## Our Amazing Kidneys

### Function and structure

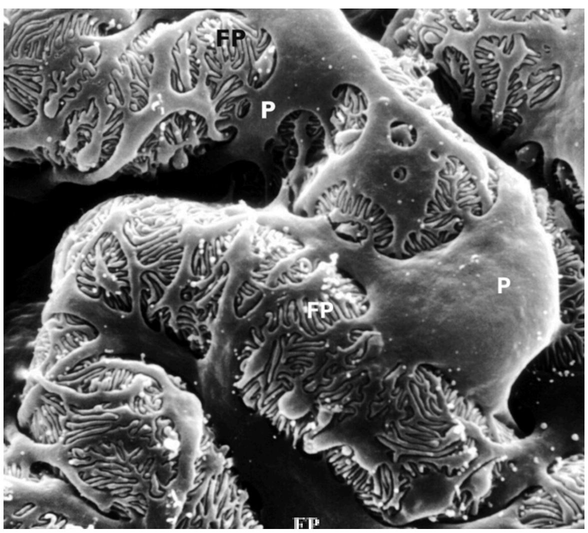
Our bodies, and every one of our cells, are made mostly of water—more than 75% by weight. Body tissues and organs are structured so that each cell occupies waterfront property. It sits no farther than one cell away from a flowing stream—liquid blood or lymph moving through tiny capillaries. Cells draw oxygen and nutrition from this stream, and they dump their waste into the same stream.

Our hearts keep the body's fluid stream constantly flowing.

Our kidneys keep the fluid stream clean.

Think of kidneys as the "pool cleaners" of the body, keeping the body water clear and clean. Also, they control the quantity of water in the body. They prevent the pool from overflowing or running dry. When we drink a lot, we make quantities of dilute urine. When we drink little, our urine is concentrated and scant.

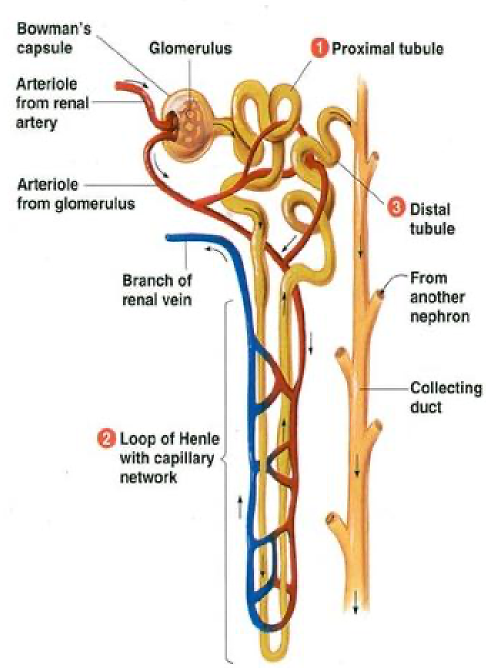
Each kidney is made up of about a million tiny cleaning units, called nephrons. A nephron consists of a filter (called the glomerulus) connected to a treatment system (the renal tubule.)




The filter: A glomerulus is a unique (and intricate) ball of capillaries. This scanning electron microscope image, 400 times normal size, shows a single glomerular capillary from the urinary side of the filter. The smooth lumps are specialized cells called podocytes (P). From these cells, tiny feather-like projections called foot processes (FP) extend to enclose the capillary wall and control what passes through it.

The "holes" of the glomerular filter are too small for circulating blood cells or most proteins to pass. Water and small molecules traverse this living barrier to form a filtrate that is the beginning of urine.

Detailed structure of a nephron




The treatment system: The liquid that filters into the urinary space contains wastes, but it is not yet urine. The job of the tubule is to reabsorb (bring back into the blood stream) most of what has been filtered, as the fluid passes through the tubule. The urine we excrete contains the waste and the water that the tubule did not reclaim.

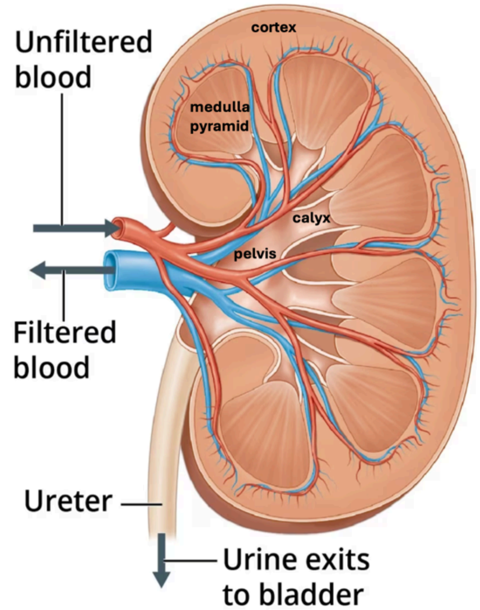
This schematic drawing shows the structure of a single nephron, with its accompanying blood vessels. A tangled looking tubule originates from the glomerulus and is made up of three parts which each do different tasks. For example, the long loop of Henle works to reclaim water and make the urine concentrated. Several distal tubules flow together into a collecting duct.

**Our Amazing Kidneys**

The bigger picture: This drawing imagines what a kidney would look like sliced in half lengthwise. Kidneys have a clear structure with discrete regions. Individual nephrons are too small to see (or draw) in a whole kidney, though there is a sense of their presence.

Most of the glomeruli are found in the outer region, called the cortex. The medulla has a striped appearance because the collecting ducts and long loops run parallel to each other as they enter the renal pyramids.

