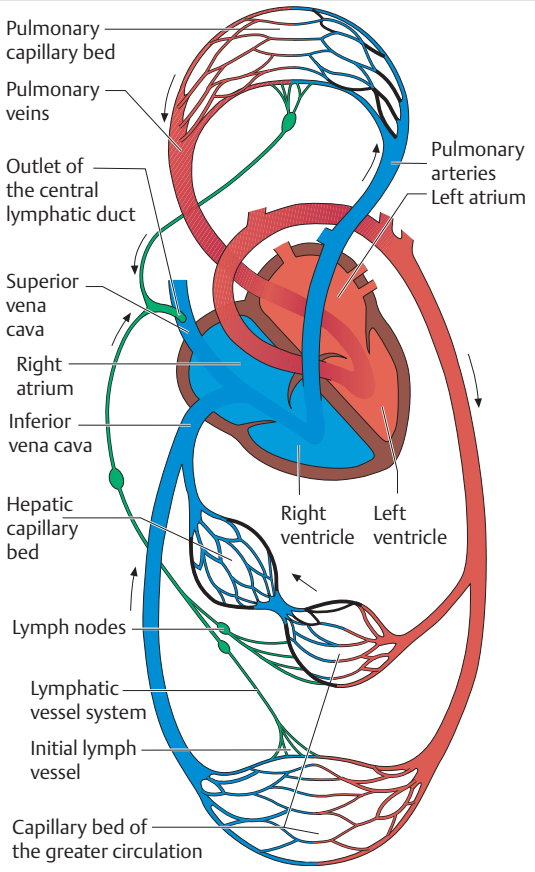


Fig. 1.6 The circulatory system.

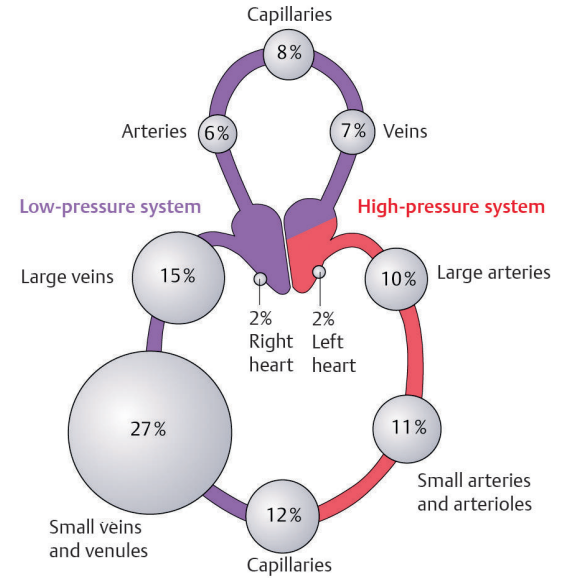


Fig. 1.7 Distribution of the blood volume in the circulatory system.

the heart. The pumping action of the right side of the heart also exerts suction on the vena cava, drawing the blood through this vessel toward the heart. Q 48

At this point, the **pulmonary or "lesser" circulation** begins. The right cardiac ventricle pumps the blood into the lungs. Oxygen exchange takes place in the pulmonary alveoli, analogous to the exchange seen in the capillary system. In this case, carbon dioxide (CO_2) is released and oxygen (O_2) is taken up. The oxygen diffuses into the erythrocytes. There it forms a compound with hemoglobin, turning into oxyhemoglobin. The blood travels from the lungs back to the left cardiac ventricle and has come full circle. Thus, the arteries provide the blood flow into the tissues and the veins provide the blood flow out of them (▶ **Fig. 1.7**).

The **blood pressure** is relatively high in the arteries and drops away further down the branches of the system (e.g., the pressure in the brachial artery of the upper arm, where blood pressure is usually taken, is in the range of 120–140/80–90 mm Hg in the healthy adult). Precapillary sphincters lower the pressure in the capillaries to 30 mm Hg. The pressure in the venous system is about 10 to 25 mm Hg; finally, in the veins close to the heart, it drops right down to 2 to 4 mm Hg.

Blood pressure is regulated by complex mechanisms, including the autonomic nervous system, hormones, and even ions. Vasoactive substances include histamine, prostaglandin, serotonin, and epinephrine. The exchange of cell nutrients takes place through the walls of the capillaries, where the flow rate is rather slow. Flow rate, blood pressure, and the diameter (caliber) of the vessels play an important role in metabolic processes. Blood flow is regulated by changes in vascular radius. The flow into the capillary areas is also regulated. At no time are all the capillaries open simultaneously. A large proportion of the blood is stored in the venous system, spleen, and liver. Vascular constriction increases the resistance to blood flow and perfusion decreases.

1.2.1 Arterial System

The arterial wall consists of three layers: the interior vascular endothelium with an elastic membrane (tunica interna or intima); the middle layer with elastic fibers and smooth muscle cells (tunica media); and the outermost connective-tissue layer, which also contains elastic fibers (tunica externa; ▶ **Fig. 1.8**).

This three-layer structure is crucial to maintaining a steady blood flow. The volume of blood expelled with each systole briefly dilates the aorta and the arteries close to the heart. During the diastolic phase, when the heart muscle

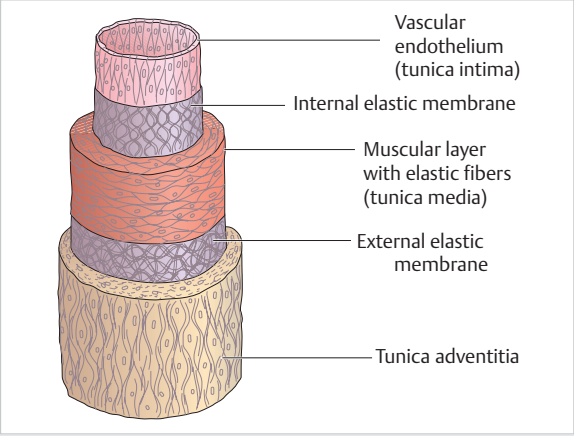


Fig. 1.8 Structure of an arterial wall of the muscular type.

relaxes, these dilated vessels recoil, pushing the blood forward. If the aorta was rigid like a pipe, the blood flow would stop after systole. This mechanism is called the **Windkessel effect**, and it is due to the relatively high percentage of elastic fibers in the vessel wall. Further toward the periphery of the body, the muscular layer is more dominant in the arterial walls. These arteries can actively contract and thus considerably increase the flow resistance of the entire system. For this reason, they are called resistance vessels; they help regulate blood distribution and blood pressure.

The resistance vessels include the arterioles, whose caliber is only 1% that of the arteries. Only about 10% of the blood volume is in the small arteries and arterioles.

The main function of these vessels is to regulate blood flow in the downstream capillary network, which they do by means of their contractility, controlled by the sympathetic nervous system (vasomotion). They therefore have a very strong effect on the function of the body parts that they supply. The precapillary sphincter has two tasks: to regulate (1) capillary blood flow and (2) blood pressure. Increased blood flow will cause active hyperemia. As mentioned earlier, precapillary sphincters can contract if energy needs are low, and send the blood directly into the venous system via an arteriovenous anastomosis. **Q 52**

1.2.2 Capillaries

The capillaries form the transition between the arterial and venous systems. With a diameter of 3 to 8 µm, they are extremely narrow. The walls of the capillaries are made of a single endothelial layer (the endothelial cells are sheathed by the endothelial glycocalyx) and a basement membrane. The wall is semipermeable; that is, depending on its structure (the size of its "windows"), certain substances can selectively pass through. The exchange of substances is additionally supported by the flow rate in the capillaries, which is very slow. The actual exchange takes place in the capillaries and does so by diffusion, osmosis, and filtration.

1.2.3 Venous System

From the capillaries, the blood travels to the venules, whose walls are only slightly thicker than the capillary walls. They have few muscle fibers and are elastic. From the venules, the venous blood travels to the larger veins, which eventually carry it all the way to the right heart, where it restarts its journey to the lungs for oxygenation. The walls of the **veins** are structured in the same way as the walls of the arteries, but they are considerably thinner; this is adequate because the pressure in the venous system is lower. In the small and middle-sized veins, the inner layers of the walls form small flaps or pouches, called venous valves, which keep the blood from running backward. **Q 48**

The activity of the muscle pump has an important role in maintaining blood flow from the veins back to the heart. When muscles surrounding the veins contract, the blood is pushed toward the heart as long as the venous valves are functioning properly. Thus, the important veins of the legs are located deep in the tissue, where the muscle pump can propel the blood with every movement of the leg. In addition to the deep veins, superficial veins also exist in the legs, forming a close network under the skin. Perforating veins connect the deep veins with the superficial veins. They act as a one-way street and physiologically only allow blood to flow from the surface to the deep layers—not in the other direction.

If the pressure on the venous walls becomes inadequate, the blood can no longer be moved along fast enough and can become stagnant. The veins give way under the internal pressure and dilate, because they have few muscle fibers. As a result, the valves no longer seal the lumen properly, and blood travels backward—increasing the internal pressure even more. This insufficiency of the venous valves leads to **varicose veins** (**varices**).

Approximately 60% of the entire blood volume is located in the venous system; this is why veins are also called **capacitance vessels**. The body can take quite large amounts of blood from this system and send them to any other region if needed, for example, to muscle tissue during physical exercise. **Q 52**

The **lymphatic system** consists of lymph vessels (also called simply "lymphatics"), lymph nodes, and organs, such as tonsils, spleen, thymus, lymphatic mucous membrane tissue, and the tissue of the appendix. Structures lacking lymphatics are epidermis, glandular epithelium, bone marrow, brain, cartilage, nails, lens, and the vitreous body. The last four of these do not contain blood vessels either.

2 Anatomy of Lymph Vessels and Lymph Nodes

The lymphatic system can be divided into a superficial system and a deep system. The superficial (epifascial) system removes the interstitial fluid of the skin. The deep (subfascial) system removes interstitial fluid from muscles, joints, organs, and vessels. The two systems are interconnected via perforating lymph vessels.

The vessels of the deep system empty into the large lymph trunks.

With regard to the lymph system, the skin is divided in sections. Initial lymph vessels (lymph capillaries) drain the lymph-obligatory load of one of the small, overlapping, circular areas of skin (1–3 cm in diameter) into which the entire covering of the body is divided. From the **initial lymph vessel**, the lymph moves to the precollectors. Several adjacent skin areas constitute a skin zone, the **precollectors** of which are interconnected and empty into a common lymph collector. **Collectors** drain lymph from strip like skin zones. Several skin zones together form a **lymph vessel bundle**, also called a **territory**. There are no anastomoses between the bundles, only between collectors within a bundle.

The vessel bundles drain into the lymph node stations (inguinal and axillary), and ultimately into the thoracic duct and the venous angle.

The superficial (epifascial) lymph vessels are spread out like a network and frequently run parallel to the superficial veins. The subfascial lymph vessels of muscles, joints, bones, and organs run with the blood vessels (in the neurovascular sheath) and do not have their own names.

Note

*The **lymph-obligatory load** is the name given to all the substances that have to be removed from the interstitium via the lymphatic vascular system.* **Q 9**

The lymphatic vascular system is a second drainage system that supports the venous system in removing substances from the interstitium. Because of its particular anatomy, the lymph vessels can absorb and remove all those molecules that are too large or too many to enter the venous system. These substances are called the "lymph-obligatory load" and consist mainly of proteins, long-chain fatty acids, cells and cell debris, and water. Exogenous substances such as viruses, bacteria, coal dust, and glass dust (silica) are also removed in this way. **Q 9**

The lymph from the entire body drains into the subclavian vein at the venous angle (terminus) and travels together with the venous blood into the right heart. Just as in the arterial and venous systems, there is a hierarchy of scale (size) in the channels of the lymphatic system.

Note

Lymph-obligatory loads: **Q 10**

- *Water (also serves transportation).*
- *Protein.*
- *Lipids.*
- *Cells.*
- *Exogenous substances.*

2.1 Initial Lymph Vessels

Prelymphatics are small channels found in the loose connective tissue. They do not have a vascular structure, but they do carry lymph-obligatory substances.

The initial lymph vessels (also known as lymph sinus, formerly called lymph capillaries) are the smallest vessels and form the beginning of the lymphatic vascular system. The lymph vessels of interest for manual lymph drainage (MLD) are those of the skin. The initial lymph vessels can be found in the entire dermis and drain the lymph-obligatory load from the connective tissue or interstitium.

Initial lymph vessels are reticulated. Some have a blind origin in the tissue. They consist of a single oak-leaf-shaped layer of endothelial cells that connect with adjacent cells. Some overlap at the edges and do not close tightly, so they can open like shutter valves (▶**Fig. 2.1**). **Q 1, Q 2**

The vessel is surrounded by a basement membrane (fiber network), which is much thinner than the basement membrane of blood capillaries. This reticular fiber network and the anchor filaments, which insert directly at the endothelial cells and the fiber network, are connected to the fibers of the surrounding tissue. When tissue pressure is low, the intercellular openings (open junctions) are closed. When the pressure in the connective tissue changes or more water enters the tissue, tissue pressure rises. The connective tissue swells and the collagen fibers of the connective tissue pull on the fiber network (matrix) and the anchor filaments, creating an opening from the endothelial cells into the initial lymph vessel. Through this opening, water, large molecules, cell debris, and cells can enter the initial lymph vessel. The exact mechanism and process of how the lymph-obligatory load flows into the initial lymph vessel is still not fully understood.

According to Zoeltzer (2003), opening and closing of the open junctions is an active process of the endothelial cell.

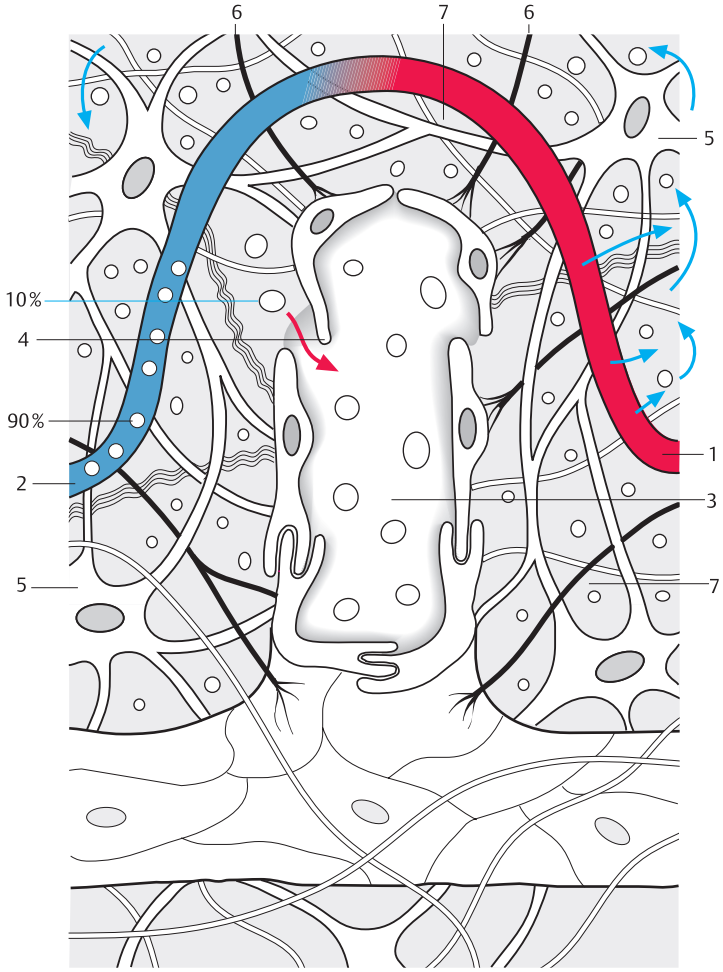


Fig. 2.1 Longitudinal section along a glove-finger-shaped initial lymph vessel with a blind origin in the tissue. 1, arterial limb of capillary; 2, venous limb of capillary; 3, initial lymph vessel; 4, swinging tip of an endothelial cell of the initial lymph vessel allowing influx of interstitial fluid (*arrow* to the left and right of 4); 5, fibrocyte; 6, anchor filaments; 7, intercellular space.

This would indicate a much more complex process than has been assumed so far. Diffusion, osmosis, or suction created through contraction of the deeper lymph vessels are considered to be a part of the mechanism. During influx into the initial lymph vessel, pressure in the vessel increases and pressure in the interstitium correspondingly decreases, while the shutter valves close. The initial lymph vessel is also called a collecting vessel and empties into the precollectors. Precollectors are often closely connected with arteries and their pulsation results in an acceleration of lymph flow. **Q 1, Q 2**

2.2 Precollectors

Initial lymph vessels turn without noticeable transition into precollectors, which pass the collected lymph on to the next vessels (the collectors). In the skin (and also in the mucous membranes), they run vertically into the deep tissues.

The precollectors show similarities to both the smaller and the larger lymph vessels. They have rudimentary valves that determine the direction of flow and also prevent reflux. There are some isolated muscle fibers and openings in the walls that allow them to absorb fluid from the connective tissue.

Precollectors have a transitional character. On the one hand, they are transport vessels and form the link between the initial lymph vessels and the collectors. In addition, though, like the initial lymph vessels they are able to absorb a small amount of lymph-obligatory substances from the interstitium and are therefore also regarded as collecting vessels. The collectors to some extent have a suction effect on the content of the precollectors, which speeds up the transport. As mentioned earlier, this suction can continue to have an effect all the way into the initial lymph vessels. **Q 3, Q 4**

2.3 Lymph Collectors

The lymph collectors are the next size up from the lymph vessels. Along their course from the periphery to the venous

angle, lymph nodes are interposed. The wall of the lymph collectors exhibits the classic three-layered structure of the entire vessel system: intima, media, and adventitia.

The **intima** consists of endothelial cells with flaps every 6 to 20 mm. The section between two paired flaps (valves) is called a lymph vessel segment or, to use Mislin's (1984) term, **lymphangion**. The valves control the direction of flow.

The **media** is mainly made up of smooth muscle cells, with a multilayered structure consisting of a medial circular layer and a longitudinal layer. This is a spiral-like plexus that may include several angions. It also contains some thin collagen fibers. The muscles are only found in the middle section between the valves: the valves themselves are without muscles. This gives an impression of constriction at the valves, leading to a "string of pearls" appearance on contrast imaging.

The **adventitia** is the support layer, made of strong collagenous fibers that merge with the extravascular connective tissue. Q 5

When the lymph flow increases, the internal pressure rises, the wall of the vessel stretches, and its tension increases. This is the triggering stimulus for the muscle cells of the lymphangion to contract. The contraction drives the lymph proximally, while the distal valves close (▶**Fig. 2.2**).

The lymph flow is also maintained by so-called **auxiliary pumps**. The following factors exert external pressure on the vessels:

- MLD.
- Contraction of skeletal muscles.
- Pulsation of large arteries (subfascially blood vessels always accompany the lymph vessels).

