The Kidney

The kidneys are such a vital organ that 25% of the blood that enters the circulatory system from each heartbeat goes directly to the kidneys through the renal artery. With such a high metabolic rate the proper functioning of this organ is critical to health. The high metabolic rate and importance of this organ makes the kidneys susceptible to many problems.

This is the kidney from a cat. It lies in a depression in the abdomen called the retroperitoneal area. You can see the dark liver on the far left, and the renal vein as it leaves the kidney and merges with the vena cava. The blood from the vena cava flows into the liver and then directly to the heart. This is the blood that has been filtered of impurities and is reentering the circulation. You can not see the renal artery or ureter, they are buried in the white fat at the top of the kidney.

This is a diagram of the internal architecture of a typical kidney found in mammals. Blood enters the renal artery and flows into the nephron where it is filtered (the rectangular box outlines where a typical nephron is located). The blood from the renal artery that has been filtered now flows out of the renal vein where it goes back into the circulatory system. The impurities that the nephron filters out of the blood collect in the pelvis and eventually out into the ureter in the form of urine.
The primary functional unit of the kidney is the nephron (outlined as the black rectangle in the above picture). Each kidney has upwards of one million, so obviously they are microscopic in size. Every nephron is a self contained unit that can form urine by itself. Not all nephrons are used at the same time, which gives the kidneys the capacity to increase their workload if called upon. This reserve capacity is lost when chronic renal failure occurs.

This is how it looks in a real kidney from a cat

The kidneys are located in a specific area of the abdomen called the retroperitoneum. This area is a small indentation at the top of the abdomen just underneath the spinal vertebrae. It affords protection to this vital organ.

Renal Physiology

The kidneys have a profound affect on almost all the physiologic processes of the body. The mechanism by which the kidneys perform these functions is extremely complex, the most important of which will be summarized:

Fluid Regulation
In relation to the kidneys, the brain monitors bloodstream levels of water, waste products, electrolytes, and red blood cells. The circulatory system has receptors like the brain to monitor blood volume also. If the water level is too low, as occurs with dehydration, the brain secretes more of a hormone, called ADH (anti-diuretic hormone), into the bloodstream. As a result, the kidneys excrete less water into the urinary tract, retaining more fluid in the bloodstream to counteract the dehydration. The brain also increases thirst simultaneously. The end result is less urination. The urine that does get excreted is more yellow than usual due to a greater concentration of waste products being excreted in relation to the amount of water being excreted. The only thing we notice is that we urinate less and it is more yellow in color.

As we drink water to quench our thirst and rehydrate, the body notes this change and the brain secretes less of the hormone called ADH. Now when we urinate more water is excreted by the kidneys, and our urination occurs with a dilute urine in greater quantity. So, the ability to concentrate the urine and dilute the urine is an important function of the kidneys. It is a fine tuned mechanism that is closely regulated to maintain optimum amounts of fluid in the bloodstream and organs.

As a fun fact, it is the inhibition of ADH by alcohol's depression effects on the brain that causes excess urination when drinking alcoholic beverages. Eventually this excess urination causes dehydration, leading to that inevitable curse called a hangover.

The kidneys also secrete a hormone called renin. Through a complicated set of biochemical pathways this ultimately leads to an increase in salt (sodium) in the bloodstream. Sodium pulls water towards it, so more sodium means more fluid in the bloodstream. It will have an effect on blood pressure, which you will learn about later.

**Waste Product Regulation**

The brain also monitors waste products that build up in the bloodstream. These waste products are the end product of normal metabolic processes, especially the metabolism of proteins. They are called nitrogenous waste products, and are measured by a blood parameter called blood urea nitrogen (BUN). Another waste product that is closely regulated by the brain and kidneys is called creatinine. It is the end product of the metabolism of muscle.

The kidneys also excrete toxins and foreign substances that are introduced into the body. Almost every medication given, either orally or by injection, is eliminated to some degree by the kidneys.

The rate at which fluid flows into the glomerulus is important. This is called the glomerular filtration rate (GFR), and is measured in ml/minute. Too small a flow and waste products are not eliminated, a problem encountered during dehydration. Too much flow and normal blood constituents like protein are excreted when they shouldn't be.

**Electrolyte Regulation**

Electrolytes are also of importance in relation to the kidneys. Sodium is of extreme importance in the normal functioning of all cells. It allows nerve impulses to occur and is critical in the regulation of water levels in the bloodstream. Through the release of a hormone called angiotensin the kidneys regulate fluids levels of sodium in the bloodstream. This has a major affect on the blood pressure. Potassium is also a critical electrolyte. Potassium levels need to be kept at a very narrow range to prevent serious consequences like heart irregularities.

**Hormone Regulation**
The kidneys also regulate calcium and phosphorous by hormones called calcitrol and parathyroid hormone, and by regulating vitamin D. Vitamin D allows the absorption of calcium from the intestines. If the kidney disease progresses long enough the excess secretion of parathyroid hormone causes the bones to become swollen and fibrous as the body attempts to maintain a normal calcium level. This is called renal osteodystrophy, as the bones become more fibrous the marrow is not able to produce red blood cells as effectively. This leads to weak and thin bones, as evidenced by a swollen face and jaw as the bones of the lower jaw weaken. It can occur in other bones also.

**Acid-base Regulation**

The pH of the bloodstream, which is a measure of acidity, is another important area of kidney physiology. The kidney regulates this acidity by excreting excessive hydrogen ions and the selective secretion and reabsorption of bicarbonate.

**Red Blood Cell Production**

The kidneys secrete a hormone called erythropoetin into the bloodstream. This hormone circulates to the bone marrow and stimulates it to produce red blood cells. A lack of adequate levels of this hormone will cause anemia. Toxic waste products that build up in the bloodstream decrease the life span of a typical red blood cell, further exacerbating the anemia. And, as you already learned above in hormone regulation, the fibrous bones have less bone marrow. There can even be clotting problems due to a low number of platelets.