THE LYMPHATIC SYSTEM

PART 1 – OVERVIEW

This first article in a four-part series gives an overview of the lymphatic system. The system consists of two major areas (Fig 1):

- Lymph and the lymphatic vessels: lymph is a milky fluid formed from the excess fluid surrounding body tissues (interstitial fluid) (Watson, 2005). It drains into the lymphatic vessels, which permeate virtually every major organ and tissue.
- Lymphoid glands and organs: these include the spleen, thymus and clusters of lymph nodes. They have many roles, most notably: the removal of damaged red blood cells (the spleen); the maturation of immune cells (thymus); and the trapping of foreign material (lymph nodes and spleen).

The system has three major functions: tissue drainage, fat transportation and immune function.

TISSUE DRAINAGE AND THE FORMATION OF LYMPH

Capillary exchange

All tissues and organs receive oxygen-rich blood from arteries. As arteries approach organs, they branch into thinner vessels, arterioles, then into even thinner-walled capillaries (Fig 2). The main functions of blood capillaries in the organs are to deliver oxygen \( (O_2) \) and nutrients and to collect waste such as carbon dioxide \( (CO_2) \).

Cells are bathed in interstitial fluid, which acts as an intermediary between the blood and the cells. Oxygen and glucose diffuse out from capillaries at the arteriole end of the capillary bed, and are picked up by cells, which emit their waste into the fluid, where it diffuses into the venous capillaries to be transported from the organ. Thus an orderly interexchange of materials \( (O_2, glucose, CO_2) \) occurs across the walls of the capillary bed.

Formation of lymph

The presence of solutes including protein molecules in the blood creates an osmotic pressure, which constantly draws interstitial fluid across the capillary wall. At the arterial end of the capillary bed, however, blood arrives with its own pressure (since it has been pumped out of the heart). This pressure is so great that it overrides osmotic pressure and forces water, \( O_2 \), glucose and ions into the interstitial fluid. At the venous end of the capillary bed, there is no such pressure, and the only pull is exerted by osmotic pressure within capillaries, thus there is a net movement of water, \( CO_2 \), and waste into venous capillaries. Approximately 85% of the water lost at the arterial end of the capillary bed is returned to the venous capillaries (Ganong, 2001). The remaining 15% is added to interstitial fluid.

Left to accumulate, this fluid would damage the cells. Underneath the blood capillary network, therefore, is the lymphatic capillary network (Fig 2), into which the fluid drains. It is now known as lymph. These porous lymphatic capillaries collect the fluid from all tissues and organs and carry it to the larger lymphatic vessels. Interstitial fluid is drawn into the vessels through mini-valves by simple capillary action. Not only is the efficient drainage of interstitial fluid from the capillary beds essential to prevent oedema (swelling), but it also allows pathogenic material, from infections and injuries, to pass into the lymphatic system where it can be effectively trapped.

Circulation of lymph

Unlike the cardiovascular system, which has a dedicated pump (the heart) to circulate the blood, the lymphatic system relies on the...
`skeletal muscle pump' to circulate lymph. During normal activity, the contraction of skeletal muscles compresses the lymphatic vessels, propelling the lymph along. Like the venous system, the lymphatic system is under low pressure and semi-lunar valves in its medium-to-large vessels ensure a gradual unidirectional flow of lymph and that lymph does not pool in the lower extremities.

Lymph finally enters the lymphatic trunks (large-diameter lymphatic vessels) and is discharged into the left subclavian vein at the top of the neck via the lymphatic/thoracic ducts.

**FAT TRANSPORT AND LACTEALS**

Most of the nutrients resulting from digestion are absorbed directly into the blood through the mucosal lining of the small intestine, which has multiple tiny folds (villi) that increase its surface area and hence its ability to absorb.

Under each villus is a complex blood capillary network (Fig 3) into which nutrients such as amino acids, simple sugars and small fatty acids pass. These are taken to the liver via the hepatic portal vein. Larger chain fatty acids cannot enter the blood directly, so they enter the cells lining the villi, and are coated with a mixture of cholesterol and protein to form small spherical aggregates (chylomicrons) (Tortora and Grabowski, 2003). These are shunted into a large vessel known as a lacteal, which is encircled by a blood capillary network (Fig 3). Lacteals are blind-ended lymphatic vessels into which these larger products of fat digestion pass by a process of diffusion.

The lymphatic system is the major route for the transportation of the products of fat digestion. It has been suggested that this may prevent long-term exposure of blood vessels to ‘sticky’ saturated fatty acids that would quickly accumulate in the form of plaque.

**IMMUNE FUNCTION**

Since lymphatic capillaries are present in virtually all organs and tissues and are continually draining interstitial fluid, infections anywhere in the body eventually end up circulating within the lymph.

**Trapping foreign material**

Strategically located throughout the body are the lymph nodes, which are highly effective at trapping pathogenic material. Lymph nodes vary in size and shape. They are typically bean-shaped structures found clustered at specific locations throughout the body (Fig 1).

The central portions of a lymph node are essential to its function, and contain large numbers of fixed macrophages which trap foreign material such as bacteria on contact (Marieb, 2006). Lymph nodes also contain B- and T-lymphocytes, which are involved in antibody production and cell-mediated toxicity. Lymph nodes are crucial to most antibody-mediated immune responses as they trap pathogenic material so that antibodies can be generated by lymphocytes. This process will be discussed in part 3 of this series, which examines the lymphatic system and immunity.

The second article in this series, to be published next week, will discuss the role of the major lymphatic organs, the spleen and the thymus.