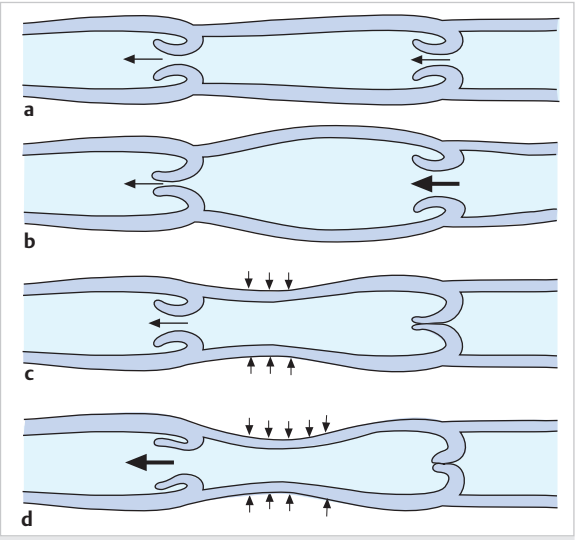


Fig. 2.2 Lymphangion, showing the action phases of lymphatic drainage. **a**, continuous flow in the distal and proximal open flap; **b**, wall distension with more filling from distal; **c**, contraction the angion wall; **d**, subsequent closure of the distal valve and expulsion of the fluid to the proximal direction (according to Pritschow).

- Increased intestinal peristalsis during MLD.
- Pressure changes in the thorax during respiration that cause intensified contraction of the large lymph trunks and produce a suction effect in the venous angle. Q 6

Lymphangions also have their own pulsation, which is independent of internal pressure, with a frequency at rest of four to eight pulsations per minute.

One of the most important auxiliary pumps is **MLD**. The collectors lie in the subcutis, and during Dr. Vodder's MLD they are stretched both lengthways and crossways. Stretching the lymphangions increases the pulsation rate, accelerating the flow of the lymph (Mislin 1984).

Hence, both a large amount of lymph and MLD result in an acceleration of lymph flow. MLD does so through a particular technique. Sympathicolysis is an additional effect of MLD, as described by Hutzschenreuter (1994). It causes dilatation of the lymph collector, which increases the contraction of the lymphangion. Q 6

There are also **inhibiting** influences on the lymphangiomotoricity, that is, the lymph flow is slowed down. Those include the following:

- Local anesthesia.
- Excessive external pressure.
- Pain.
- Strong stimulus fluctuations, for example, through temperature or current.
- Sustaining influences: increase of lymph time volume (e.g., via filtration) caused by autonomic regulation. Q 6

Note

When the lymph-obligatory load has been absorbed into the vessels from the connective tissue, and lymphangion motoricity has been increased by MLD, the suction produced by the lymphangions reaches as far as the initial lymph vessels, which then suck in more lymph-obligatory substances. Transport and removal of these are in turn accelerated by the increased lymphangion pulsation rate.

The initial lymph vessel is a collecting vessel. It absorbs the lymph-obligatory load into the vessel system.

The precollector is both a transport and a collecting vessel. It can both absorb lymph-obligatory load (though only in small amounts) and transport lymph from the initial lymph vessels to the collectors.

The collector is called a transport vessel. It maintains the lymph flow and recycles the lymphocytes. Q 6

2.4 Lymph Nodes

Lymph nodes that are usually found in groups or chains are filtering stations located along the lymph collector paths.

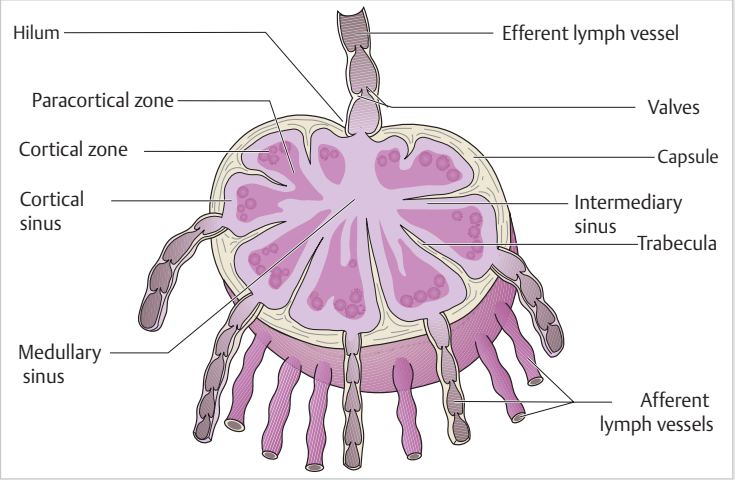


Fig. 2.3 Lymph node.

There are about 600 to 700 lymph nodes in the human body, about 160 of them in the neck region alone. They are mostly bean shaped, with a diameter of 2 to 30 mm, and are surrounded by a connective-tissue capsule that contains some smooth muscle cells (▶ **Fig. 2.3**). However, they can vary considerably in size, shape, and number. Every region of the body has its own group of **regional lymph nodes**. They consist of an internal trabecular framework, which surrounds the lymphatic tissue. Each lymph node has several afferent vessels that enter through the convex side of the capsule and empty into the sinus (marginal, intermediary, and cortical sinus) of the node. One or two lymph vessels exit the capsule at the hilum.

Blood and nerve fiber supply takes place at the hilum. Some lymph vessels may pass the lymph node by. This can be important, in cancer, for example, because it means that metastasis of more centrally located lymph nodes can occur without the regional nodes being involved. **Q 7**

The responsibilities of lymph nodes are manifold. They may be described as biological filters, filtering out everything harmful to the body and rendering it harmless—viruses, bacteria, fungi, and so on. The lymph is cleaned. In the lymph node sinus, antigens (bacteria) are broken down just as they are in the liver.

In addition, lymph is either concentrated upto about 50% or diluted in the lymph nodes, meaning that water is removed, or added, dependent on osmotic pressure differences between lymph and blood.

In the lymph nodes, mature defense cells come into contact with antigens that are being carried in the lymph. Sensitized by contact with an antigen, the lymphocytes in the lymph node are stimulated to divide and a specific defense can get under way. The agglomeration of B lymphocytes in lymph nodes is called **lymph follicle**. At first, they are primary follicles, then after contact with an infectious antigen they become secondary follicles. T lymphocytes (so-called "killer" cells) can also be found in the lymph nodes; they too will become sensitized by contact with an antigen, reproduce, and start to act specifically against that antigen. They are taken up by venules in the lymph nodes, returned to the blood circulation, and then travel back again to the lymph nodes via the lymphatic vessels. **Q 8**

B lymphocytes become plasma cells and form antibodies that are likewise part of the specific defense mechanism against antigens. In addition to initiating antigen defense responses, however, lymph nodes act as a storage place for substances that cannot be excreted by the body, including coal dust, glass dust, and soot. **Q 42**

Note

Lymph nodes have the following functions: **Q 8**

- *Lymph filtration.*
- *Lymph concentration, if necessary also dilution.*
- *Activation of the immune system (lymphocyte sensitization).*
- *Storage place for nondegradable substances.*
- *Fluid exchange.*

2.5 Lymphatic Trunks

The lymphatic trunks form the final part of the journey for the lymph on its way back into the blood circulation. The thoracic duct, 2 to 4 mm in diameter and 40 cm long in an adult, is the largest lymph vessel, followed by the right lymphatic duct (▶ **Fig. 2.4**). The valves of the thoracic duct are approximately 8 cm apart. They receive the cleansed lymph from the regional lymph nodes. Few lymph nodes are found along the ducts. Their wall structure is typically vascular and pretty much the same as in the lymph collectors, except that the muscular layer is thicker and the valves are further apart.

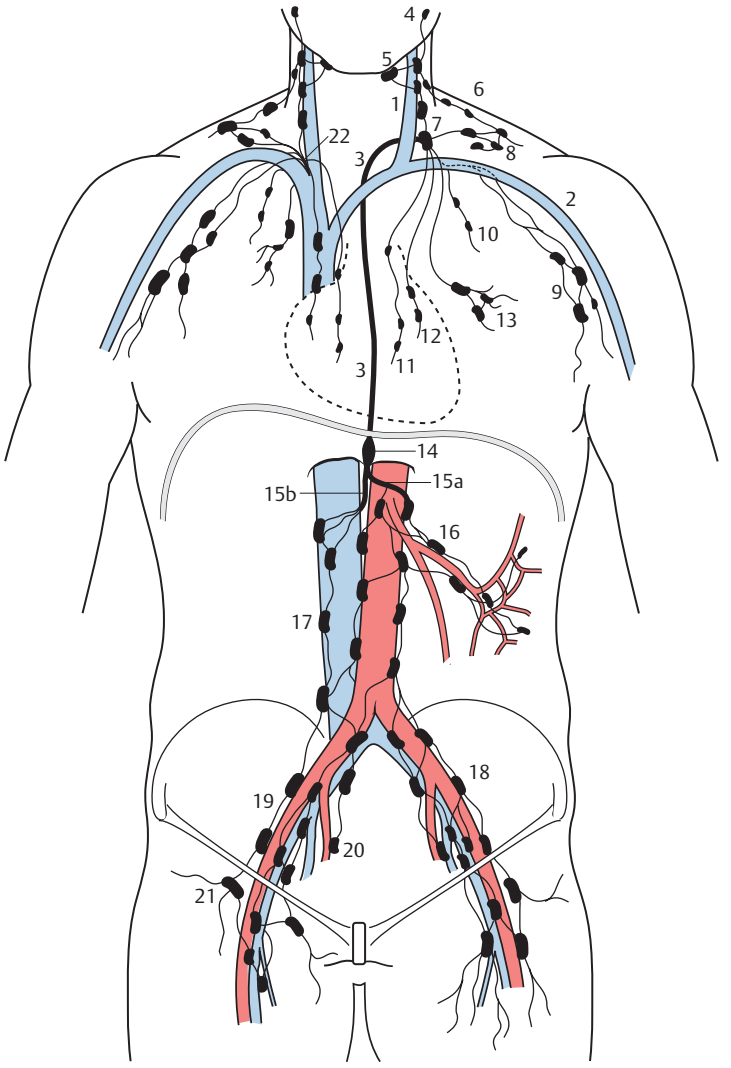


Fig. 2.4 The most important lymphatic trunks and lymph node groups of the body. 1, (left) internal jugular vein; 2, (left) subclavian vein; 3, thoracic duct; 4, parotid nodes; 5, submandibular nodes; 6, concomitant nodes of the accessory nerve; 7, internal jugular nodes with (left) jugular trunk; 8, supraclavicular nodes with (left) supraclavicular trunk; 9, axillary nodes with (left) subclavian trunk; 10, intercostal nodes with (left) intercostal trunk; 11, parasternal nodes with (left) parasternal trunk; 12, anterior mediastinal nodes with (left) anterior mediastinal trunk; 13, tracheobronchial nodes with (left) tracheobronchial trunk; 14, cisterna chyli; 15a, left lumbar trunk; 15b, right lumbar trunk; 16, mesenteric nodes; 17, lumbar nodes; 18, iliac nodes; 19, iliac nodes; 20, iliac nodes; 21, inguinal nodes; 22, right lymphatic duct.

Blood is supplied to the vascular walls through the vasa vasorum, located in the adventitia together with some nerve fibers.

2.5.1 Large Lymphatic Pathways

In the trunk, 11 large lymphatic vessels are found, 5 paired and 1 unpaired:

- Right and left iliac trunks.
- Right and left lumbar trunks.
- Intestinal trunk.
- Right and left jugular trunks.
- Right and left subclavian trunks.
- Right and left bronchomediastinal trunks.

At the level of the navel and the second and third lumbar vertebrae, the right and left lumbar trunks and the intestinal trunk merge and form the cisterna chyli, which turns into the thoracic duct.

The **cisterna chyli** collects lymph from the intestines, abdominal organs, and legs. After a fatty meal, the lymph turns a milklike color due to the fat droplets received from the intestines, hence the name chyle lymph.

The **thoracic duct**, after draining the left side of the body and skin above the diaphragm, left arm, left side of the head, and the entire body below the diaphragm , discharges into the left venous angle, where the subclavian and internal jugular veins join.

The lymph from the right upper body, the right arm, and the right side of the head passes through the right subclavian and jugular trunk (which sometimes join to form the right lymphatic duct) to discharge directly into the right venous angle.

Because the lower body is so far from the venous angles, it needs a large vessel, the thoracic duct, to carry the lymph to the discharging junction. Areas close to the junction can be drained through short single trunks. These trunks discharge into the veins by themselves (primary trunks) or joined in various combinations.

The number of lymph vessels and lymph nodes varies from person to person. What matters is that the lymph-obligatory load can be removed consistently and the lymph nodes are able to perform their function.

Lymph Vessel System of the Skin

Watersheds are notional lines drawn on the basis of the different directions of lymphatic flow. They are located only in the subcutis. In treatment with MLD, the direction of pressure depends on the flow direction of the lymph vessels of the skin, the collector vessels. Watersheds are usually found between two bundles (territories) because very few lymph vessels (cross-connections) exist between the collectors of neighboring bundles (▶**Fig. 2.5** and ▶**Fig. 2.6**). In other words, it is an interterritorial area poor in vessels. Under physiological conditions, the direction of drainage for the lymph vessels is divided. Under pathological conditions, reversion of the direction of lymph flow is possible. **Q 16**

The following watersheds are important for MLD:

- Running horizontally across the navel and the second or third lumbar vertebra, dividing the skin into upper and lower body.
- Running vertically along the midline of the body, dividing it into a right and a left half.
- Running along the clavicle and the spine of the scapula, forming a small strip above the shoulders.

Other watersheds exist, but they are not of interest for MLD. **Q 17**

The skin of the body can be divided into four **main quadrants**:

- Right upper quadrant.
- Left upper quadrant.
- Right lower quadrant.
- Left lower quadrant.

The right upper thoracic quadrant drains the lymph of the skin into the lymph nodes of the right axilla. The left upper thoracic quadrant drains into the lymph nodes of the left axilla. **Q 13b**

The lymph of the skin of the lower quadrants is drained into the respective inguinal lymph nodes.

The skin area between the clavicle and scapular spine drains directly into the supraclavicular lymph nodes (in the venous angle).

The **mammary gland** drains to the axilla, to supraclavicular and retrosternal lymph nodes. **Q 15a**

The **skin of the head** is divided into the facial and the posterior skull. The lymph is moved through periauricular, retroauricular, and submandibular lymph nodes, and through occipital lymph nodes along the nuchal line, to the superficial and deep cervical lymph nodes, emptying from there into the venous angle. There are many cross-connections (anastomoses) from one side to the other in the zones of the head. **Q 14e**

Treatment of the neck (in the absence of contraindications, Dr. Vodder's MLD always begins with treatment of the neck) relates to the following sets of lymph nodes:

- Supraclavicular.
- Infraclavicular.
- Along the internal and external jugular vein.
- Along the accessory nerve plexus.

Lymphatic Pathways of the Lower Extremities

The lymphatic vessel system of the lower extremities consists of superficial (epifascial) and deep (subfascial)

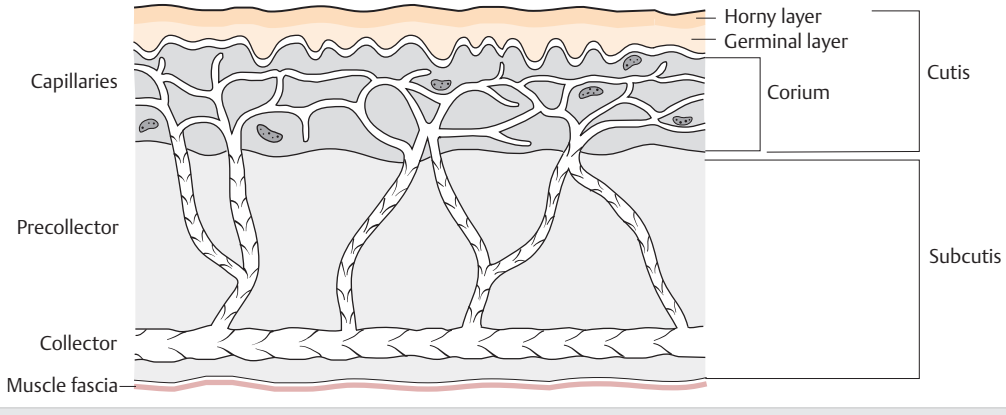


Fig. 2.5 Lymphatic system of the skin.

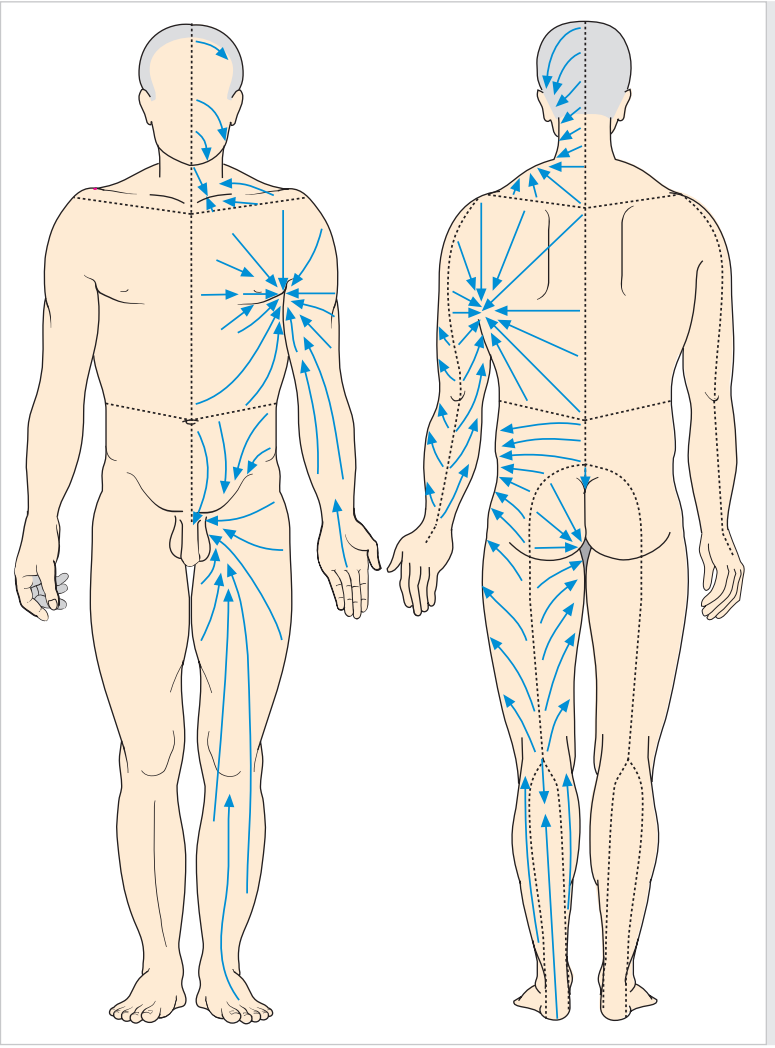


Fig. 2.6 Lymphatic watersheds, lymphatic anastomoses, and lymphatic territories.

lymph vessels (▶**Fig. 2.7**). The superficial vessels absorb approximately 80% of the lymph and the deeper vessels the other 20%. In the lower leg, there are many cross-connections between superficial and deep vessels.

