Chapter 1

Balancing fluids

Just the facts

In this chapter, you’ll learn:

- the process of fluid distribution throughout the body
- the meanings of certain fluid-related terms
- the different ways fluid moves through the body
- the roles that hormones and kidneys play in fluid balance.

A look at fluids

Where would we be without body fluids? Fluids are vital to all forms of life. They help maintain body temperature and cell shape, and they help transport nutrients, gases, and wastes. Let’s take a close look at fluids and the way the body balances them.

Making gains equal losses

Just about all major organs work together to maintain the proper balance of fluid. To maintain that balance, the amount of fluid gained throughout the day must equal the amount lost. Some of those losses can be measured; others can’t.
How insensible

Fluid losses from the skin and lungs are referred to as insensible losses because they can’t be measured or seen. Losses from evaporation of fluid through the skin are fairly constant but depend on a person’s total body surface area. For example, the body surface area of an infant is greater than that of an adult relative to their respective weights. Because of this difference in body surface area—a higher metabolic rate, a larger percentage of extracellular body fluid, and immature kidney function—infants typically lose more water than adults do.

Changes in environmental humidity levels also affect the amount of fluid lost through the skin. Likewise, respiratory rate and depth affect the amount of fluid lost through the lungs. Tachypnea, for example, causes more water to be lost; bradypnea, less. Fever increases insensible losses of fluid from both the skin and lungs.

Now that’s sensible

Fluid losses from urination, defecation, wounds, and other means are referred to as sensible losses because they can be measured.

A typical adult loses about 150 to 200 ml/day of fluid through defecation. In cases of severe diarrhea, losses may exceed 5,000 ml/day (Wait & Alouidor, 2011). (For more information about insensible and sensible losses, see Sites involved in fluid loss.)
Sites involved in fluid loss

Each day, the body gains and loses fluid through several different processes. This illustration shows the primary sites of fluid losses and gains as well as their average amounts. Gastric, intestinal, pancreatic, and biliary secretions are almost completely reabsorbed and aren’t usually counted in daily fluid losses and gains.

Following the fluid

The body holds fluid in two basic areas, or compartments—inside the cells and outside the cells. Fluid found inside the cells is called intracellular fluid (ICF); fluid found outside the cells, extracellular fluid (ECF). Capillary walls and cell membranes separate the intracellular and extracellular compartments. (See Fluid compartments.)
Fluid compartments

This illustration shows the primary fluid compartments in the body: intracellular and extracellular. Extracellular is further divided into interstitial and intravascular. Capillary walls and cell membranes separate ICFs from ECFs.

Memory jogger

To help you remember which fluid belongs in which compartment, keep in mind that inter means between (as in interval—between two events) and intra means within or inside (as in intra venous—inside a vein).

To maintain proper fluid balance, the distribution of fluid between the two compartments must remain relatively constant. In an average adult, the total amount of fluid is 42 L, with the total amount of ICF averaging 40% of the person’s body weight, or about 28 L (Seager & Slbaugh, 2011). The total amount of ECF averages 20% of the person’s body weight, or about 14 L.

ECF can be broken down further into interstitial fluid, which surrounds the cells, and intravascular fluid or plasma, which is the liquid portion of blood. In an adult, interstitial fluid accounts for about 75% of the ECF. Plasma accounts for the remaining 25%.

The body contains other fluids, called transcellular fluids, in the cerebrospinal column, pleural cavity, lymph system, joints, and eyes. Transcellular fluids generally aren’t subject to significant gains and losses throughout the day so they aren’t discussed in detail here.

Water here, water there

The distribution of fluid within the body’s compartments varies with age. Compared with adults, infants have a greater percentage of body water stored inside interstitial spaces. About 75% to 80% (40% ECF, 35% ICF) of the body weight of a full-term neonate is water. About 90% (60% ECF and 30% ICF) of the body weight of a premature (23 weeks gestation) infant is water (Ambalavanan & Rosenkrantz, 2012). The amount of water as a percentage of body weight decreases with age until...
puberty. In a typical 154-lb (70 kg) lean adult male, about 60% (93 lb [42 kg]) of body weight is water. (See *The evaporation of time*.)

**Ages and stages**

**The evaporation of time**

The risk of suffering a fluid imbalance increases with age. Why? Skeletal muscle mass declines, and the proportion of fat within the body increases. After age 60 years, water content drops to about 45%.

