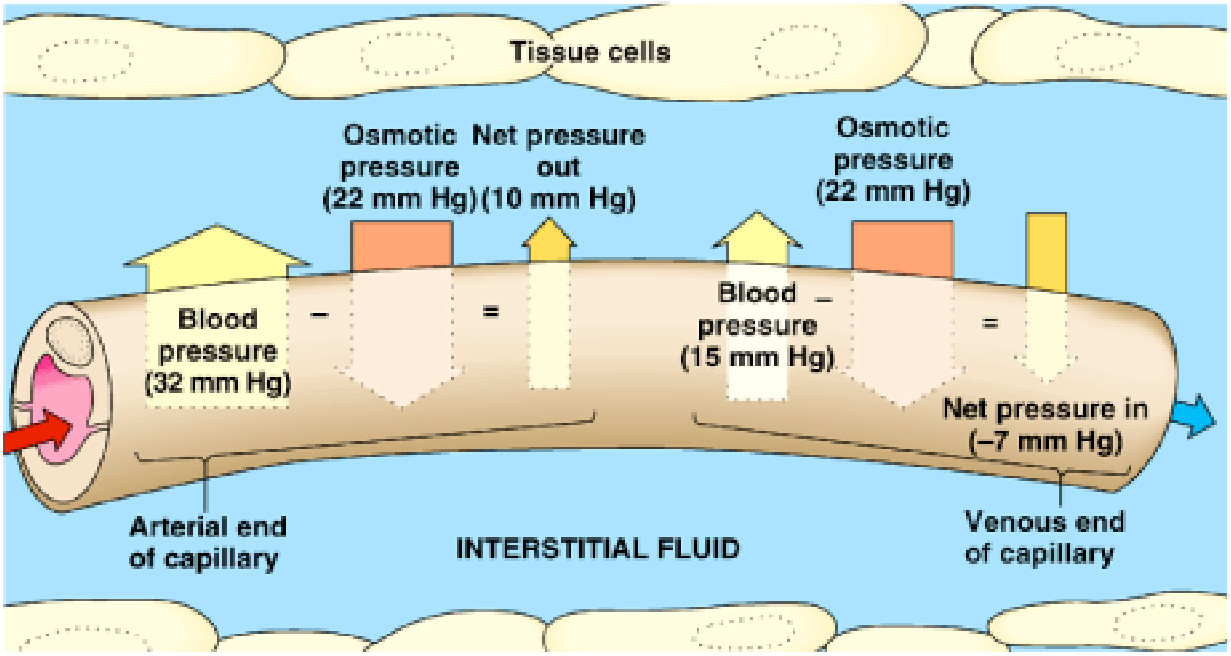
Fluid Exchange in the Capillaries

Figure 42.13 from your textbook (shown below), shows the movement of fluid between blood capillaries and the interstitial fluid.



The movement of fluid between capillaries and the interstitial fluid. Fluids flow out of a capillary at the upstream end near an arteriole and reenters a capillary downstream near a venule. The direction of fluid movement across the capillary wall at any point depends on the difference between two opposing forces: blood pressure and osmotic pressure.

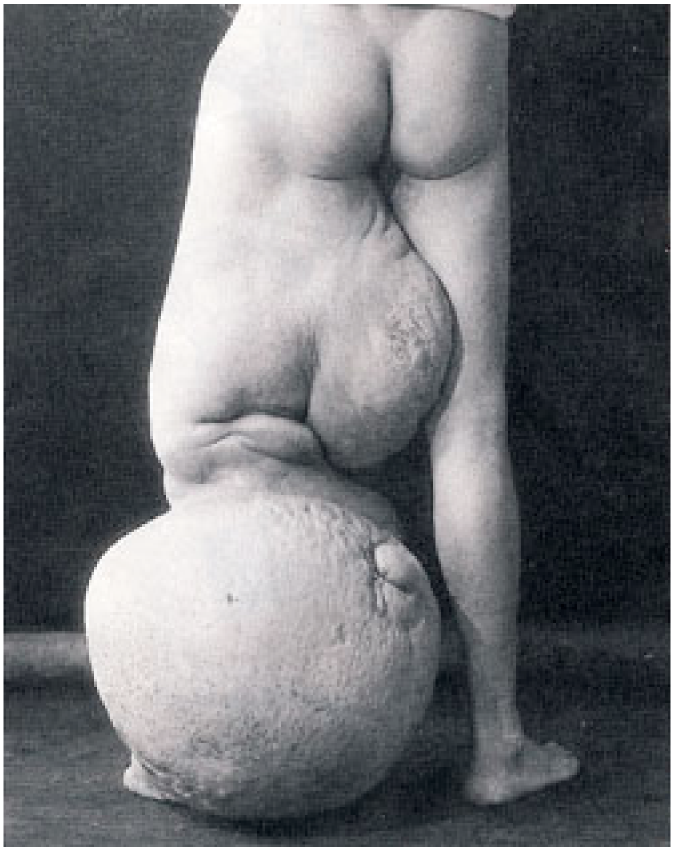
Let us examine the exchange process in more detail. The pressure exerted by fluids, such as blood and tissue fluid, against the walls of the capillaries is called hydrostatic pressure. The source of the hydrostatic blood pressure is the pumping action of the heart. At the arteriole end of a representative capillary bed, the blood pressure is, on the average, about 26 mm Hg higher than the pressure of the tissue fluid outside the capillaries. Due to the frictional resistance of the capillaries and the increased cross-sectional area, the blood pressure falls to about 21 mm Hg by the time the blood reaches the venule end of the capillary bed. The blood pressure tends to force materials *out* of the capillaries and into the surrounding tissue fluid. If this were the only force involved, there would be a steady loss from the blood by filtration of both water and those dissolved substances that could readily be carried by the water through the clefts in the capillary walls. However, there is relatively little net loss of water from the blood in the capillaries.