The lymph of the leg drains into the inguinal lymph nodes, both superficial and deep. The superficial inguinal lymph nodes drain to the deeper nodes, which also receive lymph from the deeper lymphatic pathways of the leg.

From there, the lymph travels via the external iliac lymph nodes in the pelvis to the lumbar nodes in the abdomen. Together with the gastrointestinal lymphatic trunk, they join the cisterna chili and actually form it. **Q 15**

The skin of the legs is subdivided as follows:

- *Dorsolateral bundle of the lower leg:* Lymph from the lateral margin of the foot, lateral malleolus, and the medial aspect of the calf is absorbed and drains into the deep lymph nodes in the popliteal space (popliteal nodes) and travels from there along the femur to the deep inguinal lymph nodes.
- *Ventrolateral bundle of the lower leg:* Lymph from the anterior part of the foot and the remaining skin territories of the lower leg is absorbed and drains medially into the long lymph vessels that run ventromedially along the anterior and medial part of the lower leg and the medial part of the knee. They turn into the ventromedial bundle of the upper leg and discharge (epifascially) into the inguinal lymph nodes.

The lymph vessels of the entire back of the leg run ventrally and drain into the ventromedial bundle. The anteromedial bundle contains the longest lymph vessels of the body. Some run without interruption from the foot all the way up to the inguinal lymph nodes and drain into the superficial inguinal lymph nodes. There are “bottlenecks” on the

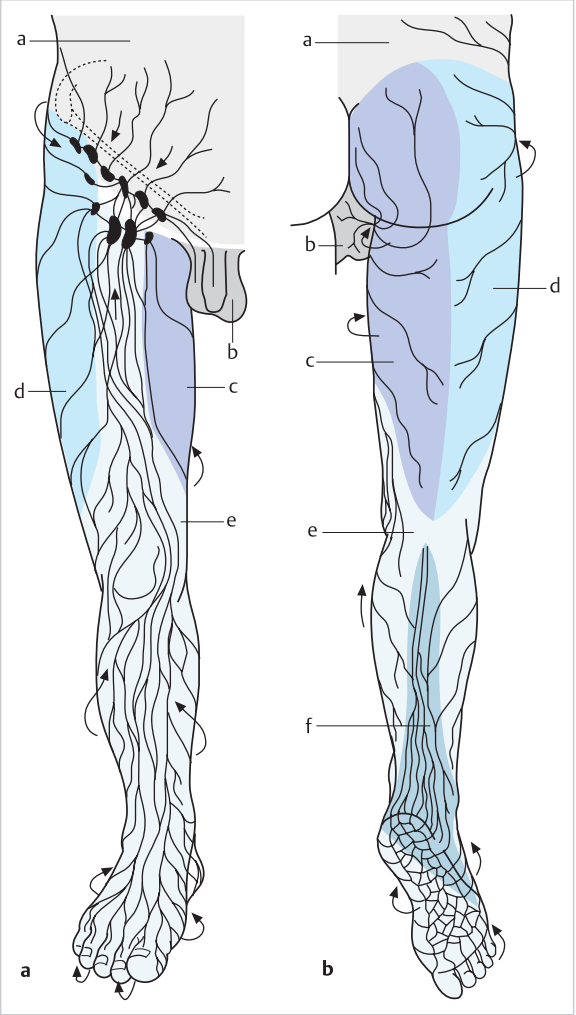


Fig. 2.7 Superficial drainage territories of the lower extremities and the adjacent trunk. The *arrows* indicate the main directions of lymphatic drainage. **(a)** Front (anterior). **(b)** Back (posterior). a, lower trunk territory; b, territory of the outer genitals; c, dorsomedial femoral territory; d, dorsolateral thigh territory; e, territory of the ventromedial bunch; f, territory of dorsolateral bunch.

medial aspect of the knee and at the medial malleolus, that is, the vessels run very close together here.

Cross-connections (anastomoses) exist between the deep and the superficial lymph vessels of the leg. Because of muscular activity, lymph travels from the deep to the superficial vessels. Q 15c

In **the lower leg, the deep lymph vessels** run along the anterior and posterior tibial arteries and the fibular arteries. In the upper leg, the deep lymph vessels run along the femoral vessels and empty into the deep inguinal lymph nodes—and sometimes directly into the iliac lymph nodes. Q 15c

Some lymph vessels, arising from the popliteal lymph nodes, run along the sciatic nerve. They drain part of the back of the upper leg and empty into the iliac or the lumbar nodes of the abdomen, passing by the inguinal lymph nodes. This is very important in patients with lymph stasis in the inguinal area! Q 15c

The lymph of the abdominal wall and the skin of the lumbar region—below the horizontal watershed—drains into the inguinal lymph nodes. Q 15b

The **external genitals** also drain their lymph into the inguinal lymph nodes. The lymph from the testicles empties into the lumbar lymph nodes.

Note

The lymph vessels that run along the sciatic nerve can become very important if the normal drainage pathways of the leg become obstructed, and may function as a circulatory bypass. Q 15c

Lymphatic Pathways of the Upper Extremities

The lymphatics in the arms are both superficial (epifascial) and deep (subfascial; ▶**Fig. 2.8** and ▶**Fig. 2.9**). They form a functional unit and are cross-connected. Thus, the lymph runs not just from distal to proximal but also from the superficial to the deep vessels and vice versa.

The lymph of the entire arm is drained to the axillary lymph nodes (lateral and central axillary, subscapular, and pectoral lymph nodes). From there, it is moved through the infraclavicular and supraclavicular lymph nodes into the subclavian trunk and the right and left venous angles. The superficial vessels running along the front of the arm in the subcutaneous connective tissue absorb approximately 80% of the lymph of the entire arm and are hence more important than the deep vessels.

The palmar rete (network) drains the volar part of the hand and fingers. Lymph collectors are located on the lateral aspects of the fingers and the back of the hand. They merge with the ulnar or radial bundle.

The **back of the hand** is almost without subcutaneous fatty tissue, and for this reason, unlike in the palm of the hand with its tight connective tissue, edema can develop easily.

In the **forearm**, a medial bundle and a radial and ulnar bundle are found; they join at the bend of the elbow, where some lymph nodes (superficial cubital lymph nodes) are present, and travel on as the medial bundle of the upper arm to the axillary lymph nodes.

The medial bundle of the **upper arm** runs parallel to the basilic vein and is also called the basilar lymphatic bundle.

The lateral and the posterolateral bundle drain the upper arm and shoulder and discharge the lymph into

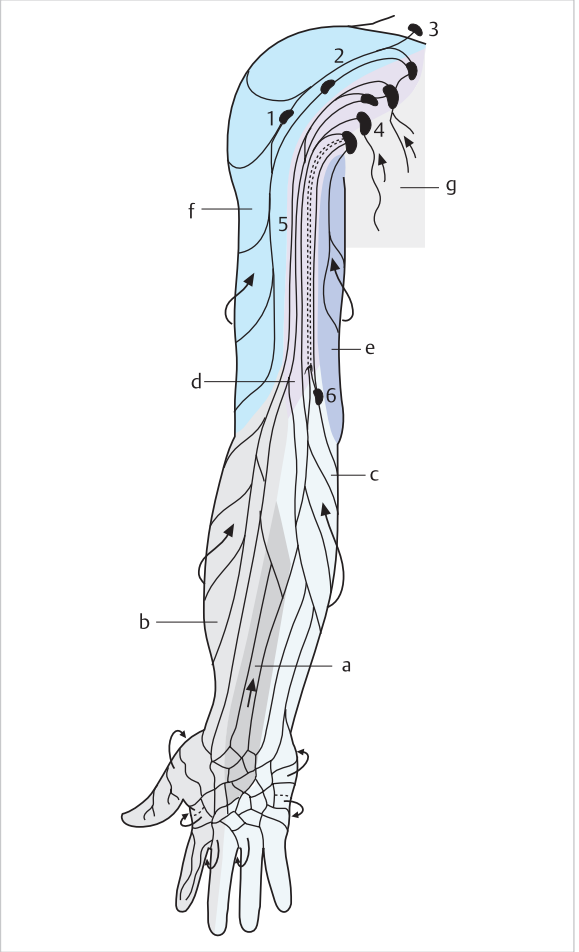


Fig. 2.8 Superficial lymphatic system of the upper extremities, front (palmar). 1, Lnn. deltoideopectoral; 2, lateral upper arm or deltoid bundle; 3, Ln. supraclavicular; 4, Lnn. axillary; 5, median upper arm; 6, Ln. cubital superficial. **a**, middle forearm territory with median forearm bundle; **b**, territory of the radial bundle; **c**, territory of the ulnar bundle; **d**, middle upper arm territory; **e**, dorsomedial upper arm territory; **f**, dorsolateral upper arm shoulder territory; **g**, upper trunk territory.

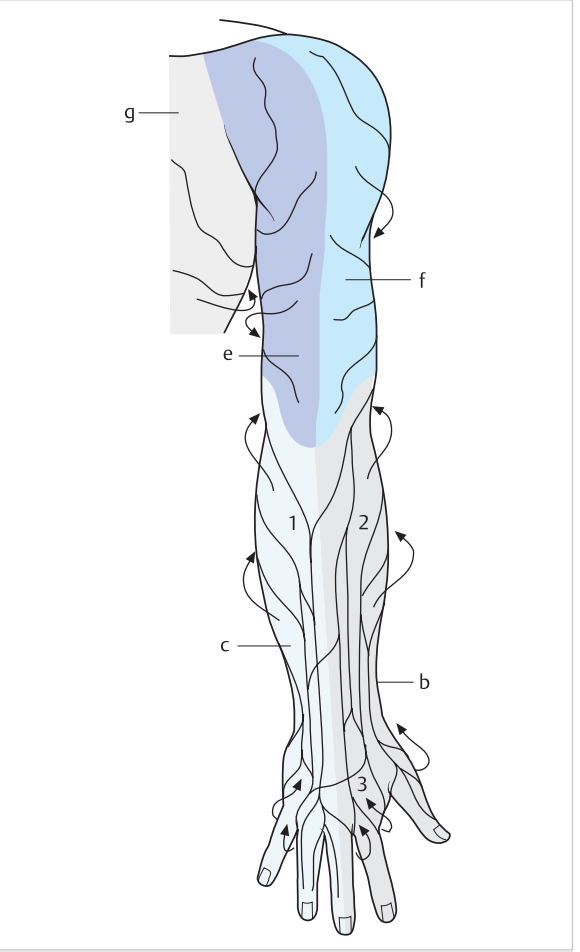


Fig. 2.9 Superficial lymphatic system of the upper extremities, back (posterior). 1, ulnar bundle; 2, radial bundle; 3, transverse collaterals between radial and ulnar hand back collectors; **b**, territory of the radial bundle; **c**, territory ulnar bundle; **e**, dorsomedial upper arm territory; **f**, dorsolateral upper arm and shoulder territory; **g**, upper trunk territory.

the axillary lymph nodes. In some but not all people, a cephalic bundle may emerge from the lateral bundle of the upper arm and travel via the deltoid muscle directly to the supra- or infraclavicular lymph nodes, bypassing the axillary nodes. There is a so-called long type, which has anastomoses to the radial lymphatic bundle of the forearm; the short type does not have these connections.

The cephalic lymph vessel is important when drainage is obstructed in the axilla after lymphadenectomy (surgical removal of lymph nodes) or radiation therapy. **Q 14a**

The anterior and posterior **thoracic walls**—as defined by the aforementioned watersheds—drain the lymph into the right and left axillary lymph nodes. **Q 14b**

The **intercostal lymph vessels** of the back drain into the paravertebral or intercostal lymph nodes, which are located along the spinal column and usually empty into the thoracic duct. **Q 14c**

The **intercostal lymph vessels** of the anterior thorax drain into the parasternal or intercostal lymph nodes and have a runoff to the venous angle and the cisterna chyli. **Q 14c**

2.5.2 Drainage from the Abdomen

From the inguinal lymph nodes, the lymph travels beneath the inguinal ligament into the plexuses and

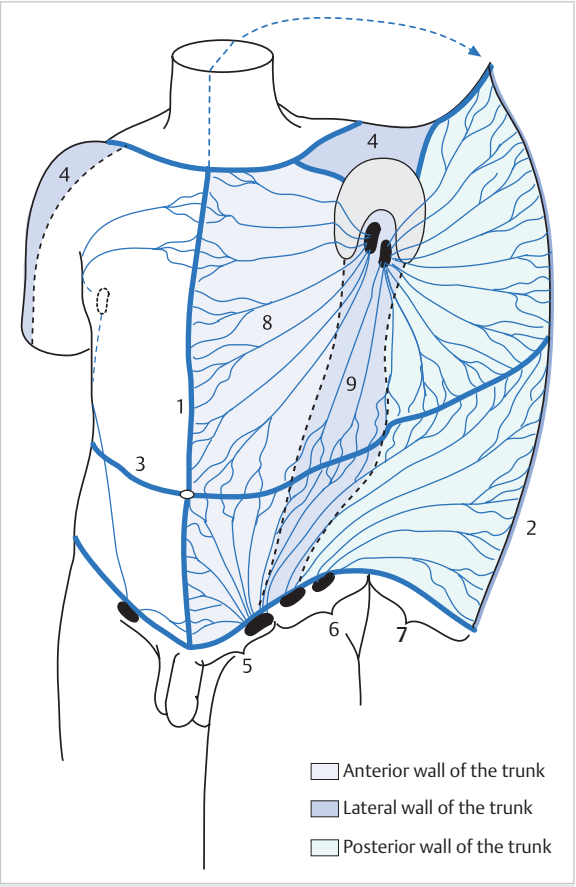


Fig. 2.10 Superficial lymphatic system of the trunk with watersheds and anastomosis. 1, front vertical watershed; 2, rear vertical watershed ("unfolded"); 3, transversal watershed; 4, drainage area of the lateral upper arm bundle; 5, anterior trunk wall; 6, middle hull wall; 7, rear hull wall; 8, interaxillary collaterals; 9, axillo-inguinal collaterals.

nodes of the lesser pelvis—the (paired) iliac lymph nodes, which absorb and remove the lymph from the urogenital organs of the lesser pelvis (urethra, bladder, prostate, pelvic floor, etc.). From the aortic bifurcation, these lymphatic pathways accompany the aorta and the inferior vena cava as the right and left lumbar trunks (again in the form of plexuses) to the cisterna chyli. They drain the lymph of the abdominal organs and, together with the intestinal trunk that joins them coming from the large and small intestines, form the cisterna chyli, from which the thoracic duct originates. After a meal, the lipid content gives the lymph the milklike appearance that gives the cisterna chyli its name. The intestinal lymph is also called chyle lymph. It is removed by various vessels, all of which empty into the cisterna chyli. **Q 15d**

2.5.3 Drainage from the Thorax

The thorax contains four large lymphatic trunks:
- Anterior mediastinal trunk.
- Bronchomediastinal trunk.
- Parasternal trunk.
- Posterior intercostal trunk.

All of these have a right and a left branch. The bronchomediastinal trunks collect the lymph from the lymph nodes located along the aorta, the esophagus, and the lungs. **Q 14c**

Note

Lymph from the left lower lobe of the lung, the heart, and the right lung is transported to the right venous angle via the right bronchomediastinal trunk and the right lymphatic duct.

The parasternal trunks receive the lymph from the medial area of the mammary glands and from the intercostal spaces of the anterior thorax, and transport it via the infraclavicular lymph nodes to the venous angle or retrograde to the thoracic duct or the cisterna chyli. The lateral aspect of the mammary glands flows into the axillary. **Q 14c**

The anterior mediastinal trunks receive lymph from organs including the thyroid gland, thymus, and trachea, and empty into the thoracic duct. **Q 14d**

The inflow from the vessels that eventually deliver the lymph to the venous angle varies considerably.

2.5.4 Drainage from the Brain

The brain has no lymph vessels. Neurons are serviced by glial cells, which supply nutrients to the nerve cells and remove metabolic waste. Hence, no lymph-obligatory substances are produced. In the glandular area, where the metabolic exchange rate is high and some of the blood capillaries are fenestrated, lymph-obligatory load is produced; here it is called **prelymph**. With no lymph vessels in either the brain or the spinal cord, there must be other ways for the prelymph to be removed from these regions.

In experiments with injected ink, color particles were found in the cerebrospinal fluid, showing that the lymph-obligatory load can leave the bony skull in this way, from the spinal cord into the venous plexus.

The cranial nerves serve as a “conductor” for the prelymph toward the lamina cribrosa (ethmoid bone).

About 40 to 50% of the prelymph in the brain exits the skull with the olfactory nerve. The nerve fibers run through the sievelike structure of the ethmoid bone. Extracranially, the prelymph is received by the lymph vessels of the nasopharyngeal area, passes the palatal arches, and travels to the deep lymph nodes of the neck. The optic and the vestibulocochlear nerves likewise serve as a "guide track" for the prelymph. Preformed tissue channels of the blood vessels of the brain (the intraadventitial Virchow–Robin spaces) also exist, which lead the prelymph to the lymphatic pathways of the blood vessel system (carotid artery, vertebral artery, internal jugular artery). **Q 13**

In addition, we would like to quote from Weissleder and Schuchhasrdt (2015): "Experiments provided the following results: it was shown that in mice cerebro-spinal fluid is also drained into the meninges via lymph vessels. Lymph vessel structures were also detected in the human dura. Additional studies in regard to their exact location and further analysis are considered imperative."

2.5.5 Anastomoses

Anastomoses are "inactive" vessels that can be activated when necessary. The activation can be brought about by pressure changes in the lymphatic system caused by stasis (congestion) in the efferent vessels. They can also be opened in the desired direction by MLD. The following anastomoses are important in the treatment of lymphedema:

- Axilloaxillary across the sternum and between the shoulder blades.
- Axilloinguinal, between axillary and inguinal lymph nodes, right and left, or inguinal axillary.
- Suprapubic and across the sacrum.
- Between intercostal vessels and the skin.

Lymph can also be moved across all the watersheds and in all directions in the area of the initial lymph vessels, because of the overlapping skin areas. **Q 43**

Note

All lymph produced below the navel are ultimately drained by the thoracic duct.

Note

When crossing joints, lymph vessels usually run on the medial aspect, rarely along the extensor side. This prevents overextension of the vessels, which could occur if they were on the extensor side.

All joints are drained through the deep lymphatic system. Drainage begins in the synovial and fibrous membrane of the joint capsule.

3 Physiology of the Lymphatic System, Lymph, and Interstitium

3.1 Loose Connective Tissue

Loose connective tissue plays a huge role in determining the body shape. It does this in conjunction with cartilage and bones, which belong to the more rigid supportive type of connective tissue. The different types of connective tissues are also differentiated through the varying ratio of these components. Connective tissue is divided into three types:

- Mesenchyme, rich in cells (embryonic connective tissue).
- Loose, adipose connective tissue, rich in fibers and cells.
- Dense, rigid supportive connective tissue (tendons, ligaments, cartilage, and bones).