Urine from many nephrons drains together into collecting ducts. Next the collecting ducts merge in the renal pyramids. Then urine flows from the pyramids into the renal calyxes. From the calyxes, urine drains into the renal pelvis and is conveyed down the ureters into the bladder.




**Understanding tests for measuring kidney function**
At present, there is no lab test that can measure the actual number of functioning nephrons. Instead, doctors use estimates of glomerular filtration rate (GFR). Whether measured or estimated, GFR roughly parallels the percentage of normal kidney function.

To understand the idea behind glomerular filtration rate (GFR), think of the kidneys as pool cleaners again. Pool water quality reflects how well the system is working. When the pool is in operation, its filter system runs continuously. At the same time nearby trees drop their leaves into the pool, and algae grows, around the clock.

In our bodies, the process of metabolism means that our cells generate waste at a constant rate, and they dump that waste into the blood stream at a constant rate. So, the blood level of a metabolic waste indicates its rate of removal by the kidneys.

Two substances are used routinely to estimate how well the kidney is filtering the blood. **Creatinine** is a byproduct of normal wear and tear on muscles. **Cystatin-C** is made by every cell with a nucleus. These compounds are produced and shed into the bloodstream at a constant rate. So, when their levels rise in a blood test, doctors can infer that kidney function has decreased.

Most clinical laboratories offer both a direct measurement and a calculated interpretation of a blood creatinine and/or cystatin-c result. Creatinine is expressed as a concentration in milligrams per deciliter (mg/dL). Cystatin C is expressed in milligrams per Liter (mg/L). An estimated glomerular filtration rate (eGFR) is calculated from a formula based on the results of similar measurements in thousands of patients.

In adults, a normal eGFR is more than 90 milliliters per minute (ml/min). This strange way of expressing and describing kidney function means that every minute, 90 ml of blood are cleared of creatinine or cystatin-c. Similarly, the kidneys of a person with an eGFR of 20ml/min will be able to remove creatinine from only 20 mL of blood in a minute.

In children, it can be difficult to interpret blood tests for creatinine or cystatin-c and to calculate eGFR. Cancer and its treatment make interpretation even more difficult.

In some clinical situations an accurate measurement of kidney function is required to determine the dosages of medications, or to evaluate renal recovery after surgery. Although specialized GFR testing is more accurate, it is much more cumbersome than a simple blood test.

The gold standard—inulin clearance, involves infusion of inulin (a simple sugar) followed by timed collections of urine and blood. Plasma clearance of radiopharmaceutical markers such as $^{125}$I-Iothalamate or $^{99}$mTc-DTPA, involve expensive markers and radiation exposure.

This table from the National Kidney Foundation shows the relationship between the eGFR (or the measured GFR if that was used) and the level of kidney function.
https://www.kidney.org/atoz/content/gfr#kidney-numbers-and-ckd-heat-map

**What are the stages of chronic kidney disease (CKD)?**

| Stage | Description | eGFR | Kidney Function |
|---|---|---|---|
| 1 | Possible kidney damage (e.g., protein in the urine) with ***normal*** kidney function | 90 or above | 90-100% |
| 2 | Kidney damage with ***mild loss*** of kidney function | 60-89 | 60-89% |
| 3a | ***Mild to moderate*** loss of kidney function | 45-59 | 45-59% |
| 3b | ***Moderate to severe*** loss of kidney function | 30-44 | 30-44% |
| 4 | ***Severe loss*** of kidney function | 15-29 | 15-29% |
| 5 | Kidney ***failure*** | Less than 15 | Less than 15% |

People with kidney disease have very few symptoms until they reach stage 5, kidney failure. Their remaining nephrons keep on working, even when waste products in the blood have reached the level of uremia.

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Complications like high blood pressure, changes in the balance of salts, minerals and acid in the blood, and swelling may require treatment when moderate kidney disease (stage 3) is present. Renal replacement therapies (dialysis or transplant) become necessary at stage 5 kidney failure,

**What happens when there is only one kidney?**

This drawing shows the location of two kidneys in a child. An adrenal gland sits on top of each kidney and a ureter drains urine from the kidney to the bladder.

In health, both kidneys function as one. If a kidney is removed, then half of the body's nephrons are removed with it. New nephrons do not form after birth. However, those nephrons that remain work twice as hard.

Most people live a normal life with just one kidney. Giving a healthy kidney to a loved one is generally believed to carry an acceptable medical risk. Kidney donation allows two people to share close-to-normal kidney function. However, over many years, some people with reduced nephron numbers can develop high blood pressure or start to leak protein into the urine.

With fewer nephrons, the remaining kidney takes longer to get its work done. So, the dosages and timing of medications that are removed by the kidney need to be adjusted. Doctors must give special attention to adjusting medicines that have known renal toxicity.

Drawing originally published by the American Society of Clinical Oncology

Nutrition is a key to protecting kidney health and is particularly important numbers (early renal insufficiency). The National Kidney Foundation recommends the DASH (Dietary Approaches to Stop Hypertension) diet to lower blood pressure. DASH is rich in fruits, vegetables, whole grains, fish, beans, seeds, and nuts. DASH is low in salt and sodium, added sugars and sweets, and fatty meats. https://www.kidney.org/atoz/content/Dash_Diet

A pediatric or renal dietician can be a solitary kidney's good friend, helping to balance the need of a growing child for protein and nutrients, with renal protection.

**More articles to come.**

Written by Wilms' grandmother
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