This other force derives from the difference between the osmotic pressure of the blood and tissue fluid. The blood of mammals contains a relatively high concentration of proteins (7 to 9 g/100 mL), and these large molecules cannot easily pass through the capillary walls. The same kinds of proteins also occur in the tissue fluids, but in much lower concentration (about 2 g/100 mL). Because of the different protein concentrations on the two sides of the capillary wall, the blood and tissue fluids have different osmotic pressures. Normally, the osmotic pressure of the blood is about 25 mm Hg higher than that of the tissue fluid. Thus, the blood is hypertonic to the tissue fluid, with the result that water tends to move *into* the capillaries from the tissue fluid by osmosis.

We have, then, a system in which hydrostatic blood pressure, exerted by the heart, tends to force water *out* of the capillaries and osmotic pressure, reflecting a difference in protein concentrations, tends to draw water *into* the capillaries. The net movement of fluid is determined by the relative magnitudes of these two opposing forces. Notice that at the arteriole end of our representative capillary bed the hydrostatic pressure differential is 36 mm Hg and the osmotic pressure differential is 25 mm Hg. Subtracting one from the other, we find that there is a net pressure of 11 mm Hg tending to force water out of the capillaries. At the venule end of the capillary bed, the hydrostatic pressure differential has fallen to 15 mm Hg, while the osmotic pressure differential has not changed greatly There is, therefore, now a net pressure of at least 10 mm Hg tending to draw water into the capillaries. In summary, the balance between hydrostatic blood pressure and osmotic pressure is such that water is forced out of the capillaries at the arteriole end and into the capillaries at the venule end. Since the water carries with it molecules of many dissolved substances, we can say that the blood in the capillaries first unloads materials for the tissues at the arteriole end and then picks up materials for transport at the venule end. In the process, there is normally only a slight imbalance between filtration and reabsorption, with slightly more filtration of fluid into the tissue spaces than is reabsorbed. About nine-tenths of the fluid that has filtered out is reabsorbed; *the other one-tenth flows into lymph vessels.*

The lymphatic system is an accessory route by which fluids can flow from the tissue spaces into the blood. And, most important of all, the lymphatic vessels can carry proteins and large particles away from the tissue spaces, neither of which can be absorbed directly into the blood capillary. *The removal of proteins from the tissue spaces is an absolutely essential function, without which we would die within about 24 hours.*

The balance of hydrostatic and osmotic pressures in the capillaries is very delicate. Since this balance plays such an important role in the exchange of materials between the blood and tissue fluid, disturbing it may have profound effects on the organism. For example, an average 20 mm rise in capillary pressure causes an increase net filtration pressure which results in 68 times as much net filtration of fluid into the tissue spaces as normal, and this would require 68 times the normal flow of fluid into the lymphatic system, an amount that is usually to much for the lymphatics to carry away. As a result, fluid begins to accumulate in the tissues, and an abnormal swelling, called **edema**, occurs. Conversely, if capillary pressure is very low, net reabsorption into the blood increases at the expense of the tissue fluid volume. Increasing or decreasing the protein concentration in the blood also profoundly affects capillary exchange.



Elephantiasis. Elephantiasis is a condition of extreme edema that occurs when lymph vessels become blocked by filarial worms. Here the left leg is swollen with the fluids accumulated in the tissues as a result of the blockage.