The loose connective tissue, sometimes also referred to as soft tissue, is the connective tissue that is relevant in manual lymph drainage. When we speak of connective tissue in this text, we refer to **soft or loose connective** tissue. This connective tissue joins cells to form tissue groups, tissue groups join to form organs, and organs join to form an organism (▶ **Fig. 3.1**).

Every massage technique that works via the skin to affect the underlying structures involves all the tissues that are present in the subcutis: blood vessels, lymphatics, nerves, and fluids (interstitial fluid). The effect of the massage on the autonomic pathways should not be overlooked.

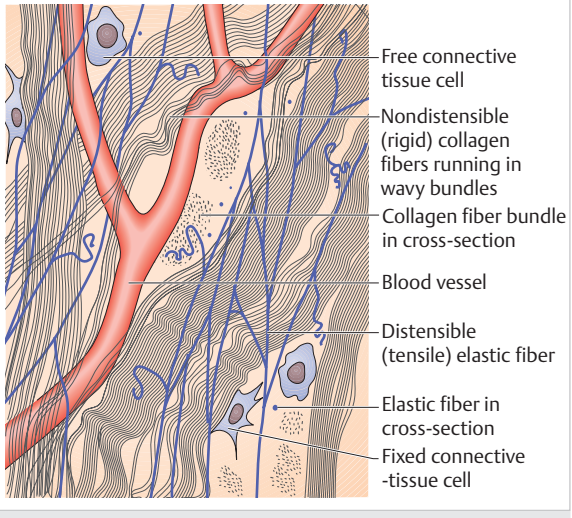


Fig. 3.1 Loose connective tissue is the most widespread type of connective tissue. Typical features are the isolated tissue cells and the undulating collagen fibers. Loose connective tissue fills the gaps between other structures; however, it is much more than just a "stopgap."

The connective tissue serves as a supportive connecting structure filling the spaces between all the organs and organ parts in the entire organism. In addition to supporting form, connective tissue surrounds nerves and vessels, stores fluids, and provides flexibility. Since its network contains many defense cells, it also has important functions in the immune system and regenerative processes.

The space between the cells of the connective tissue is filled with **intercellular substance**. Its main components are the matrix, known as ground substance, which is present in large amounts and leads to the cells of the connective tissue being spaced quite far apart, and the fibers. The cells outnumber the fibers. All types of connective-tissue cells are present, though fibrocytes and macrophages predominate.

What is this connective tissue composed of?

- Fixed and mobile cells.
- Collagen fibers, reticular fibers, and elastic fibers.
- Ground substance (interstitial fluid).
- Fatty (adipose) tissue.

3.1.1 Fixed and Mobile Cells

The fixed portion of the cells in the connective tissue consists of fibrocytes and their precursors, fibroblasts. **Fibrblasts** have many irregular cytoplasmic processes that provide their cross-connections. They synthesize procollagens and acid mucopolysaccharides (glycosaminoglycans), the most important components of the ground substance, as well as the enzyme collagenase, which is responsible for the physiological dissimilation (degradation) of collagen.

Fibrocytes are smaller than fibroblasts, less active, and have fewer processes. They synthesize the same substances: collagen, elastin, and polysaccharide–proteins. Connective-tissue cells are capable of producing, in a short period of time, an amount of extracellular substance that considerably exceeds their own weight. To do this, the connective-tissue cell must be supplied with adequate nutrients: energy-rich nutrition plus oxygen. The condition of the connective-tissue cells has consequences in terms of the laws of diffusion, because the extracellular substance (ground substance) to a certain extent constitutes part of the environment of the cells, in the sense of a healthy, "clean" cell environment as opposed to a cell environment filled with disease-causing factors. It does not require much imagination to envisage that cells living in a healthy milieu have better living conditions. Manual lymph drainage "cleanses" the connective tissue through its tissue-draining effect.

The mobile portion of the cells consists of macrophages or mast cells, granulocytes, lymphocytes, and histiocytes. These progeny of leucocytes possess amebic properties that allow them to enter the connective tissue via the blood and move about freely.

Note

The ability of histiocytes (macrophages) to produce proteolytic enzymes plays an important role in the body's fight against lymphedema.

3.1.2 Fibers

Because of their structure, **collagen fibers** are a high-tensile, inelastic element (they can only be stretched about 5%), well suited to power transmission. They are found mainly in bones, cartilage, tendons, fascia, and subcutis. In addition, they are also found around elastic fibers, where they have a protective function.

In its stretched state, the **elastic fiber** is as long as the accompanying collagen fiber. In this way, the collagen fiber protects the elastic fiber and prevents it from being torn or overstretched. Elastic fibers, too, are formed by fibroblasts. They always occur as a network, and they are subject to an aging process that reduces their elasticity greatly. If an elastic fiber is stretched for a long period, it takes a long time to return to its original length once the tension has been relieved. This is one reason why, after an edematous extremity has been drained, the skin cannot contract as much as the edema volume has been reduced. Elastic fibers occur in the skin, arteries, lungs, elastic cartilage, and in the connective-tissue capsules of various organs. In the skin, the aging process of the elastic fibers causes wrinkles. In pregnancy stretch marks (striae gravidarum), the elastic fibers have become overstretched and the collagen fiber network has torn. Overstretching of fibers in the lungs can lead to emphysema.

Reticulin fibers have a similar structure to collagen fibers but are much more delicate. They occur in many organs (e.g., liver and kidneys) and in connective tissue, where they form the basic framework. The vascular basement membrane is made of feltlike networks of reticulin fibers.

3.1.3 Ground Substance/Interstitial Fluid

The ground substance is a homogeneous, structureless, colorless, puttylike substance consisting mainly of procollagen, collagen, and glycosaminoglycans (chondroitin sulfate in cartilage, mucoitin sulfate in connective tissue, hyaluronic acid in the synovial fluid, subcutis, and the vitreous body). These substances bind water and other substances. Electrolytes, peptides, amino acids, vitamins, and hormones are also present.

Hyaluronidase is a protein that depolymerizes (breaks down) hyaluronic acid and liquefies the ground substance.

Usually, both hyaluronic acid and hyaluronidase are present in equal amounts in the organism. This balance guarantees a healthy relation between breakdown and synthesis. Adding hyaluronidase would disturb this balance.

Interstitial fluid serves as the environment for molecules carrying nutrients from blood capillaries to cells and metabolic waste from cells back to capillaries. We call it the "transit stretch." This fluid contains many immunoglobulins that are important for defense against infections.

The ground substance consists largely of water. It is movable and of varying viscosity. One might say that ground substance has thixotropic properties.

Thixotropy is the property to liquefy and become a sol through mechanical impact and then revert to gel again. This means that if shear force or pressure is exerted on this tissue, its viscosity decreases toward that of a sol. When the shear force or pressure subsides, the viscosity increases again. The substance is gel-like but liquefies when shaken. An everyday life example is ketchup. It is easy to see that transporting substances through the interstitium is easier when it is in the energy-rich, thin sol state. Shear forces and deforming energies, which must be adapted to the structures of the connective tissue, cause ground substance to liquefy, which one might compare to the liquefaction of synovial fluid during movement of a joint. Heat, too, can dissolve the aggregation of macromolecules in the ground substance, which shows itself in the gel state. Under the sudden application of pressure, connective tissue can display a glass-hard consistency with a corresponding ten ency to tear—that is, the macromolecules have no time to orient themselves in space. Tendon and muscle tears occur during athletic activities not preceded by a warm-up. A typical Achilles tendon tear takes place when the tendon is put under stress in cold conditions. Tendon and muscle tears occur particularly often under sudden, unexpected, forceful impact.

Pischinger (2009) interprets the "cell–milieu system" as a functional unit. Today we speak of microcirculation. Pischinger considers the connective tissue an organ, and by this he means the connective tissue is omnipresent, with connective-tissue cells, ground substance, blood capillaries, and initial lymph vessels, leucocytes, monocytes, and cells where the fibers of the autonomic nervous system end. A network of free axons exists in the ground substance, which release neurotransmitters directly into the connective tissue with regulatory effect,

meaning that the ground substance, with its physicochemical and colloid-chemical changes, is connected via the autonomic nervous system with all other areas of the body. Pischinger's system of basic regulation offers an explanation for the long-distance effect of manual lymph drainage, repeatedly observed during therapy.

Blood and lymph vessels, as well as terminal fibers of the autonomic nervous system, are considered part of the connective tissue. Nerves, capillaries, and cells form a triad that is able to trigger regulatory processes in the connective tissue. These regulatory processes relate to the functions and qualities of the connective tissue described later. Manual lymph drainage is a massage technique that is suited to this type of tissue. It helps regulate the composition and function of the connective tissue, because with the special manual lymph drainage techniques, fluids and solutes can be moved about in the connective tissue in any direction, extravascularly.

When deforming forces act upon the connective tissue, for example, gentle vibration or manual lymph drainage—forms of massage that are suited to the connective-tissue structures in terms of pressure and skin displacement—the connective tissue can be freed of substances that are having an irritant or disease-sustaining effect.

Stimulation of lymphangiomotoricity through manual lymph drainage leads more easily to increased removal of macromolecular substances and water in a sol environment. The connective tissue is rid of metabolic waste, with all the positive consequences for regular cell nutrition and waste removal.

Manual lymph drainage has the following effects on connective tissue:

- The special technique of manual lymph drainage together with the fact that each treatment session is quite long means that the gel state of the interstitial fluid changes into a sol state.
- Through stimulation of lymphangiomotoricity, water and macromolecular substances (the entire lymph-obligatory load and toxins) are removed from the connective tissue.
- The connective tissue is "normalized." Q 22

We would like to quote Prof. Weissleder: "It must be assumed that micro-edemas in the connective tissue are the cause of a multitude of diseases." Therefore, by removing the microedema we help the connective tissue to regenerate and reassume its great variety of tasks.

3.1.4 Function and Qualities

The connective tissue is an organ and possesses a multitude of functions and qualities. It maintains the unconscious and undifferentiated vital functions. Its structure is crucial for the functioning of the body because all the information and substances traveling to and from a cell always pass through the connective tissue. With its high water content, it provides a hydroculture for cells; they receive minerals, energy carriers, and building materials from it, and return to it the products of aerobic and anaerobic metabolism. Connective-tissue fibers determine the mechanical properties and also act as mechanical barriers against microorganisms. Many cells and substances of the body's defense system are located in the connective tissue, which makes it an important part of the immune system. Nerve cells (nerve fibers) are tasked with undisturbed communication within the organism. Every cell can absorb any nutrient from the tissue fluid in which it is bathed. If a nutrient deficiency occurs in any cell, it can at any time draw any nutrient from the ubiquitous reservoir without delay due to long transport routes.

Some people are of the opinion that connective tissue is merely a passive transit route for the transport of substances from the blood capillaries to the cells and back. Pischinger (2009), however, classifies the connective tissue as an organ. This leads to the concept of the "cell–milieu system," according to which the cells' quality of life depends on their environment. That seems plausible, particularly as terminal nerve fibers of the autonomic nervous system are present in the connective tissue.

Another quality of the connective tissue is its ability to regenerate itself. When organ tissue perishes or volume loss occurs in the tissue, fibroblasts multiply and fill the defect with cells, fibers, and ground substance. Blood capillaries can regenerate as well. The connective tissue is also responsible for scar formation (fibroblasts).

3.1.5 Adipose Tissue

Adipose or fatty tissue, which provides almost the entire energy supply for the body, is a special form of reticular connective tissue. Each cell stores fat as a single droplet. If the energy supply is increased, the fat droplets in the cells swell and may push nucleus and cytoplasm to the cell membrane (▶ **Fig. 3.2**).

Fat cells are fixed in their environment by elastic and collagen fibers. They can be shifted about under pressure. When the pressure subsides, the tissue returns to its old shape.

We know adipose tissue as cushioning fat in the palms of the hands, soles of the feet, gluteal area, orbit, cheek, and renal bed.

We have storage fat in the subcutis and under the peritoneum of the colon. Excess nutrition is stored as fat that can be metabolized when nutrition is low. The subcutaneous fat layer helps us to maintain a proper body temperature. The interstitial connective tissue can

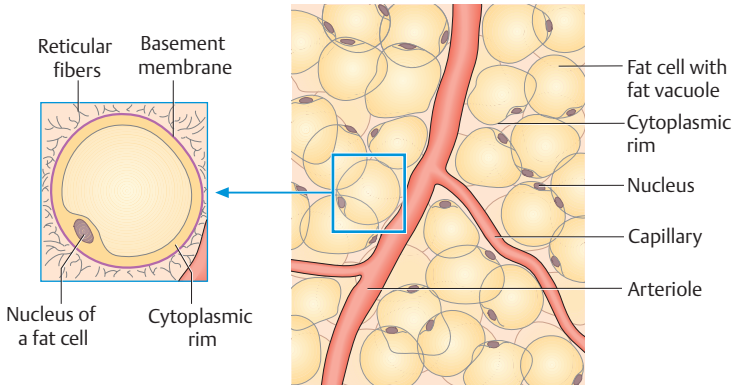


Fig. 3.2 In the adipose tissue, the individual fat cells (adipocytes) are enveloped by a basement membrane and a network of reticular fibers (Faller 2004).

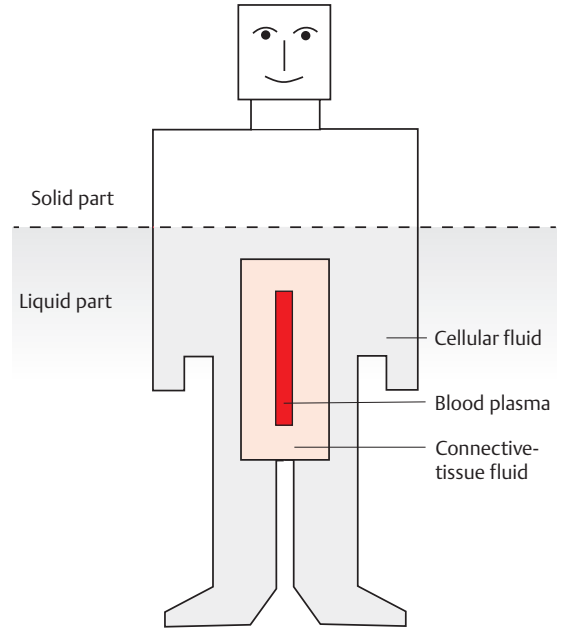


Fig. 3.3 Fluid balance.

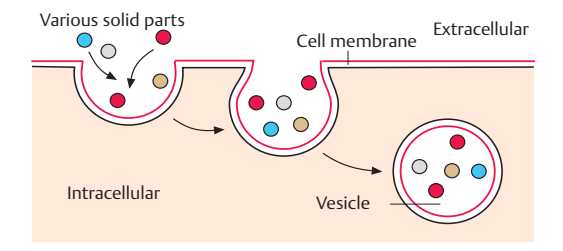


Fig. 3.4 Pinocytosis/transcytosis.

be regarded as a filling between the organs and in the neurovascular compartment. It has a protective effect.

3.1.6 Water Balance

The body consists of two-fifths solid substances and three-fifths a fluid similar to seawater (▶**Fig. 3.3**)—an indication that all land-dwelling creatures originated in the ocean.

The fluid can be roughly divided as follows:

- Eleven percent (3 L) blood plasma.
- Twenty-six percent (12 L) interstitial or connective-tissue fluid.
- Sixty-two percent (28 L) intracellular fluid.

The fluids are of great importance because substances can only be transported in the liquid milieu. Health often depends on metabolism (i.e., the circulation of substances), which makes it a transport issue.

3.1.7 Protein Circulation: Active Transport Mechanism

In this context, macromolecular substances are usually protein molecules. If the blood protein concentration in a healthy individual is too high, various mechanisms of the endothelial cells of the blood capillaries will cause the protein to be released into the tissue in order to maintain homeostasis.

When blood is saturated with the right amount of protein, a steady intracellular flow of protein takes place. Small proteins trickle through the large pores of the capillary walls and enter the connective tissue.

The active, energy-requiring transport of fluids and solid substances through the endothelial cell is called **pinocytosis/transcytosis** (▶**Fig. 3.4**, **Q 6**). This active transport of protein and other substances through the endothelial cells takes place in transport vesicles. In a process called **endocytosis,** the vesicle takes a protein molecule, for example. On the opposite side of the cell, it releases it (**exocytosis**). These vesicles are often found in large numbers in the endothelial cells of venules.

The transport process is as follows: the endothelial cell membrane forms an invagination (pocket) into which it receives a protein molecule from the lumen of a blood vessel, then the pocket closes off to form a small sac (the vesicle). Like an elevator, the vesicle transports the protein through the cell, opens up when it reaches the other side, and releases the protein. Through this transport process, proteins are constantly being transported from the blood into the tissue and back from the tissue into the blood. Other substances undergo the same process. Active transport mechanisms require energy. This also applies to phagocytosis. **Q 37**

A protein passing through an endothelial cell inside a vesicle keeps its molecular structure unchanged, whereas a protein entering the intracellular space directly and crossing the endothelial cell plasma will usually undergo a change to its molecular structure.

According to Földi (2005), all protein molecules leave the bloodstream within 24 to 48 hours, enter the connective tissue, and most of them are returned to the bloodstream via the lymphatic vascular system, so the term **"protein circulation"** is justified.

As mentioned earlier, some of the tissue proteins return to the blood. The average diameter of a blood capillary pore is 80 to 90 Å, although there are a few with a diameter of 100 Å. Albumins have a diameter of 70 Å, which means that they can enter the tissue through the larger pores. Gamma globulins are larger than 100 Å. Albumins are transport vehicles. Their cargoes include water, metals, enzymes, vitamins, penicillins, insulin, and hormones. Gamma globulins have defense functions. Amino acids are the building blocks of proteins and also of cells. Beta globulins are carriers of fatlike substances. Altogether, there are more than 100 different proteins in the blood. One refers to the "vehicle" or transport function of the plasma proteins, which carry vital substances to the cells and carry metabolic waste away from them. The many and diverse tasks undertaken by the proteins show that protein circulation is as important as every other circulation in the body. And proteins circulate via the lymphatic vascular system; their circulation is maintained by it.

So the protein circulation needs a properly functioning lymphatic vascular system; otherwise, there will be blockages and build-ups in the connective tissue, that is, the concentration of protein in the tissue will rise. This will lead to reactive chronic inflammation, which in its turn will result in cell proliferation (fibrosis). **Q 6**

Storage of nutrients: In healthy people, the level of all nutrient molecules in the blood increases after a meal containing all food groups. The elevated nutrient level in the blood produces a high diffusion pressure, which pushes the nutrient molecules through the pores of the basement membrane of the blood capillaries into the connective-tissue fluid, and the level of nutrients in the blood returns to normal. The first thing that happens now is that the cells satisfy their own nutritional needs. Nutrient molecules are then stored in the connective tissue:

- Proteins in collagen and the amino group of mucopolysaccharides.
- Glucose in the sugar part of mucopolysaccharides.
- Fat in fat cells.
- Water in the domain of the mucopolysaccharides molecules.