Likewise, the distribution of fluid within the body changes with age. For instance, about 15% of a typical young adult’s total body weight is made up of interstitial fluid. That percentage progressively decreases with age.

About 5% of the body’s total fluid volume is made up of plasma. Plasma volume remains stable throughout life.

Skeletal muscle cells hold much of that water; fat cells contain little of it. Women, who normally have a higher ratio of fat to skeletal muscle than men, typically have a somewhat lower relative water content. Likewise, an obese person may have a relative water content level as low as 45%.

Accumulated body fat in these individuals increases weight without boosting the body’s water content.

**Fluid types**

Fluids in the body generally aren’t found in pure forms. They’re usually found in three types of solutions: isotonic, hypotonic, and hypertonic.

**Isotonic: Already at match point**

An isotonic solution has the same solute (matter dissolved in solution) concentration as another solution. For instance, if two fluids in adjacent compartments are equally concentrated, they’re already in balance, so the fluid inside each compartment stays put. No imbalance means no net fluid shift. (See *Understanding isotonic fluids.*)
**Understanding isotonic fluids**

No net fluid shifts occur between isotonic solutions because the solutions are equally concentrated.

![Diagram of isotonic solution](image)

For example, normal saline solution is considered isotonic because the concentration of sodium in the solution nearly equals the concentration of sodium in the blood.

**Hypotonic: Get the lowdown**

A hypotonic solution has a lower solute concentration than another solution. For instance, say one solution contains only one part sodium and another solution contains two parts. The first solution is hypotonic compared with the second solution. As a result, fluid from the hypotonic solution would shift into the second solution until the two solutions had equal concentrations of sodium. Remember that the body constantly strives to maintain a state of balance, or equilibrium (also known as homeostasis). (See *Understanding hypotonic fluids*.)

**Understanding hypotonic fluids**

When a less concentrated, or hypotonic, solution is placed next to a more concentrated solution, fluid shifts from the hypotonic solution into the more concentrated compartment to equalize concentrations.

![Diagram of hypotonic solution](image)

Half-normal saline solution is considered hypotonic because the concentration of sodium in the solution is less than the concentration of sodium in the patient’s blood.
Hypertonic: Just the highlights

A hypertonic solution has a higher solute concentration than another solution. For instance, say one solution contains a large amount of sodium and a second solution contains hardly any. The first solution is hypertonic compared with the second solution. As a result, fluid from the second solution would shift into the hypertonic solution until the two solutions had equal concentrations. Again, the body constantly strives to maintain a state of equilibrium (homeostasis). (See Understanding hypertonic fluids.)

Understanding hypertonic fluids

If one solution has more solutes than an adjacent solution, it has less fluid relative to the adjacent solution. Fluid will move out of the less concentrated solution into the more concentrated, or hypertonic, solution until both solutions have the same amount of solutes and fluid.

For example, a solution of dextrose 5% in normal saline solution is considered hypertonic because the concentration of solutes in the solution is greater than the concentration of solutes in the patient’s blood.

Fluid movement

Just as the heart constantly beats, fluids and solutes constantly move within the body. That movement allows the body to maintain homeostasis, the constant state of balance the body seeks. (See Fluid tips.)
Fluid tips

Fluids, nutrients, and waste products constantly shift within the body’s compartments—from the cells to the interstitial spaces, to the blood vessels, and back again. A change in one compartment can affect all of the others.

Keeping track of the shifts

That continuous shifting of fluids can have important implications for patient care. For instance, if a hypotonic fluid, such as half-normal saline solution, is given to a patient, it may cause too much fluid to move from the veins into the cells, and the cells can swell. On the other hand, if a hypertonic solution, such as dextrose 5% in normal saline solution, is given to a patient, it may cause too much fluid to be pulled from cells into the bloodstream, and the cells shrink.

For more information about I.V. solutions, see chapter 19, I.V. fluid replacement.

Within the cells

Solutes within the intracellular, interstitial, and intravascular compartments of the body move through the membranes, separating those compartments in different ways. The membranes are semipermeable, meaning that they allow some solutes to pass through but not others. In this section, you’ll learn the different ways fluids and solutes move through membranes at the cellular level.

Going with the flow

In diffusion, solutes move from an area of higher concentration to an area of lower concentration, which eventually results in an equal distribution of solutes within the two areas. Diffusion is a form of passive transport because no energy is required to make it happen; it just happens. Like fish swimming with the current, the solutes simply go with the flow. (See Understanding diffusion.)
Understanding diffusion

In diffusion, solutes move from areas of higher concentration to areas of lower concentration until the concentration is equal in both areas.