Thus, all nutrients are stored in the connective tissue, each in its storage molecule. The subcutaneous connective tissue of an overfed person thus becomes several centimeters thick. The connective-tissue storage of an overweight person therefore contains not just adipose tissue but also all other nutrients in the proportion in which they were present in the diet that led to being overweight.

All nutrients travel into the connective tissue for storage or nutrition as long as the capillary basement membrane is healthy, pores are open, and transportation pathways through the pores are freely accessible. This causes the overweight person to be overweight but maintains his health, because the increase of storage molecules in the connective tissue does not have a negative effect.

3.2 Physiology of the Exchange Processes between Interstitium and Terminal Vessels

3.2.1 Molecular Motion: Passive Transport Mechanism

An adult consists of approximately 60% water, half of which is stored inside the cells (intracellular fluid). The rest of the water is divided between the blood plasma, interstitium, fluids such as cerebrospinal fluid, synovial fluid, and the body cavities. Interstitial fluid surrounds all the cells in the body. Basically, metabolism can only take place via this fluid.

The **cell membrane** is the border between the intracellular milieu and the extracellular space. However, the cell needs a great variety of substances to survive and fulfill its functions. In addition, it has to be able to selectively release a wide variety of substances. The cell membrane is very well supplied with proteins for these purposes, and also makes use of a number of laws of physics for transport. Transport is divided into active transport and passive transport (▶**Table 3.1**).

Table 3.1 Transport mechanisms of the body

Passive transport mechanisms	Active transport mechanisms
Diffusion	Primary active transport (transport against a concentration gradient using adenosine triphosphate)
Osmosis	Secondary active transport ("piggyback" transport against a concentration gradient)
Filtration Q 38	Phagocytosis (absorption of cell debris and bacteria; characteristic of defense cells)
	Pinocytosis (formation of transport vesicles)
	Endocytosis (absorption of particles)
	Exocytosis (release of a pinocytosis vesicle)
	Transcytosis (pinocytosis vesicle crossing the cell) Q 34

Passive transport mechanisms follow the laws of physics and chemistry. They do not require energy input. These mechanisms are as follows:

- Diffusion.
- Osmosis.
- Filtration.

All molecules move owing to their inherent thermal energy (Brownian motion). At absolute zero (–273°C or 0°K), all molecular motion ceases. For example, the wood molecules in a tabletop vibrate in place. Molecules in a fluid or gaseous aggregate state move in a straight line until they collide with other molecules of the same type, ricochet, and thereby change their position (like billiard balls). This spontaneous motion of molecules is the basis of diffusion. Q 38

Diffusion is the mixing of substances in gases or fluids that takes place on the basis of this molecular motion. Each molecule is constantly moving.

Free diffusion takes place when solutions are not separated by a membrane. If there is a membrane between the solutions that is equally permeable by all the molecules, this is called impeded diffusion.

Most substances in the body move about via diffusion. Supply of nutrients and removal of waste products mostly take place through diffusion. The distance between blood capillary and cell is the diffusion distance, also called the "transit stretch." For good cell maintenance, it needs to be short. A transit stretch of 0.1 mm is only just short enough for adequate maintenance. If it is longer, the cell suffers.

Diffusion is a substance exchange that is independent of energy: in order to speak of diffusion, a concentration gradient is required. Diffusion always strives toward concentration equilibrium; that is, the movement of molecules is always in the direction of the lower concentration.

For example, the molecules of a dissolving sugar cube at the bottom of a cup of coffee move "chaotically"—they collide and bounce off one another. They begin to move increasingly into the sugar-free area of the coffee, because here there are fewer sugar molecules to collide with. They also move back to where they came from, because they are not moving in a determined direction, but in whatever direction collisions send them. After some time (4–6 weeks), the sugar would be mixed with the coffee (▶**Fig. 3.5**). Nobody would sweeten their coffee through diffusion, though: we add energy, that is, stir the cup, and our coffee is sweet immediately.

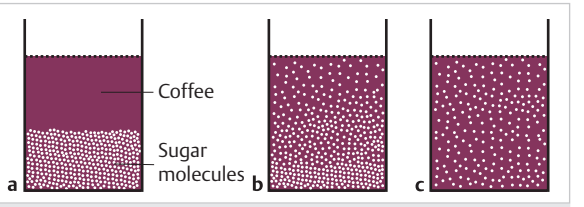


Fig. 3.5 Free diffusion. **(a)** High concentration of sugar molecules at the bottom of the cup, coffee on top. **(b)** Sugar molecules travel into the coffee area (but the majority of sugar molecules are still at the bottom of the cup). **(c)** Complete intermingling. Diffusion is complete; all remaining motion is molecular motion.

For the main function of diffusion (cell nourishment and waste removal) to be fulfilled without delay, the diffusion distance has to be very short. Diffusion depends on temperature. The higher the temperature, the faster the molecules move. The smaller the molecules, the faster they can move. The greater the concentration gradient, the faster the particles diffuse. Tissue viscosity also plays a role: the lower it is, the faster the diffusion (▶**Fig. 3.6**). Q 18

Time is also a factor in diffusion: the shorter the transit stretch, the faster the mixing. The rate of diffusion falls as the square of the distance. If the transit stretch doubles, diffusion takes four times as long; if it triples, the molecule takes nine times as long to reach its destination (i.e., the cell).

The length of the transit stretch is of particular significance for the supply of oxygen to the cells. Oxygen arrives at the periphery bound to hemoglobin in the blood, is "unloaded," and then has to pass along the transit stretch to the cell. There is no way to store oxygen in the interstitial space—every second of our lives, every cell must be supplied with oxygen and carbon dioxide must be removed if cell death is to be avoided. So, the length of the transit stretch is extremely important, and increased length of

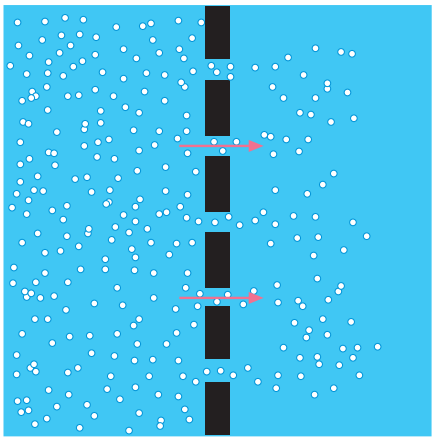


Fig. 3.6 Particles diffuse through a permeable membrane from the side where the concentration is higher to the side where it is lower.

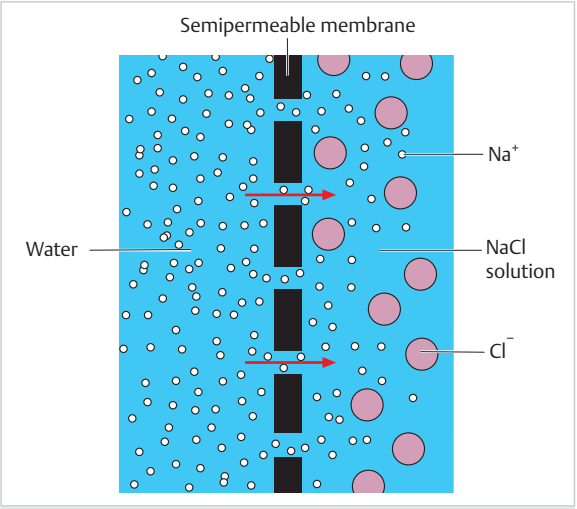


Fig. 3.7 Only small particles can pass through the semipermeable membrane.

the transit stretch can be regarded as "microedema" in the connective tissue. **Q 18**

Osmosis, independent of energy like diffusion, is the name given to the water motion of particles through a semipermeable membrane. This membrane separates the micromolecular solvent into two halves, one half containing few macromolecular substances and one half containing many. The macromolecular substances cannot pass the membrane, but the solvent can. In this case, the micromolecules of the solvent move from the lower concentration of macromolecular substances to the higher concentration of macromolecular substances (▶ **Fig. 3.7**).

In other words, if a membrane separates two solutions of differing concentrations—for example, water on one side and water and salt on the other side—the two solutions have different "water concentrations," because the side containing salt has fewer water molecules. Osmosis strives for concentration equilibrium and water molecules diffuse through the membrane. This causes an increase of water on the "salt" side (= increased pressure = osmotic pressure).

The water-attracting force of salts and sugars is termed osmosis, while **oncosis** or colloid osmosis is the water-attracting force of proteins. **Q 36**

Herpertz writes: "Osmosis is the one-way diffusion of liquids through a semipermeable membrane, in which water in particular moves into the macromolecular solution. The result is a rise in pressure through volume increase in the space containing the macromolecules."

Osmotic force can be measured. Using the previous example, the higher the concentration of salt molecules on one side, the higher the osmotic force. Osmosis is important for the transport of water, salts, carbohydrates, etc., through the cell or capillary walls. **Q 19**

Colloid osmosis relates to proteins. Proteins are macromolecules with a water-attracting force that is called oncotic or colloid osmotic pressure (COP), or suction. **Q 33**

Osmosis can only take effect if there is a semipermeable membrane between the water and the protein solution: for example, the basement membrane of the blood capillaries. The wall of the blood capillaries is impermeable, or nearly so, to proteins. The COP is initiated particularly by the albumins (which are small protein molecules). The protein content of the blood is approximately 7.4%. This represents a COP of 25 mm Hg. This is the force with which water would be sucked out of the interstitium into the capillaries if the interstitium did not contain proteins. But the interstitium does contain protein molecules, which also exert COP, drawing water from the blood capillaries. The difference between these two pressures—in the blood and in the interstitium—results in the suction pressure by which the plasma proteins reabsorb water from the interstitium. ("Pressure" can also be called "suction.") According to latest research results, it requires certain prerequisites for this statement to hold true. **Q 19**

Filtration is a process that takes place along the blood capillaries when a fluid is pressed through the capillary wall owing to the hydrostatic pressure difference between the blood capillaries and the COP of the blood.

The amount of the filtrate depends not only on the structure of the filtration area and the pressure difference but also on the forces counteracting the hydrostatic pressure (COP of the blood). The wave of blood pressure increases the hydrostatic pressure in the blood capillaries

so that fluids containing salts and low-molecular-weight nutrients are pressed into the interstitium.

The backflow of interstitial fluid into the blood capillaries is called **reabsorption**. Q 33

Since macromolecular substances cannot exit the blood capillaries because of their size, there exists an **active transport mechanism** to take them through the cell, which uses energy (adenosine triphosphate [ATP] dissimilation). Q 37

Long-chain fatty acids and macromolecular proteins from nutrients enter the chyle vessels in the same manner (lymph from the intestines is called chyle lymph, or simply chyle).

3.2.2 The Starling Equilibrium

Many years ago, the physiologist Starling stated that equilibrium is present if blood pressure and COP in the blood capillaries are balanced. He observed the forces acting on and in the blood capillaries (blood pressure, tissue pressure, and COP of the plasma and tissue proteins). He called them filtering and reabsorbing forces.

Starling describes four forces:

- Blood capillary pressure is a filtering force.
- Tissue pressure is a reabsorbing force.
- Oncotic or COP of the blood is a reabsorbing force.
- Oncotic or COP of the tissue is a filtering force.

The pressure of the tissue is not a constant. It depends on the elasticity of the tissue, the amount of connective tissue and its components, and the condition of the ground substance (gel vs. sol). The COP of tissue proteins is not constant either.

In Starling's opinion, only the endothelial cells of the blood vessels act as the vascular barrier between vessel lumen and interstitium. This led to the assumption that filtration is allowed by a pressure gradient from inside the vessel toward its outside. Reabsorption takes place when the venous COP (suction) exceeds the blood capillary pressure. It was presumed that 90% of the entire filtrate (100%) is reabsorbed into the blood capillaries and the final 10% are lymph-obligatory load.

Recent findings have called this opinion into question. Present knowledge regarding the transvascular exchange of fluids has expanded and changed. The Starling equilibrium has remained unchanged: equilibrium exists when blood pressure and colloid osmotic blood capillary pressure are balanced. Water does not exit the vessel.

Glycocalyx

New findings show that the colloid concentration in the blood vessel and in the interstitium is approximately the same. These results incorporate glycocalyx (*glykos* is Greek for sugar and *kalyx* is Greek for coat) into the Starling principle. Every healthy vessel is coated with an endothelialglycocalyx, a carbohydrate-enriched coat covering the vascular endothelium. This coat is in a state of constant composition and decomposition, the dynamics of which have not been clarified yet. At the same time, it is serving as a barrier for macromolecules—including proteins traveling outward—and acting as a protective shield between blood plasma and the endothelial cell. This protective shield can easily be damaged through inflammation, atherosclerosis, or ischemia. In such cases, considerable disturbance of the transvascular fluid exchange is to be expected. As a result, an increased amount of substances—mainly plasma proteins—leaves the blood capillaries, allowing the formation of tissue edema. This increases the significance of inflammation even further than previously assumed. The **entire** filtrate can only be removed from the tissue via the lymphatic vessel. Reabsorption into the venous system is reduced to a minimum or does not take place at all. This information is based on the research of Chappell et al (2008).

Under certain conditions, the blood capillaries can reabsorb. This depends on the constellation in the area of the glycocalyx and the COP in the interstitium (high COP at the glycocalyx surface and low COP in the interstitium near the capillaries). Through the reabsorption of water, the COP in the interstitium rises, which reestablishes equilibrium relatively quickly. As mentioned previously, in lymph nodes the lymph can condense, which results in a higher protein concentration in the efferent lymph collectors. Q 35

3.3 Function of Lymph Vessels

The lymphatic vascular system is regarded as a safety valve; that is, everything that cannot be drainedvia the venous system becomes lymph obligatory. The lymph volume depends on the structure of the capillary wall and the blood flow through the respective organs. If the blood capillaries are expanded (e.g., to regulate temperature), filtration increases in that area. The same process also takes place during muscular activity. In both cases, more lymph-obligatory load is produced.

As long as the lymphatic vascular system can cope with the additional fluid, everything is all right: the system has a "**functional reserve**." However, once the lymph-obligatory load, particularly the water load, exceeds the transport capacity (TC) of the lymphatic vessel system, edema forms (dynamic insufficiency). Functional reserve (▶**Fig. 3.8**): difference between TC and lymph-obligatory load. Q51, Q 46

The quantity of lymph that can be managed by the TC of the lymph vessel in a certain unit of time is known as the **lymph time volume**. Q 40

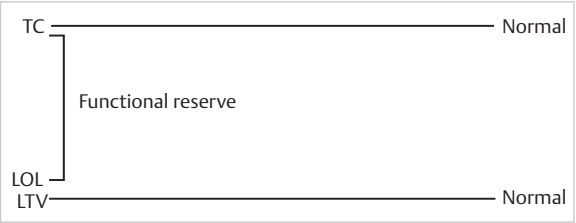


Fig. 3.8 Functional reserve. TC, transport capacity; LOL, lymph-obligatory load; LTV, lymph time volume.

TC is the amount of lymph-obligatory load that the lymphatic vessel system can transport during a certain time unit. **Q 41**

Note

Dynamic edema develops as a result of an increased lymph time volume that exceeds the TC of the healthy lymphatic vascular system (high-volume insufficiency). **Q 51**

There are various causes of this **high-volume insufficiency**:

- **Renal edema**: the body excretes increased amounts of proteins through the kidneys, resulting in decreased COP of the blood.
- **Hunger edema**: the body receives insufficient protein, for example, due to malnutrition or inappropriate diet.
- **Protein-losing enteropathy**: the body excretes proteins via the intestines. The intestinal lymphatic vessels become more permeable, because lymph stagnates in them (lymphatic stasis) or ulcers in the intestinal mucous membrane allow the lymph to flow out. A congenital abnormality of the intestinal lymphatic channels could also be the cause.
- **Vascular hypertrophy**: venous stasis always leads to increased venous capillary pressure and can lead to dynamic edema.
- Cardiac decompensation or right heart failure: **"cardiac edema"** is the result of a very complex process involving a series of neural, hormonal, circulatory, and renal disturbances. The heart muscle is weakened. Congestion in the right cardiac ventricle results, leading to increased pressure in the venous system all the way to the venous capillaries. As a result, venous drainage is impaired; this is known as **passive hyperemia**. It is assumed that the lymph vessels are under a dual burden: they have to deal with the increased fluid volume, while at the same time the absorption of lymph in the venous angle is complicated by the elevated intravascular pressure. **Q 32**

4 Lymphedema

Lymphedema is a swelling of the soft tissue. The underlying problem is mechanical insufficiency of the lymphatic vascular system, that is, the vascular system is damaged or unable to absorb the normal lymph-obligatory load. The result is reduced transport capacity, which leads to congestion of protein in the interstitium. Proteins are macromolecular substances that can only be removed from the interstitium via the lymph vessels. As has been mentioned, proteins (just like salts and sugar) possess water-attracting properties. Proteins that remain in the interstitium attract and hold water molecules. This causes interstitial pressure to rise, which then causes increased filtration. Q 47

The classical division of edema was set up by Földi. He divided them into three categories:

- Lymphostatic edema (due to mechanical insufficiency induced by organic or functional changes; low-volume insufficiency, protein rich; ▶**Fig. 4.1**).
- Dynamic edema (due to dynamic insufficiency; high-volume insufficiency, protein poor; ▶**Fig. 4.2**).
- Exhaustion of functional reserve, known as "safety valve insufficiency" (▶**Fig. 4.3** and ▶**Fig. 4.4**).

Additional options for edema classification are as follows:

- Acute/chronic, tending to progress.
- Benign/malignant.
- Primary/secondary.
- According to stages. Q 27

In 1892, Winiwarter described the development of lymphedema:

"In the beginning, the skin appears unchanged, just a little taut. Pressing with a finger leaves a depression, but the consistency of the skin and the subcutaneous tissue is more elastic than doughy (as in a simple edema). If one tries to lift a fold of the integument, the skin is noticeably thicker, more resistant, and more tightly connected to the underlying tissue than normal. Later, the consistency becomes increasingly hard and tough; or only part of the extremity remains edematous, while the rest hardens. Gradually, after 5 to 10 years, the circumference of the limb as it continues to swell reaches monstrous dimensions.

Usually, the extremity turns into a shapeless, uniformly thick cylinder, or it narrows suddenly above the ankle as though tied off, like "bloomers," or thick bulges and pendulous lobes hang down past the dorsum of the foot right down to the ground, like the folds of a robe, while the foot itself maintains normal dimensions. If the elephantiasis has spread further distally, the foot turns into a massive, shapeless lump…"

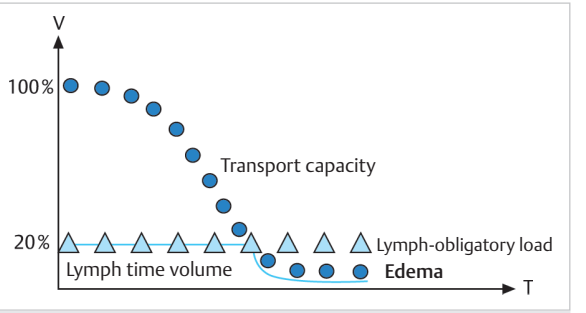


Fig. 4.1 Low-volume insufficiency: the lymphatic system is **diseased** (lowered transport capacity) and unable to process the lymph-obligatory load, the volume of which is normal. This is mechanical insufficiency; lymphostatic lymphedema develops. The transport capacity is decreased. Q 33

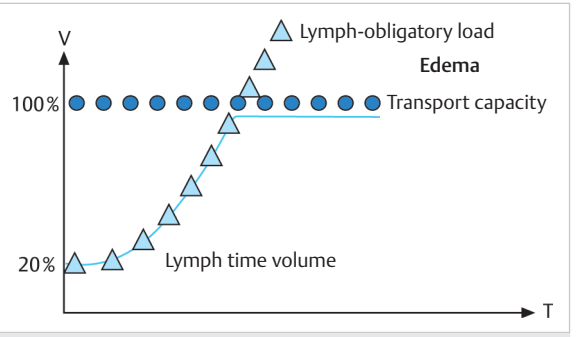


Fig. 4.2 High-volume insufficiency: the lymphatic system is **healthy** but unable to process the lymph-obligatory load, mainly water, the volume of which is **increased.** The transport capacity of the system is exceeded. Dynamic edema develops, not lymphedema. Q 32

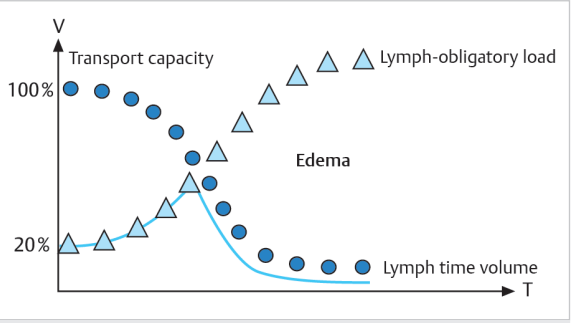


Fig. 4.3 Exhaustion of functional reserve (previously called "safety valve insufficiency"). The lymphatic system is diseased and is unable to process the lymph-obligatory load, the volume of which is increased. The physiological "functional reserve" is exhausted or exceeded. The result is mechanical combined with dynamic insufficiency of the lymphatic vascular system. Q 33

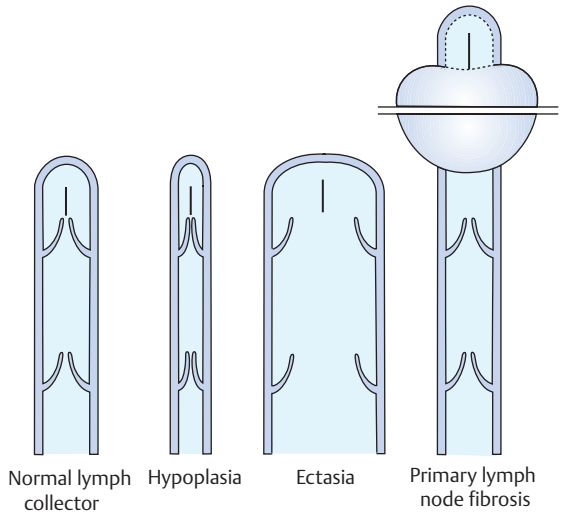


Fig. 4.4 Anatomical causes for a primary lymphedema (according to Herpertz).

Note

*In **lymphostatic or mechanical** lymphedema, the transport capacity of the lymphatic vascular system is reduced and unable to absorb the **normal** lymph-obligatory load (low-volume insufficiency, protein rich).* Q 33

*In **dynamic edema**, the transport capacity is maintained at 100%. The vascular system is healthy but unable to process the increased lymph-obligatory load—generally water load—(high-volume insufficiency, protein poor).* Q 32

***Exhausted functional reserve (safety valve insufficiency)** indicates that the lymph-obligatory load is increased, as occurs with inflammation or dynamic insufficiency. At the same time, the transport capacity is restricted and is further reduced, for example, by infection in the edematous area. This leads to massive tissue damage and may include necrosis.* Q 45

Lymphedema is divided into primary lymphedema (congenital damage) and secondary lymphedema (acquired damage). Both are caused by mechanical insufficiency of the lymphatic vascular system.

4.1 Primary Lymphedema

Primary lymphedema is described as a congenital developmental disorder of the lymphatic vessels and/or the lymph nodes. It is classified into sporadic (95%), hereditary (3%), and accompanying syndromes (2%; Herpertz 2003). The following may be underlying disorders:

- Hypoplasia (fewer lymph collectors).
- Hyperplasia (more collectors, possibly malfunctioning).
- Aplasia (absence of some collectors).
- Genetic.

With regard to lymph nodes, hypoplasia is usually the cause of the disturbance. Characteristic of lymphedema is interstitial enrichment with proteins and water.

Women are more often affected (85%) than men. A congenital transport disorder of the lymph vessels (congenital lymphedema) may exist at birth. It is not necessarily manifested at the time of birth, but may develop later in life, usually during puberty or pregnancy.

Slight injuries (distortion, insect bite) or long air journeys can also cause primary lymphedema, because the lymph vessels that are present are no longer able to transport the increased amount of lymph-obligatory load. In a primary lymphedema, fibrosis forms first at the toes. Q 55

4.2 Secondary Lymphedema

Secondary lymphedema is the name given to edema with a known cause. Lymph vessels or lymph nodes may have been damaged or removed by surgery, radiation, or trauma. Q 33

The term “malignant lymphedema” is used when the lymphatic pathways are constricted by a tumor or the vessels or lymph nodes are congested by metastases. Q 53

Artificial edema is edema caused by the patient himself or herself (self-mutilation). This type of damage is most frequently observed in dermatology. Q 53

The various types of lymphedema, their origin, treatment, and relevant precautions are discussed in the advanced therapy courses.

Lymphedema is a chronic disease and must be treated, because it tends to get worse, that is, the volume tends to increase. Collectors degenerate under consistent increased pressure.

The stages of edema are usually differentiated according to their extent:

- **Stage 0:** The absence of clinical swelling does not mean that the lymphatic vascular system is anatomically healthy and functioning properly. This stage may be considered as subclinical lymphedema, latent stage, or stage 0. Q 30
- **Stage I:** A visible, soft edema that reduces in size when the extremity is raised. It can reverse spontaneously.
- **Stage II:** Raising the limb no longer improves the edema. Tissue proliferates and becomes fibrotic; often skin changes take place (pachydermia, papillomatosis). It does not reverse spontaneously and treatment is imperative. Fibrosclerotic alterations may already have occurred. The condition is not painful. Stemmer’s sign is positive. Skin fold testing is recommended on both sides. With combined decongestive therapy (CDT), volume reduction and softening of the fibrosis are possible. This is the typical clinical picture of lymphedema.

- **Stage III:** This stage is called lymphostatic elephantiasis. It is a more pronounced version of stage II including fibrosis and/or sclerosis that can affect lymph vessels, veins, and arteries and also cause severe skin changes (such as pachydermia, papillomatosis). Reduced immune defense can result in nail and interdigital mycosis (fungal infection). Pain may be present when nerves have been damaged by pressure. Increase in adipose tissue may occur.

Lymphedema is staged on the basis of its pathoanatomical features. A large lymphedema does not necessarily have to be classified as stage III. **Q 30**

Stemmer's sign is measured at the dorsal aspect of the proximal phalanx of the second toe. It is done by trying to lift a skin fold between the thumb and the index finger. A positive Stemmer sign means that the enlarged and hardened skin fold cannot be lifted. Always try on both feet. A negative Stemmer sign does not exclude the existence of a lymphedema. In case of an existing lymphedema, the positive Stemmer sign confirms the condition. **Q 56**

In summary, lymphedema is classified as follows:

- Primary lymphedema can be congenital (sporadic or hereditary) or can accompany Turner's (congenital deformation) or Nonne–Milroy (hereditary, congenital) syndrome
- Secondary lymphedema, in which a distinction is made between benign (e.g., trauma) and malignant (primary tumor, metastases, or tumor recurrence).
- Lymphedema caused by filariasis, an infestation by nematodes that initiates an allergic tissue reaction to filaria antigens, causing alterations of lymph vessels and nodes. **Q27**

The generally known and most effective therapy is CDT, which consists of the following: **Q28**

- Manual lymph drainage.
- Compression therapy/bandages.
- Skin care.
- Respiratory therapy.
- Exercises.

4.3 Possible Complications of Lymphedema

- **Fibrosis:** Increase and cross-linking of collagen fibers caused by fibroblasts. Shift of the interstitial fluid into a gel state.
- **Erysipelas** (infection causing an inflammatory reaction, see later).
- **Lymphocele:** A mass that contains lymph, usually from diseased or injured lymphatic channels, with no endothelial lining.
- **Lymphocyst:** Extension of cutaneous lymph vessels; may also be found along the intestines. The cyst is a cavity with endothelial lining.
- **Lymph fistula:** The cyst can become a fistula, that is, the vessel opens to the surface of the body. The cause is the increased pressure in the lymph vessel. **Q44**
- **Papillomatosis:** Enlargement of the papillary dermis.
- **Pachydermia:** Thickening and hardening of dermis.
- Development of secondary tumors or relapses due to chronic lymphostasis.
- **Nail mycosis or athlete's foot,** because edema is an ideal breeding ground for bacteria and other germs.
- **Malignant secondary tumors:** A person may get a different tumor (also malignant) from the one which caused the edema.

4.3.1 Infection

Infection is the body's (interstitium's) answer to various noxious stimuli. The five cardinal signs of infection are the following:

- Redness.
- Pain.
- Heat.
- Swelling.
- Functional impairment.

The local reaction of the connective tissue causes a local circulatory disturbance with increased vascular permeability for blood plasma and blood cells. The release of epinephrine briefly brings about constriction of the arterioles. The autonomic nervous system relaxes the arteriolar spasm, and local hyperemia and blood stasis follow. The change in permeability is initiated by histamine and serotonin, followed by other biologically active mediators such as kinins, prostaglandins, and others. Granulocytes, macrophages, and lymphocytes move in. Their phagocytic effect determines the course of the infection and whether it will be overcome (▶ **Fig. 4.5**).

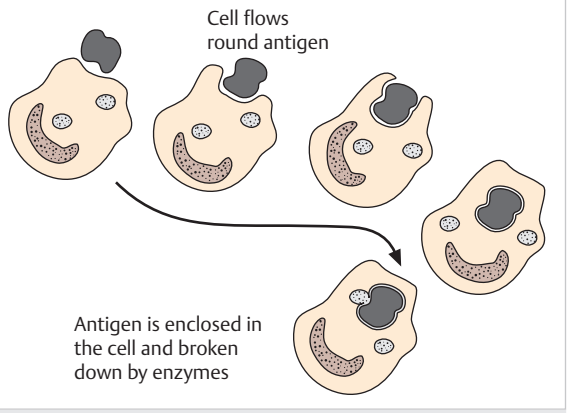


Fig. 4.5 Phagocytosis of an antibody by a defense cell.

Note

Inflammation: *Epicondylitis (tennis elbow) is an inflammation without infection.*

General reactions to an inflammation can be the following:

- Fever.
- Immune responses.
- Subjective sensations of illness, pain, and exhaustion.

4.4 Physical Reactions to Lymphedema

Interruption of the lymph flow results in stasis and backup of lymph, because the lymph-obligatory load cannot be removed. Lymph vessels distal to the disturbance dilate, the internal pressure rises, and collateral vessels or anastomoses to a different drainage area may open up. Formation of new lymph vessels is also possible (▶ **Fig. 4.6**).

The pulsations of the lymph vessels close to the blockage increase because of the increased lymph-obligatory load. The lymph time volume rises and the transport capacity is utilized in full.

A lymph vessel lying distal to the blockage may grow into another lymph vessel.

Due to the increased tissue pressure in the edematous area, edematous fluid can cross watersheds into other territories via prelymphatic channels, cross-connections between collectors, and anastomoses.

At the cellular level, the body reacts with the migration of macrophages into the area threatened by edema. Macrophages can reduce tissue proteins to small pieces (proteolysis). The fragmented protein cannot form water bonds and is reabsorbed by the blood capillaries. Q 31

Except for the last point (the cellular reaction), manual lymph drainage has a positive effect on all the above reactions.

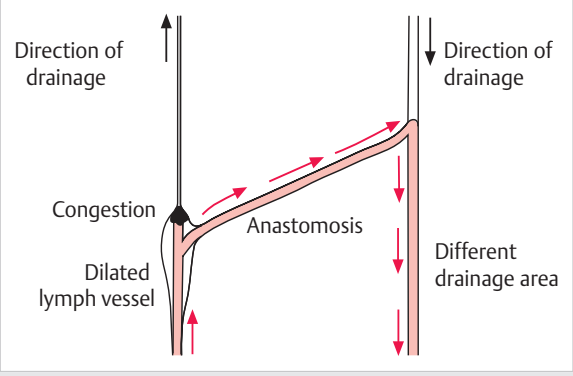


Fig. 4.6 Opening up of an anastomosis into a different drainage area.

4.5 Additional Indications for Manual Lymph Drainage

4.5.1 Venous Edema of the Leg

Phlebedema

Veins transport the blood back to the heart. They move the blood "uphill." Valves (every 0.5–1 cm) mainly prevent the venous return and at the same time excessive increase of pressure in the veins. Varicose veins indicate valves that do not close properly. The pressure in the veins, mainly in the lower legs, increases. Blood cells are forced into the tissue, which causes a bluish discoloration of the skin. Brownish discoloration indicates hemosiderin deposition. This is a visible sign for venous insufficiency that requires treatment.

Long-term overload of the lymphatic pathways is considered the cause of phlebedema development. Particularly during the second half of the day, the patient suffers stasis and swelling in and of the legs. Once the tissue is chronically indurated, the lymph vessels are damaged. A positive Stemmer sign confirms lymph drainage disorder that leads to edema. This is termed phlebedema.

Chronic Venous Insufficiency (CVI)

CVI is a venous disorder of the lower extremities that is accompanied by microcirculation disturbances and trophic changes in the lower legs and feet.

It develops through increased pressure in the veins of the legs and is advanced by the following factors:

- Phlebothrombosis.
- Lack of counter pressure of the muscles in the lower leg (muscle pump).
- Malfunction of the venous valves.

These changes initiate a vicious cycle that causes further damage to the veins with increased valve insufficiency.
CVI is classified into different severity levels:

- Reversible edema: dark blue skin discoloration at the medial and lateral edge of the foot.
- Irreversible edema: hemosiderin deposit, dermatosclerosis, varicose eczema, cyanotic skin color, severe tissue tension, and phlebedema.
- Ulcus cruris.
- Positive family history, age, and lack of exercise are considered risk factors.

Post Thrombotic Syndrome (PTS)

The term PTS summarizes all sequelae of thrombosis in the deep veins of the legs and pelvis. There is either decreased venous drainage in the affected section of the veins or insufficiency of the valve system.

The clinical picture of PTS is diverse. It includes everything from discrete swelling to severe trophic disorders with venous ulcers on the lower leg. The first year

following thrombosis is termed initial-stage PTS. This turns subsequently into the diagnosis of a late-stage PTS, which basically persists for life combined with the risk of another thrombosis.

In the patient's health history, acute thrombosis is included. There are also silent courses or thrombosis. They are masked by other causes for swelling, such as posttraumatic causes. The level of severity can be determined through functional and morphologic examination methods. Doppler and duplex sonography are suitable methods. The aim of physical therapy is activation of the muscular venous pump through motion exercises. Manual lymph drainage brings about decongestion.

Behavior patterns of the patient are of great importance:

- No standing up for long periods of time.
- Elevating the legs.
- No wearing of restrictive clothing.
- No hyperthermia.
- Exercises to activate the muscular venous pump.

Phlebedema usually occurs in the lower extremities as a result of increased pressure in the venous system caused by insufficiency of the valves. There are different stages: edema, edema with skin changes, and edema with ulcer.

4.5.2 Lipedema

Lipedema is a chronic disease. It is a painful inherited condition that occurs almost exclusively in women. It causes symmetrically painful and disproportional fatty tissue distribution, supported by constitutional factors. In some of the affected individuals, it may result from lipohypertrophy (see Chapter 4.5.3). Lipedema usually extends between the iliac crest and the ankles, where adipose lumps can be palpated. The arms are rarely affected. Increased permeability and fragility of the blood capillaries are known to be associated with lipedema. The small veins and lymph vessels are compressed. There are ectasia and aneurisms of the lymph vessels. Characteristically, the feet and toes (hands and fingers) are usually free of edema.

Women affected by lipedema complain about heaviness of the legs and tightness and fullness of the tissue. They are very sensitive to pressure and touch. The lightest touch may cause a hematoma that lasts for days. The pinch test is positive, that is, painful. It is performed on the lateral aspect of the thigh as a diagnostic test. Ultrasound is used for diagnosis (snow flurries).

There is a marked tendency to edema formation in orthostatism. Weight control from an early age is extremely important. If obesity accompanies the lipedema in the advanced stage, as it frequently does, often secondary lymphedema develops. This is termed **lipo-lymphedema.**

The lipedema can remain unchanged for years if normal weight is consistently maintained.

In true lipedema, Stemmer's sign is always negative.

Erysipelas does not occur.

The disease usually begins at puberty, and is characterized by larger hips and heavy lower legs. **Q 54**

The feared "orange peel skin" (cellulite) is diagnosed in stage II of the disease. Compression stockings and compression pants are recommended (compression class II).

Lipedema has nothing to do with obesity and therefore cannot be improved by diet (unless there is an additional adipose component). Normal weight is rarely found. The condition can develop into lipo-phlebedema.

In lipedema, different forms of distribution can be seen:

- Leg: entire leg, upper leg, lower leg.
- Arm: entire arm, upper arm, lower arm.

The edema begins proximal to the malleoli or the wrist with a visible or palpable adipose tissue barrier. **Q 54**

4.5.3 Lipohypertrophy

Lipohypertrophy is also diagnosed as disorder of fatty tissue distribution, with disproportionate swelling of the legs in relation to the trunk. Unlike in lipedema, the swollen tissue is not painful or sensitive to pressure. There is also no tendency to edema formation in orthostatism.

Lipodystrophy is a loss of adipose tissue that occurs, for example, in persons with diabetes.

Obesity, which is related to nutrition, should be regarded quite separately from all other conditions. The excess weight is evenly distributed on the trunk and the extremities. Through a change of lifestyle and dietary habits, the excess weight can be reduced to normal weight. Manual lymph drainage can be helpful to support skin regeneration.

4.5.4 Cardiac Edema

This edema is always of symmetrical appearance and begins usually at the lower legs and feet. It may spread across the entire legs and torso, due to right heart failure based on increased venous pressure with increased filtration and invariable reabsorption.