Giving that extra push

In active transport, solutes move from an area of lower concentration to an area of higher concentration. Like swimming against the current, active transport requires energy to make it happen.

The energy required for a solute to move against a concentration gradient comes from a substance called adenosine triphosphate or ATP. Stored in all cells, ATP supplies energy for solute movement in and out of cells. (See Understanding active transport.)
Understanding active transport

During active transport, energy from a molecule called *adenosine triphosphate (ATP)* moves solutes from an area of lower concentration to an area of higher concentration.

Some solutes, such as sodium and potassium, use ATP to move in and out of cells in a form of active transport called the *sodium-potassium pump*. (For more information on this physiologic pump, see chapter 5, *When sodium tips the balance.*) Other solutes that require active transport to cross cell membranes include calcium ions, hydrogen ions, amino acids, and certain sugars.

Letting fluids through

*Osmosis* refers to the passive movement of fluid across a membrane from an area of lower solute concentration and comparatively more fluid into an area of higher solute concentration and comparatively less fluid. Osmosis stops when enough fluid has moved through the membrane to equalize the solute concentration on both sides of the membrane. (See *Understanding osmosis.*)
Understanding osmosis

In osmosis, fluid moves passively from areas with more fluid (and fewer solutes) to areas with less fluid (and more solutes). Remember that in osmosis, fluid moves, whereas in diffusion, solutes move.

Within the vascular system

Within the vascular system, only capillaries have walls thin enough to let solutes pass through. The movement of fluids and solutes through capillary walls plays a critical role in the body’s fluid balance.

The pressure is on

The movement of fluids through capillaries—a process called capillary filtration—results from blood pushing against the walls of the capillary. That pressure, called hydrostatic pressure, forces fluids and solutes through the capillary wall.

When the hydrostatic pressure inside a capillary is greater than the pressure in the surrounding interstitial space, fluids and solutes inside the capillary are forced out into the interstitial space. When the pressure inside the capillary is less than the pressure outside of it, fluids and solutes move back into the capillary. (See Fluid movement through capillaries.)
Fluid movement through capillaries

When hydrostatic pressure builds inside a capillary, it forces fluids and solutes out through the capillary walls into the interstitial fluid, as shown below.

Keeping the fluid in

A process called reabsorption prevents too much fluid from leaving the capillaries no matter how much hydrostatic pressure exists within the capillaries. When fluid filters through a capillary, the protein albumin remains behind in the diminishing volume of water. Albumin is a large molecule that normally can’t pass through capillary membranes. As the concentration of albumin inside a capillary increases, fluid begins to move back into the capillaries through osmosis.

Think of albumin as a water magnet. The osmotic, or pulling, force of albumin in the intravascular
space is called the **plasma colloid osmotic pressure**. The plasma colloid osmotic pressure in capillaries averages about 25 mm Hg. (See **Albumin magnetism**.)

---

### Albumin magnetism

Albumin, a large protein molecule, acts like a magnet to attract water and hold it inside the blood vessel.

As long as capillary blood pressure (the hydrostatic pressure) exceeds plasma colloid osmotic pressure, water and solutes can leave the capillaries and enter the interstitial fluid. When capillary blood pressure falls below plasma colloid osmotic pressure, water and diffusible solutes return to the capillaries.

Normally, blood pressure in a capillary exceeds plasma colloid osmotic pressure in the arteriole end and falls below it in the venule end. As a result, capillary filtration occurs along the first half of the vessel; reabsorption, along the second. As long as capillary blood pressure and plasma albumin levels remain normal, the amount of water that moves into the vessel equals the amount that moves out.

### Coming around again

Occasionally, extra fluid filters out of the capillary. When that happens, the excess fluid shifts into the lymphatic vessels located just outside the capillaries and eventually returns to the heart for recirculation.

### Maintaining the balance

Many mechanisms in the body work together to maintain fluid balance. Because one problem can affect the entire fluid-maintenance system, it’s important to keep all mechanisms in check. Here’s a closer look at what makes this balancing act possible.
The kidneys

The kidneys play a vital role in fluid balance. If the kidneys don’t work properly, the body has a hard time controlling fluid balance. The workhorse of the kidney is the nephron. The body puts the nephrons to work every day.

A nephron consists of a glomerulus and a tubule. The tubule, sometimes convoluted, ends in a collecting duct. The glomerulus is a cluster of capillaries that filters blood. Like a vascular cradle, Bowman’s capsule surrounds the glomerulus.

Capillary blood pressure forces fluid through the capillary walls and into Bowman’s capsule at the proximal end of the tubule. Along the length of the tubule, water and electrolytes are either excreted or retained depending on the body’s needs. If the body needs more fluid, for instance, it retains more. If it needs less fluid, less is reabsorbed and more is excreted. Electrolytes, such as sodium and potassium, are either filtered or reabsorbed throughout the same area. The resulting filtrate, which eventually becomes urine, flows through the tubule into the collecting ducts and eventually into the bladder as urine.

Superabsorbent

Nephrons filter about 125 ml of blood every minute, or about 180 L/day. That rate, called the glomerular filtration rate, usually leads to the production of 1 to 2 L of urine per day. The nephrons reabsorb the remaining 178 L or more of fluid, an amount equivalent to more than 30 oil changes for the family car!
A strict conservationist

If the body loses even 1% to 2% of its fluid, the kidneys take steps to conserve water. Perhaps the most important step involves reabsorbing more water from the filtrate, which produces a more concentrated urine.

The kidneys must continue to excrete at least 20 ml of urine every hour (about 500 ml/day) to eliminate body wastes. A urine excretion rate that’s less than 20 ml/hour usually indicates renal disease and impending renal failure. The minimum excretion rate varies with age. (See The higher the rate, the greater the waste.)

Ages and stages

The higher the rate, the greater the waste

Infants and young children excrete urine at a higher rate than adults because their higher metabolic rates produce more waste. Also, an infant’s kidneys can’t concentrate urine until about age 3 months, and they remain less efficient than an adult’s kidneys until about age 2 years.

The kidneys respond to fluid excesses by excreting urine that is more dilute, which rids the body of fluid and conserves electrolytes.

Antidiuretic hormone

Several hormones affect fluid balance, among them a water retainer called antidiuretic hormone (ADH). (You may also hear this hormone called vasopressin.) The hypothalamus produces ADH, but the posterior pituitary gland stores and releases it. (See How antidiuretic hormone works.)
How antidiuretic hormone works

ADH regulates fluid balance in four steps.

Adaptable absorption

Increased serum osmolality, or decreased blood volume, can stimulate the release of ADH, which in turn increases the kidneys’ reabsorption of water. The increased reabsorption of water results in more concentrated urine.

Likewise, decreased serum osmolality, or increased blood volume, inhibits the release of ADH and causes less water to be reabsorbed, making the urine less concentrated. The amount of ADH released varies throughout the day, depending on the body’s needs.

This up-and-down cycle of ADH release keeps fluid levels in balance all day long. Like a dam in a river, the body holds water when fluid levels drop and releases it when fluid levels rise.

Memory jogger

Remember what ADH stands for—antidiuretic hormone—and you’ll remember its job: restoring blood volume by reducing diuresis and increasing water retention.

Renin-angiotensin-aldosterone system

To help the body maintain a balance of sodium and water as well as a healthy blood volume and blood pressure, special cells (called juxtaglomerular cells) near each glomerulus secrete an enzyme called renin. Through a complex series of steps, renin leads to the production of angiotensin II, a powerful vasoconstrictor.

Angiotensin II causes peripheral vasoconstriction and stimulates the production of aldosterone.
Both actions raise blood pressure. (See *Aldosterone production*, page 14.)

**Aldosterone production**

This illustration shows the steps involved in the production of aldosterone (a hormone that helps to regulate fluid balance) through the renin-angiotensin-aldosterone system.

![Diagram of aldosterone production](image)

Usually, as soon as the blood pressure reaches a normal level, the body stops releasing renin, and this feedback cycle of renin to angiotensin to aldosterone stops.

**The ups and downs of renin**

The amount of renin secreted depends on blood flow and the level of sodium in the bloodstream. If blood flow to the kidneys diminishes, as happens in a patient who is hemorrhaging, or if the amount of sodium reaching the glomerulus drops, the juxtaglomerular cells secrete more renin. The renin causes vasoconstriction and a subsequent increase in blood pressure.

Conversely, if blood flow to the kidneys increases, or if the amount of sodium reaching the glomerulus increases, juxtaglomerular cells secrete less renin. A drop-off in renin secretion reduces
vasoconstriction and helps to normalize blood pressure.