Diuretics or digitalis are used for basic therapy. In this type of venous edema, manual lymph drainage and compression therapy may also be applied. However, compression pressure must be very low.

If the cardiac edema has not been sufficiently treated with medication, manual lymph drainage and compression therapy are absolutely contraindicated. Overspeeding reabsorption could cause edema of the lungs because of a bottle neck at the venous angle. **Q 29**

Questions

1. Describe the anatomy of the initial lymph vessels. **Q 1**, **Q 2**
2. Describe the function of the initial lymph vessels. **Q 1**, **Q 2**
3. Describe the anatomy of the precollectors. **Q 3**, **Q 4**
4. What are the functions of the precollectors? **Q 3**, **Q 4**
5. Describe the anatomy of the lymphangions. **Q 5**
6. What is the function of the lymph collectors? **Q 6**
7. Describe the anatomy of the lymph node. **Q 7**
8. What are the functions of the lymph node? **Q 8**
9. What does the term "lymph-obligatory load" signify? **Q 9**
10. What does the lymph-obligatory load consist of? **Q 10**
11. What are the functions of the lymphatic vascular system? **Q 6**, **Q 8**, **Q 11**
12. How can lymphangiomotoricity be influenced? What are the inhibiting and sustaining mechanisms?
13. What is prelymph and how is it drained from the brain? **Q 13**
14. Describe the lymphatic drainage pathways of the skin above the navel watershed:
    a) Of the arm. **Q 14a**
    b) Of the thorax. **Q 14b**
    c) The deep lymphatic drainage pathways of the thorax. **Q 14c**
    d) The deep lymphatic drainage pathways of the mammary gland. **Q 14d**
    e) Skin of the head. **Q 14e**
15. Describe the lymphatic drainage pathways of the skin below the navel watershed:
    a) Of the leg. **Q 15a**
    b) Of the abdomen and loin. **Q 15b**
    c) Of the deep lymphatic drainage pathways of the leg. **Q 15c**
    d) Of the deep lymphatic drainage pathways of the abdomen. **Q 15d**
16. Explain the term "watershed." **Q 16**
17. Where are the most important watersheds? **Q 17**
18. What is diffusion? How do temperature, molecule size, and distance affect it? **Q 18**
19. How do you explain osmosis? What is the significance of osmosis for the human body? **Q 19**
20. What are the absolute contraindications for manual lymph drainage and their rationale? **Q 20**
21. What are the relative contraindications for manual lymph drainage and the precautions that may be necessary with regard to treatment? **Q 21**
22. What effects can be achieved through manual lymph drainage? **Q 22**
23. What are the special points that must be observed in the practice of Dr. Vodder's manual lymph drainage? **Q 23**
24. What influences the massage pressure applied during manual lymph drainage? **Q 24**
25. How can protein exit the bloodstream? **Q 25**, pages 21, 22
26. How is protein removed from the tissue? page 22
27. What classifications for lymphedemas do you know? **Q 27**
28. What are the therapeutic elements of CDT? **Q 28**
29. How is cardiac edema treated? **Q 29**
30. What stages of lymphedema do you know? **Q 30**
31. What reactions of the body against impending lymphostasis do you know? **Q 31**
32. Describe dynamic edema and give examples. Why is it called high-volume insufficiency? **Q 32**, **Q 51**
33. Describe lymphostatic edema (lymphedema) and give examples. Why is it called low-volume or mechanical insufficiency? **Q 33**
34. List dos and don'ts for a patient with lymphedema of the leg. **Q 34** page 111
35. What is the Starling equilibrium? What is glycocalyx? **Q 35**
36. What is the water-attracting force of proteins called? **Q 36**
37. What is the difference between active and passive transport? **Q 37**
38. Which passive transport mechanisms do you know? **Q 38**
39. What is meant by pinocytosis (transcytosis)? pages 21, 23
40. How do you define the term "lymph time volume" (LTV)? **Q 40**
41. What is meant by the "transport capacity" of a lymph vessel? **Q 41**
42. What type of lymphocytes do you know? **Q 42**
43. What are anastomoses? **Q 43**

44. What is the difference between a lymphocele, a lymphocyst, and a lymph fistula? **Q 44**
45. Explain the term “functional reserve of the lymphatic vascular system” (also safety valve insufficiency). **Q 45**
46. What happens in the tissue if the transport capacity of the lymphatic vascular system is exceeded? **Q 46**
47. What happens in the tissue when lymph nodes are surgically removed? **Q 47**
48. What are venous valves and why do veins have valves? **Q 48**
49. What are pluripotent stem cells? **Q 49**
50. List the subgroups of leukocytes. **Q 50**
51. Briefly describe the difference between dynamic edema and lymphostatic edema. **Q 32**, **Q 33**, **Q 51**
52. Explain the anatomical difference between arteries and veins. **Q 48**, **Q 52**
53. What is a malignant lymphedema? What is an artificial lymphedema? **Q 53**
54. How do you recognize a lipedema? **Q 54**
55. Where does fibrosis start in a primary edema of the leg? **Q 55**
56. What is Stemmer’s sign? **Q 56**

Answers

1	The initial lymph vessels are the smallest vessels of the lymphatic vascular system. They have a plexuslike origin in the tissue and a single layer of endothelial cells that partially overlap. The vessel is enveloped by a basement membrane, which is considerably thinner than the one belonging to the blood capillaries. This fiber network and the anchor filaments are connected to fibers of the surrounding tissue. **Q 1,** pages 7, 8.
2	Absorption of the lymph-obligatory load from the tissue due to the suction effect exerted by deeper-situated collectors, pressure changes in the interstitium, and osmotic processes. It can also be an active process of the endothelial cell. After entering the initial lymph vessels, the lymph-obligatory load is called lymph. **Q 2** Pages 7, 8.
3	Precollectors have rudimentary flaps, and a few muscle cells are found. They can absorb a small amount of lymph-obligatory load. They are called transport and collector vessels. **Q 3** page 8, **Q 4** page 8.
4	Precollectors connect the initial lymph vessels with the lymph collectors. **Q 3** page 8, **Q 4** page 8.
5	A lymph collector consists of many lymphangions or segments that form a functional unit. Like blood vessels, their walls are made of three layers (intima, media, and adventitia). The middle layer (tunica media) contains bundles of smooth muscle cells. Muscle-free flaps are located proximally and distally in a lymphangion. They control the direction of the lymph flow. The triggering factors for contraction of an angion are: (1) increased internal pressure (increased influx of lymph) and (2) active extension of vessels with manual lymph drainage. Assisting mechanisms ("auxiliary pumps") affect the vessel from the outside, increasing the lymphangiomotoricity. They include contraction of the skeletal muscles, pulsation of blood vessels, increased intestinal peristalsis, and pressure change in the thorax during respiration. The angion also has its own pulsation (autonomic motoricity). It is called transport vessel. **Q 5** page 9.
6	To maintain lymph flow, protein circulation, and recirculation of lymphocytes **Q 6** pages 9, 21, 22.
7	Lymph nodes are lymphatic organs. There are about 600–700 in the human body. They have a connective-tissue capsule with some muscle fibers and (incomplete) trabecular divisions. The space in between is filled with a meshwork of reticular cells. In the cortex of the lymph node, primary and secondary follicles are found as well as nonsensitized lymphocytes and lymphocytes that are sensitized through contact with an antigen. The medulla of the lymph node contains many macrophages (nonspecific defense) and plasma cells. Afferent vessels enter the lymph node on the convex side of the capsule and empty into the sinus (marginal and intermediary). From there, the (generally) protein-rich lymph exits the lymph node at the hilum via the cortical sinus and the efferent vessels (one or two). Blood and neural supply are via the hilum. **Q 7** page 10.
8	Biological filtration of lymph. Up to 50 % concentration (thickening) or diluting of lymph. Activation of the immune system. Storage of nondegradable substances. **Q 8** page 10.
9	Everything that cannot be absorbed by the venous system becomes lymph obligatory. **Q 9** page 7.
10	Protein, water, cells (cell debris), fat (long-chain fatty acids), and foreign substances. **Q 8** page 10; **Q 10** page 7.
11	Absorption of lymph-obligatory load, maintenance of fluid balance, maintenance of protein circulation, recirculation of lymphocytes. **Q 6** pages 9, 21, 22; **Q 8** page 10; **Q 11** pages 3, 38.
12	Inhibiting influences: local anesthetics, excessive external pressure, pain, and stimulus fluctuation, for example, temperature and current. Sustaining influences: arterial pulsation, muscle contraction, respiration, and manual lymph drainage. Page 9.
13	Prelymph is the lymph-obligatory load before it is absorbed by a lymph vessel. Prelymph in the brain is drained via the cerebrospinal fluid, along the cranial and spinal nerves, and through the Virchow–Robin spaces (intra-adventitial spaces of blood vessels). **Q 13** page 16.
14	a) Arm: **Q 14a** pages 14, 15. b) Thorax: **Q 14b** page 15. c) Deep lymphatic drainage pathways in the thorax: **Q 14c** page16. d) Deep lymphatic drainage pathways of the mammary gland: **Q 14d** page 16. e) Skin of the head: **Q 14e** page 12.
15	a) Leg: **Q 15a** pages 12, 13. b) Abdomen and loin: **Q 15b** page 14. c) Deep lymphatic drainage pathways of the leg: **Q 15c** pages 13, 14. d) Deep lymphatic drainage pathways of the abdomen: **Q 15d** pages 15, 16.
16	Watersheds are notional lines drawn on the basis of the different directions of lymphatic flow through the collectors. They are interterritorial areas poor in lymph vessels. Under healthy conditions, separation of drainage flow is possible; under pathological conditions, reversion of drainage direction is possible. Watersheds can be crossed with manual lymph drainage because it is possible to push the lymph from one drainage area to another (carried away by the initial lymph vessels and precollectors). **Q 16** page 12.
17	Horizontal across the navel and the second and third lumbar vertebrae along the clavicle and the scapular spine, and vertical along the midline of the body (anterior and posterior). **Q 17** page 12.

18	Precondition is a concentration gradient. Mixing of substances in gas or liquids due to movement on the molecular level. The higher the temperature, the faster the diffusion. The smaller the molecules, the faster they move. The shorter the distance, the faster the diffusion. Diffusion time increases as the square of the distance (double the distance = four times the duration). **Q 18** page 23.
19	Particles move through a semipermeable membrane that does not allow macromolecular substances to pass. Herpertz talks about "one-way diffusion of fluids through a semipermeable membrane." Osmosis is important for the transport of water, salts, carbohydrates, and amino acids through the cell and the capillary wall. **Q 19** page 24.
20	Untreated malignant diseases, acute inflammations, acute thrombosis, acute phlebitis, and significant cardiac insufficiency. **Q 20** page 39.
21	Hypotonia, thyroid malfunctions, pregnancy, bronchial asthma, chronic inflammation, sequelae of cancer treatment, cardiac insufficiency, area around a nevus, and toothache. **Q 21** pages 39, 40.
22	Manual lymph drainage dilates the lymphangions, which is considered a sympathicolytic reaction. By applying appropriate stretch stimuli, manual lymph drainage increases the pulsation of the angion and lymph transport is accelerated. The suction effect reaches the initial lymph vessels, with increase of lymph formation and decongestion of the tissue. Manual lymph drainage has a calming effect because it lowers the activity of the sympathetic nervous system, a pain-reducing effect (Gate control), accelerates immune reaction (lymphocytes reach lymph nodes faster, where sensitization takes place), and decongests—normalizes—connective tissue. **Q 22** page 42, 43.
23	The movements are done slowly, monotonously, rhythmically, working with the skin but not working on it (no sliding). The work always begins proximally. No lubricant is used, if possible. The pressure phase is longer than the so-called zero phase (relaxation). The treatment must not cause pain or redness. **Q 23** page 50.
24	Elasticity of the skin, turgor of the tissue, thickness of the subcutis, and, if muscles or tight tissue (tendons) are located beneath the skin, fibrosis, edema, and angle of slope of the fingers (flat or pointed). **Q 24** page 49.
25	Through pinocytosis/transcytosis from the blood into the tissue and back. Transcellular transport through the cell plasma (albumins) involving adenosine triphosphate (ATP). **Q 37** pages 22, 25.
26	Protein is lymph-obligatory load and is removed through the lymph vessels. Migrating macrophages phagocyte the protein. **Q 25** page 22.
27	Acute, chronic, with a tendency for progression, benign/malignant; primary/secondary; artificial, in stages 0–3. **Q 27** pages 28, 29.
28	Skin care, manual lymph drainage, bandage or compression stocking, therapeutic exercises, and respiratory therapy. **Q 28** pages 110, 111.
29	With medication (diuretics). Stasis edema of the legs may be treated with manual lymph drainage and light compressions. If the stasis edema has not been sufficiently treated with medication first, it is an absolutely contraindicated condition. **Q 29** page 31.
30	Latent stage 0 to III lymphostatic elephantiasis. Lymphedema is staged based on its pathoanatomical aspects. **Q 30** pages 28, 29.
31	Formation of new lymph vessels, transport capacity is utilized in full, edematous fluid can cross watersheds into other territories via prelymphatic channels, migration of macrophages. **Q 31** pages 29, 30.
32	Transport capacity is normal. The vascular system is healthy, functions properly, but is unable to process the existing (increased) lymph-obligatory load (mostly water). High-volume insufficiency is not lymphedema; it is just called "edema" low in protein. The lymph time volume exceeds the transport capacity. **Q 32** pages 25, 26, 27, 28.
33	Transport capacity is reduced. It cannot process the regular lymph-obligatory load. Low-volume insufficiency—high in protein. Primary lymphedema: congenital disorder, secondary lymphedema: mechanical disruption of lymph flow due to surgery, trauma, radiation therapy, etc. **Q 33** pages 27, 28, 29.
34	Therapeutic exercises: Nordic walking, bicycling, walking, and going up and down stairs. Do not exaggerate activities or they will produce the opposite of the desired effect. Prior to any therapeutic exercises, the leg must be bandaged or covered with compression stockings. Possibly skin care before starting the exercise. **Q 34** pages 111, 125.
35	If the capillary pressure = the colloid osmotic pressure (suction) in the capillary = Starling's equilibrium. Hypothesis: Capillary pressure: filtration. • Colloid osmotic pressure (suction) in the capillary—reabsorption (disputed). • Tissue pressure: reabsorption (disputed by latest research). • Colloid osmotic pressure (suction) of tissue: filtration. • Glycocalyx. Carbohydrate-rich layer on the vascular endothelium, which is constantly synthesized and broken down, serves as safety shield between blood plasma and endothelial cell. **Q 35** page 25.
36	Oncosis or colloid osmotic pressure/suction. **Q 36** page 24.
37	Active transport mechanisms require energy (ATP). Passive transport mechanisms can function without energy input. They follow physical and chemical laws (concentration gradient). **Q 38** page 23.
38	Diffusion, osmosis, and filtration. **Q 38** page 23.
39	Transcytosis (pinocytosis) = vesicle transport through the cell employing energy (ATP), for example, macromolecular plasma proteins. **Q 6** pages 9, 21, 22, **Q 36** page 24.

40	Lymph time volume is the amount of lymph that can pass through a vessel during a certain unit of time. **Q 40** page 26.
41	Transport capacity = the maximum amount of lymph that the system can hold during a certain unit of time. Edema develops if the maximum transport capacity is exceeded. **Q 41** page 26.
42	T-lymphocytes (also called killer cells), T-helper cells, and T-suppressor cells. B lymphocytes: produce antigens after sensitization and turn into plasma cells. **Q 42** page 10.
43	Lympho-lymphatic connections of collectors across watersheds into another territory, also via initial lymph vessels and precollectors. **Q 43** page 17.
44	Lymphocele: collection of lymph in a space that has no endothelial lining. Lymphocyst: extension of a lymph vessel of the skin with endothelial lining. Lymph fistula: a cyst can turn into a fistula, that is, the vessel opens onto the body surface. **Q 44** page 29.
45	Transport capacity minus lymph time volume equals the available functional reserve. **Q 45** pages 28.
46	Once the body's own reactions are depleted, dynamic or lymphostatic (mechanical) edema develops, depending on the cause. **Q 46** page 25.
47	Backup of lymph-obligatory load occurs in the area that was drained by the lymph node that was surgically removed. The body activates its possibilities to avoid lymphedema through bypass circuit (anastomoses), formation of new vessels, and macrophages. **Q 47** page 27.
48	Venous valves are folds in the endothelia of a vein. They can be found most frequently in the legs because generally blood must be transported against gravity in this area. They prevent the back flow. **Q 48** page 6.
49	Stem cells can differentiate into various cell or tissue types, depending on the type of stem cell and its manipulation. **Q 49** page 2.
50	Monocytes, lymphocytes, and granulocytes. **Q 50** pages 3, 4.
51	Dynamic edema: increased lymph-obligatory load, mainly water, or lymph time volume exceeds the transport capacity. Lymphostatic lymphedema: reduced transport capacity cannot process the normal lymph-obligatory load. **Q 51** pages 25, 26.
52	Arteries: their walls consist of three layers—tunica interna (intima) elastic membrane; tunica media (media)—is made of elastic fibers and smooth muscle cells; tunica externa (adventitia)—connective-tissue layer with elastic fibers. Veins: their walls consist of three layers, lower internal pressure than in an artery of equal size. In many veins, the internal layer (tunica intima) forms the valves. Middle layer (tunica media) is made of smooth muscle cells. Tunica adventitia is a connective-tissue layer (with nerves) that fixates the vein in its surrounding. **Q 48 Q 52** pages 5, 6.
53	Malignant lymphedema: develops if lymphatic pathways/nodes are congested or constricted by a tumor or metastases. Artificial lymphedema: caused by the patient himself or herself through self-mutilation. **Q 53** page 28.
54	Disproportional impaired fatty tissue distribution that generally affects the legs only (possible to affect arms), always symmetrical. Great sensitivity to pressure, fragility of blood capillaries, tendency to form hematoma, marked tendency to edema formation in orthostatism, feet and hands are usually free of edema. Cannot be improved by diet. **Q 54** page 31.
55	At the toes **Q 55** page 28.
56	Enlarged and indurated skin fold (second toe dorsal aspect) indicates positive Stammer's sign, which is an indication for lymphedema. Negative Stemmer's sign does not exclude lymphedema. Compare to the other side. **Q 56** page 29.

Part II

Manual Lymph Drainage

II

5 Equilibrium and Balance as the Aim of Massage

5.1 Fluid Equilibrium

All treatments that stimulate blood flow also increase filtration into the tissue. In order to assure fluid balance in the soft tissue, lymph time volume increases. Manual lymph drainage can recreate fluid balance. The intensity of drainage depends on whether there are any drainage problems in the tissue involved. This is easily determined by careful palpation. Soft, loose tissue has a greater tendency to edema formation. Firm, taut tissue deals better with increased blood flow and requires less manual lymph drainage. Manual lymph drainage should be integrated into physical therapy in accordance with these principles. Blood flow is stimulated first, followed by manual lymph drainage to maintain fluid equilibrium. **Q 11**

5.2 Balance in Alternative Healing Methods

All natural healing systems aim to produce a state of balance in the organism. For example, in acupuncture, which comes from Chinese medicine, therapists insert needles into specific points located along energy paths (meridians) with the intention of introducing or releasing energy; that is, they aim to create a situation of balance in the energy paths.

Yoga has its origin in Indian culture. It exercises body and spirit and its movements contain elements of tension and relaxation. Its aim is creating a balance between the body and mind, thus a balanced human being.

Yin and yang, the acid–alkaline balance, and many other examples in nature display this natural interrelation.

When we employ blood flow–stimulating treatments, the balancing procedure is manual lymph drainage to restore fluid equilibrium in the tissue.

6 Indications and Contraindications for Manual Lymph Drainage

6.1 Indications

Manual lymph drainage (MLD) or combined decongestive therapy (CDT) can be employed in the following disorders:

- Lymphedema.
- Phlebedema
- Lipedema.
- Traumatic edema.
- Postsurgical edema.
- Arthropathy.
- Reflex sympathetic dystrophy—Sudeck's atrophy (post-traumatic osteoporosis).
- Rheumatic diseases.

(*These and additional diseases will be discussed in detail in the therapy courses.*)

On the basis of many years of experience, we also employ MLD in many other disorders. We have been prompted to this by our patients' own testimonies and the often visible results, especially since the results are repeatable. Although there are as yet no clinical trials on the success and effects of MLD in these disorders, we would like to pass these experiences on to our students. Perhaps some therapists will feel inspired to initiate such trials and explore these findings in greater depth. The disorders under this heading are the following:

- Cosmetic disorders: acne, rosacea, scars, and striae gravidarum (stretch marks).
- Orthopedic/surgical/trauma-related disorders: whiplash, burns, keloids, arthropathies, and surgery on large joints.
- Gynecological disorders: mastodynia and lactation disorders.
- Neurological disorders: stroke, multiple sclerosis, and Down's syndrome.
- Autonomic imbalance and as health spa treatment: for burnout syndrome/stress, after serious operations or severe illness in older people, for those on a fasting diet, and in children with recurrent infections ("lymphatic children").

6.2 Absolute Contraindications

MLD may not be used in patients with certain disorders.

At the top of this list are **malignant diseases** that have not been treated surgically or with radiation or chemotherapy. According to current teaching opinion, MLD does not evoke metastases or promote the spreading of tumor cells, but no risks should be taken. In some circumstances, however, MLD is used palliatively.

Another absolute contraindication is **acute inflammation**, whether local or systemic, that is, inflammation caused by antigens such as bacteria, viruses, fungi, chemicals, etc. Next on the list are **allergies** caused by pollen, detergents, foods, etc.

In the case of inflammation or allergy, MLD can aggravate the condition because it accelerates the lymph flow. The pathogenic substances form part of the lymph-obligatory load, and lymph drainage would speed up their spread throughout the body via the lymphatic pathways. The pathogens would pass by the lymph nodes without defense cells or antibodies being activated.

Another important contraindication is acute **deep vein thrombosis** of the legs. Patients often have to remain in bed in order to avoid the risk that a thrombus will become detached from the vessel wall and travel as an embolus to, for example, the lungs. This is why MLD cannot be employed in a patient with acute thrombosis.

Cardiac insufficiency is another absolute contraindication for MLD. This contraindication relates to the edematous area, which as a rule means the feet, ankles, and calves. Deep abdominal drainage must also be avoided. **Q 20**

Note

Absolute contraindications for manual lymph drainage:

- *Untreated malignant disease, including tumor recurrence or metastases.*
- *Acute inflammation.*
- *Acute allergy.*
- *Acute thrombosis.*
- *Acute phlebitis.*
- *Relevant cardiac insufficiency.* **Q 20**

6.2.1 Relative Contraindications

The conditions in which MLD may be carried out with caution and with certain preconditions are called relative contraindications.

MLD lowers blood pressure, and this may aggravate existing **low blood pressure** or vegetative dystonia. At the start of a treatment series, a full-body treatment should not be given immediately, but should be built up slowly, starting with short treatment times and small treatment areas. The patient should not feel nauseous. Treatment times are then slowly increased.

Thyroid disorder can also be a relative contraindication for MLD. Whatever happens, the patient must experience

the treatment of the neck area as pleasant. This may mean omitting the profundus–terminus treatment and performing only the occiput–profundus treatment. The duration of the treatment should be slightly shorter.

Deep abdominal drainage should be avoided during menstruation.

MLD also should not be employed during the first months of **pregnancy** or when there are complications during pregnancy. In uncomplicated pregnancies, MLD can be employed until the very end and is particularly useful and helpful on legs and breasts. On the abdomen, only the skin technique should be applied.

In **bronchial asthma,** the bronchoconstriction attacks are triggered by the parasympathetic nervous system. Due to its sympathicolytic effect, MLD can prompt an attack. Treatment with MLD should therefore be started slowly and during an attack-free interval. Treatment should never continue for more than 45 minutes. Strokes on the sternum are omitted. Patients must always have their inhaler with them.

In patients with a **chronic infection**, MLD treatment also begins with short sessions in order to not trigger an acute reaction. Drainage begins distal to the focus of inflammation. If necessary, one should discuss the best approach with the treating physician.

Lymphedema is a frequent sequela of **cancer treatment** (surgery/radiation). This edema can and must be treated, but only by therapists who have successfully completed the 4-week MLD/CDT training.

In case of cardiac insufficiency, it is possible to relieve the patient through MLD. But the treatment should be short, cover only small areas, and include a light bandage. The patient must have an entirely pleasant experience. At the beginning of the follow-up treatment, the therapist questions the patient about past treatment and its results.

To avoid unnecessary skin irritation, the area around a **nevus** should not be treated.

Toothache has a special position in relation to indications: it may become better or worse with MLD. MLD can relieve an existing toothache caused by a cold or other disorder. The toothache can get worse if a focus of infection is located somewhere in the jaw. Where a tooth is dead, a granuloma can develop, which becomes activated and painful with MLD. If a septic tooth is extracted but the part of jawbone involved was not cleaned out at the same time, persistent osteitis can develop, which can also become painful due to MLD treatment. Q 21

7 Effect of Manual Lymph Drainage on the Smooth Muscles of Blood Vessels and Lymphangions

Blood vessels and lymph vessels are innervated by the sympathetic nervous system. With its sympathicolytic effect, manual lymph drainage relaxes these vessels, i.e., vascular spasm is released.

Lymph vessels are anatomically different from blood vessels. Manual lymph drainage dilates lymph vessels through the effect described earlier. At the same time, however, the pulsation rate is increased. The main influence on pulsation is from stretch stimuli, which may originate inside the vessel, through volume (filling), and/or from the outside. Mislin (1984) showed experimentally that stretching lymphangions length- and cross-wise increases their pulsation rate. The skin displacements performed in the special lymph drainage technique developed by Dr. Vodder produce this longitudinal and transverse stretching of the lymph vessels and thus increase the pulsation.

Increased **lymphangiomotoricity** (pulsation of the angions) will always lead to accelerated lymph flow. The function of the lymph vessel is to maintain lymph flow. Lymph transport, according to Hutzschenreuter (1991), is the **transport of lymph** in the lymph collectors through the main lymphatic trunks (e.g., thoracic duct, right intercostal trunk, and left intercostal trunk). Peripherally, lymph transport takes place actively through lymphangion contractions. In the area of the main lymphatic trunks, the transport primarily takes place through pressure changes in the abdomen and thorax (see Chapter 13.4.2).

It must be remembered that the fluid contained in the various vessel system of the body is constantly moving. This movement takes place in the form of circulation within these systems, and outside them—when the fluids pass the boundaries of the vessels—diffusion, osmosis, filtration, and active transport.

Since every fluid-containing space is a continuous system, the fluids can move freely within it. Factors that impede this free circulation are frictional resistance against the bordering cells and internal friction related to the specific properties of the fluids, that is, chiefly their viscosity.

The main features that cause the circulation to occur are as follows:

- Contraction gradients and osmotic gradients.
- Differences in the density of the medium, which depends on the temperature gradients of the individual spaces.
- Mechanical and motor forces, of which the latter are by far the most effective.

If body compartments are so structured and arranged that the mechanical forces can and do evoke regular movement of fluid, circulation systems are present. Usually, the fluid flows through sharply delineated channels, pipes, hoses, or vessels.

If vessels can actively contract, as for example lymph vessels can, they play an important role in fluid transport—in lymph drainage.

Three types of lymph drainage can be distinguished:

- **Extravascular lymph drainage** relates to lymph formation and the extravascular circulation. Lymph is formed from water that enters the interstitium by filtration and diffusion, from various types of protein that enter the interstitium in the same way or by active transport, from macromolecular lipids from the digestive tract, and from nonmigratory cells.
- **Extramural lymph drainage**, i.e., external mechanical effects on the lymph vessel, is based on the stimulation of angiomotoricity through external forces. These include the following:
  - Movements of skeletal muscles and joints.
  - Pulsation of the arteries (which subfascially are always accompanied by veins and lymph vessels).
  - Intestinal peristalsis.
  - Movement of the diaphragm.
  - Correct abdominal breathing that, together with different pressure conditions in the thorax, causes accelerated flow and transport of lymph to the venous angle.
- **Auxiliary lymph drainage**: Manual lymph drainage as an auxiliary mode of lymph drainage supports the physiologic lymph drainage.

Mislin (1973, 1984) said in one of his lectures about the effectiveness of manual lymph drainage: "If manual lymph drainage did not yet exist, it would have to be invented just the way it is practiced now." He described how manual lymph drainage with its own particular techniques stimulates lymphangiomotoricity:

"Physiologic vasomotor lymph drainage is based on the autonomic pulsation of the lymphangion or, rather, chain of lymphangions. Manual lymph drainage has considerable impact on this drainage system. Its process is composed of rhythmically repeating dilatations and contractions of a series of lymphangions working metachronally. This produces a peristaltic contraction wave. This means that the lymphangions are synchronized in their dilatation–contraction frequency and are peristaltically metachronized in the resulting pulsation. Myogenic automation and neural control of vascular activity via synergistically functioning receptors in the vessel walls ensure coordinated lymph transport.

The main physiological stimuli are pressure and temperature stimuli. Intravascular transverse and longitudinal stretch stimuli increase the 'pulse rate' of the lymphangions. Smooth muscle cells, such as are present for example in the vascular wall, exhibit electrical and mechanical reactions when they undergo passive stretching. Muscles of the vascular wall that possess autonomic (i.e., pacemaker) characteristics need to be stretched to a variable degree that depends on how full the vessels are, in order for the regulation of their rhythmical pace making always to be appropriate to the situation. For all these reasons, the technique of manual lymph drainage, which introduces (though in a certain sense inappropriate) tensile stimuli within the physiological range, has the effect of stimulating vasomotor lymph drainage."

This is achieved through the special lymph drainage technique developed by Dr. Vodder. The pumping capacity of the lymph vessels is provided by the sum of the lymphangions. Increasing the intralymphatic pressure leads to an increase in the lymphatic pulse rate. As lymph-obligatory load increases, **lymph time volume** (LTV) increases as well. This means that increased lymph production, for example, through manual lymph drainage, automatically results in accelerated lymph drainage. The lymphangion contraction rate is also temperature dependent, rising when the temperature rises.

7.1 Different Effects of Manual Lymph Drainage

7.1.1 Relaxing, Calming, and Stimulating the Lymph Flow

The sympathetic and parasympathetic nervous systems are part of the autonomic nervous system. The sympathetic nervous system could be called "day nerve" and allows us to be active (if overstimulated, we may be "stressed"). The parasympathetic nervous system is the "night nerve," the antagonist. It allows us to sleep, to relax, and our body can rejuvenate.

The innervation of the lymphatic vascular system is sympathetic. Manual lymph drainage reduces the activities of the sympathetic nervous system, which results in a relaxing and calming effect. The patient becomes drowsy or may even fall asleep during manual lymph drainage treatment.

Hutzschenreuter (1991) showed that manual lymph drainage reduces sympatheticotonia. The pressure that is applied during manual lymph drainage changes the receptor potential of the mechanoreceptors in the skin. Through the vegetative regulatory circuit, the central nervous system receives the information to reduce sympatheticotonia of the lymph vessels. As a result, the lymph collectors expand. This leads to increased pressure in the lymph collectors, which causes—as previously described—elevated contraction rate of the lymphangions. It can be considered a **sympathicolytic** reaction if lymph collectors expand during manual lymph drainage. In order to achieve this alteration, it is important that the manual lymph drainage techniques are performed with steady pressure increase and decrease, with the exact pressure (excessive pressure causes histamine release in the tissue resulting in hyperemia and/or pain sensation), and a steady rhythm. Treatment of neck, face, and abdomen achieves the best sympathicolytic effect. It could be said that sympathicolysis is equal to indirect stimulation of the parasympathetic nervous system. The flow rate in blood and lymph vessels also increases. But this is a centrally controlled sympathicolytic response. Comparative measurements of the flow rate in blood vessels confirmed the sympathicolytic reaction initiated by the central nervous system as a result of manual lymph drainage treatment (Hutzschenreuter et al. 1991).

7.1.2 Pain Relieving

The perception of pain is termed nociception. The receptors responsible for this process are called nociceptors. They are free nerve endings of sensor neurons of the spinal cord and can be found in all tissues susceptible to pain. Depending on their location, nociceptors trigger different types of pain. There is surface pain, which is perceived by nociceptors located superficially in the skin. The pain can be undoubtedly allocated to the affected tissue. Depending on the location of the nociceptors, deep tissue pain is categorized as muscle pain and bone pain.

Manual lymph drainage has not only a relaxing and calming effect but also a pain-relieving effect. The following deliberations are intended to explain the analgesic effect of manual lymph drainage. As long as pain acts on our skin/body, nociceptors of the skin and body send action potentials via excitatory synapses of the spinal cord through the brain stem to the cerebrum. In the cerebrum, pain is finally perceived as such. We become aware of it and can do something to remove the pain-producing stimulus or treat an injury. As long as the pain continues, nociceptors send action potentials according to the intensity of the pain. Nociceptors are proportional sensors, that is, the greater the stimulus intensity, the more action potentials, and the greater the pain.

We have a number of different receptors in the skin, for example, for heat, cold, and also touch, the so-called mechanoreceptors. When touched, they send action potentials via the spinal cord through the brain stem to the cerebrum, where we become aware of the touch. The nerve fiber of the mechanoreceptor has a collateral in

the spinal cord, which leads to an inhibiting synapsis. In the spinal cord, this inhibiting synapsis has a connection to the pain control center. Action potentials sent by the inhibiting synapsis can eliminate action potentials that are sent by the nociceptors (gate control theory) and this produces a pain-relieving effect. Mechanoreceptors are differential sensors, that is, excitation is equal to action potential only if there are stimulation (touch) changes. The pressure of properly applied manual lymph drainage (stretching and releasing) constantly stimulates the mechanoreceptors. The extent of the pain-relieving effect depends on the precision of the manual lymph drainage treatment (**Fig. 7.1**). Q 22

However, there is a limit to the inhibiting effect of pain control. In cases of great pain, the inhibiting effect of manual lymph drainage is not strong enough. We merely speak of alleviation. Nevertheless, this concept takes effect in painful hematomas or distortions. This pain-relieving effect of manual lymph drainage facilitates relatively quick improvement in acute injuries and postsurgical or posttraumatic conditions.

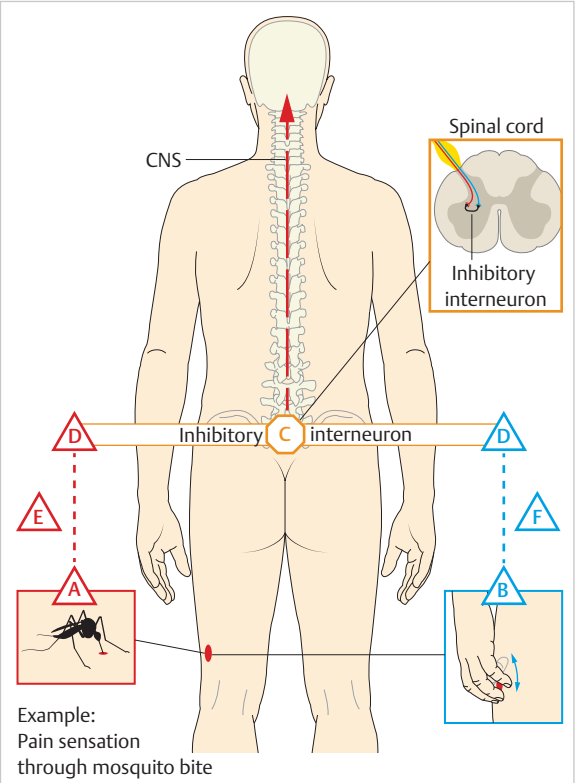


Fig. 7.1 The gate control theory. CNS, central nervous system.

The decongesting and pain-relieving effects of manual lymph drainage also allow optimal treatment of large extremity edema with tension pains. With the decrease of edema volume, the painful tension is also reduced, which results in improved mobility of the joints. In the joint, lymph is transported through the synovial membrane to the evacuant vessels of the fibrous cartilage of the joint.

The best analgesic results are achieved when we work in the direction of drainage and outside of the painful area, rhythmically, monotonously, and with pressure adapted to the pain. We continue to do so until the affected area can be touched without causing pain. This means we start distally to the pain and work our way proximally closer to the painful area.

Another analgesic effect is due to the decongestion of the connective tissue. The pain mediators located in the tissue (such as bradykinin, prostaglandin, cytokine, etc.) are lymph-obligatory loads that are removed through the lymphatic pathways.

7.1.3 Affecting the Immune System

We speak of an effect on the immune system that has not been proven yet. We know from experience that there is an increase in the body's own defense that can be attributed to an accelerated lymph flow. Pathogens (bacteria, viruses, or other foreign substances) are lymph-obligatory loads and are removed from the tissue only through the lymphatic system. Proper lymph circulation moves antigens quickly to the lymph nodes where they form antibodies that reach their targets swiftly via the blood and lymphatic pathways.

7.1.4 Decongesting: Reducing Edema

Properly performed manual lymph drainage produces an increase in lymphangiomotoricity (pulsation of the lymphangions), which leads to an acceleration of lymph flow (see lymphangiomotoricity, p. 9). The fact that manual lymph drainage treatment always starts proximal to congestions (or edema) is particularly relevant due to its known suction effect on distal lymph vessels (all the way to initial lymph vessels).

Consequently, proper manual lymph drainage treatment can produce effects such as the following:

- Decongesting—through stimulation of lymphangiomotoricity.
- Calming—through relaxation of the sympathetic nervous system.
- Pain reducing—through stimulation of the mechanoreceptors (gate control theory); removal of pain mediators.
- Immunologic—through acceleration of lymph flowing toward the lymph nodes. Q 22