**Sodium and water regulator**

The hormone aldosterone also plays a role in maintaining blood pressure and fluid balance. Secreted by the adrenal cortex, aldosterone regulates the reabsorption of sodium and water within the nephron. *(See *How aldosterone works.*)*
How aldosterone works

Aldosterone, produced as a result of the renin-angiotensin mechanism, acts to regulate fluid volume as described below.

Triggering active transport

When blood volume drops, aldosterone initiates the active transport of sodium from the distal tubules and the collecting ducts into the bloodstream. When sodium is forced into the bloodstream, more water is reabsorbed and blood volume expands.

Atrial natriuretic peptide

The renin-angiotensin-aldosterone system isn’t the only factor at work balancing fluids in the body. A cardiac hormone called atrial natriuretic peptide (ANP) also helps keep that balance. Stored in the cells of the atria, ANP is released when atrial pressure increases. The hormone counteracts the effects of the renin-angiotensin-aldosterone system by decreasing blood pressure and reducing intravascular blood volume. (See How atrial natriuretic peptide works.)
How atrial natriuretic peptide works

When blood volume and blood pressure rise and begin to stretch the atria, the heart’s ANP shuts off the renin-angiotensin-aldosterone system, which stabilizes blood volume and blood pressure.

This powerful hormone:
- suppresses serum renin levels
- decreases aldosterone release from the adrenal glands
- increases glomerular filtration, which increases urine excretion of sodium and water
- decreases ADH release from the posterior pituitary gland
- reduces vascular resistance by causing vasodilation.

Stretch that atrium

The amount of ANP that the atria release rises in response to a number of conditions; for example, chronic renal failure and heart failure.

Anything that causes atrial stretching can also lead to increases in the amount of ANP released, including orthostatic changes, atrial tachycardia, high sodium intake, sodium chloride infusions, and use of drugs that cause vasoconstriction.

Thirst

Perhaps the simplest mechanism for maintaining fluid balance is the thirst mechanism. Thirst occurs as a result of even small losses of fluid. Losing body fluids or eating highly salty foods leads to an increase in ECF osmolality. This increase leads to drying of the mucous membranes in the mouth, which in turn stimulates the thirst center in the hypothalamus. In an elderly person, the thirst mechanism is less effective than it is in a younger person, leaving the older person more prone to dehydration. (See Dehydration in elderly people.)
Dehydration in elderly people

The signs and symptoms of dehydration may be different in older adults. For example, they might include:
- confusion
- subnormal temperature
- tachycardia
- pinched facial expression.

Quench that thirst

Normally, when a person is thirsty, he drinks fluid. The ingested fluid is absorbed from the intestine into the bloodstream, where it moves freely between fluid compartments. This movement leads to an increase in the amount of fluid in the body and a decrease in the concentration of solutes, thus balancing fluid levels throughout the body.
Balancing fluids review

Fluid balance basics
• Fluid movement throughout the body helps maintain body temperature and cell shape.
• Fluids help transport nutrients, gases, and wastes.
• Most of the body’s major organs work together to maintain fluid balance.
• The amount of fluids gained through intake must equal the amount lost.

Fluid losses
• Insensible losses
  – Immeasurable
  – Examples: through the skin (affected by humidity and body surface area) and lungs (affected by respiratory rate and depth)
• Sensible losses
  – Measurable
  – Examples: from urination, defecation, and wounds

Understanding body fluids
• Different types of fluids are located in different compartments.
• Fluids move throughout the body by going back and forth across a cell’s semipermeable membrane.
• Distribution of fluids varies with age.

Fluid compartments
• ICF—fluid inside the cell; must be balanced with ECF
• ECF—fluid outside the cell; must be balanced with ICF; made up of 75% interstitial fluid (fluid surrounding the cell) and 25% plasma (liquid portion of blood)
• Transcellular fluid—in the cerebrospinal column, pleural cavity, lymph system, joints, and eyes; remains relatively constant

Fluid types
• Isotonic—equally concentrated with other solutions
• Hypotonic—less concentrated than other solutions
• Hypertonic—more concentrated than other solutions

Fluid movement
• Diffusion—form of passive transport (no energy is required) that moves solutes from an area of higher concentration to an area of lower concentration, resulting in an equal distribution of solutes between the two areas
• Active transport—uses ATP to move solutes from an area of low concentration to an area of higher concentration; example: sodium-potassium pump
- **Osmosis**—passive movement of fluid across a membrane from an area of lower solute concentration to an area of higher solute concentration; stops when both sides have an equal solute concentration
- **Capillary filtration**—movement of fluid through capillary walls through hydrostatic pressure; balanced by plasma colloid osmotic pressure from albumin that causes reabsorption of fluid and solutes

**Maintaining fluid balance**

**Kidneys**
- Nephrons form urine by filtering blood.
- If the body needs more fluid, nephron tubules retain or reabsorb water and electrolytes.
- If the body needs less fluid, tubules absorb less, causing more fluids and electrolytes to be excreted.
- Kidneys also secrete renin, an enzyme that activates the renin-angiotensin-aldosterone system.
- Aldosterone secreted by the adrenal cortex regulates sodium and water reabsorption by the kidneys.

**Hormones**
- **ADH**—Also known as vasopressin, ADH is produced by the hypothalamus to reduce diuresis and increase water retention if serum osmolality increases or blood volume decreases.
- **Renin-angiotensin-aldosterone system**—If blood flow decreases, the juxtaglomerular cells in the kidneys secrete renin, which leads to the production of angiotensin II, a powerful vasoconstrictor; angiotensin II stimulates the production of aldosterone; aldosterone regulates the reabsorption of sodium and water in the nephron.
- **ANP**—This hormone, produced and stored in the atria of the heart, stops the action of the renin-angiotensin-aldosterone system; ANP decreases blood pressure by causing vasodilation and reduces fluid volume by increasing excretion of sodium and water.

**Thirst**
- Regulated by the hypothalamus
- Stimulated by an increase in ECF and drying of the mucous membranes
- Causes a person to drink fluids, which are absorbed by the intestines, moved to the bloodstream, and distributed between the compartments

---

**Quick quiz**

1. If you were walking across the Sahara Desert with an empty canteen, the amount of ADH secreted would most likely:
   - A. increase.
   - B. decrease.
   - C. stay the same.
   - D. have no effect.

   **Answer:** A. Because your body would probably be dehydrated, it would try to retain as much fluid as possible. To retain fluid, ADH secretion increases.
2. If you placed two containers next to each other, separated only by a semipermeable membrane, and the solution in one container was hypotonic relative to the other, fluid in the hypotonic container would:
   A. move out of the hypotonic container into the other.
   B. pull fluid from the other container into the hypotonic container.
   C. cause osmosis to occur.
   D. stay unchanged within the hypotonic container.

   **Answer:** A. Fluid would move out of the hypotonic container into the other container to equalize the concentration of fluid within the two containers. Osmosis occurs when fluid moves from an area with more fluid to an area with less fluid.

3. Hydrostatic pressure, which pushes fluid out of the capillaries, is opposed by colloid osmotic pressure, which involves:
   A. reduced renin secretion.
   B. a decrease in aldosterone.
   C. the pulling power of albumin to reabsorb water.
   D. an increase in ADH secretion.

   **Answer:** C. Albumin in capillaries draws water toward it, a process called **reabsorption**.

4. When a person’s blood pressure drops, the kidneys respond by:
   A. secreting renin.
   B. producing aldosterone.
   C. slowing the release of ADH.
   D. secreting ANP.

   **Answer:** A. Juxtaglomerular cells in the kidneys secrete renin in response to low blood flow or a low sodium level. The eventual effect of renin secretion is an increase in blood pressure.

5. Giving a hypertonic I.V. solution to a patient may cause too much fluid to be:
   A. pulled from the cells into the bloodstream, which may cause the cells to shrink.
   B. pulled out of the bloodstream into the cells.
   C. pushed out of the bloodstream into the extravascular spaces.
   D. pulled from the cells into the bloodstream, which may cause the cells to increase in size.

   **Answer:** A. Because the concentration of solutes in the I.V. solution is greater than the concentration of solutes in the patient’s blood, a hypertonic solution may cause fluid to be pulled from the cells into the bloodstream, causing the cells to shrink.

---

**Scoring**

★★★★ If you answered all five questions correctly, congratulations! You’re a fluid whiz.
★★★★ If you answered four correctly, take a swig of water; you’re just a little dry.
★★★★ If you answered fewer than four correctly, pour yourself a glass of sports drink and enjoy an invigorating burst of fluid refreshment!
References

