CERTIFIED HEALTH & NUTRITION COUNSELOR ONLINE COURSE - SESSION 10:

- **Water and the Major Minerals**

Water and dissolved minerals provide the medium in which nearly all of the body's reactions take place, participate in many of these reactions, and supply the means for transporting vital materials to cells and waste products away from them. Every cell in the body is bathed in a fluid of the exact composition that is best for it. Each of these fluids is constantly undergoing loss and replacement of its constituent parts as cells withdraw nutrients and oxygen from them and excrete carbon dioxide and other waste materials into them. Yet the composition of the body fluids in each compartment remains remarkably constant at all times. Every important constituent of body fluids is similarly regulated. The interstitial fluid, for example, always has a high concentration of sodium and chloride ions and lower concentrations of about eight other major ions. The intracellular fluid always has high potassium and phosphate concentrations and lower concentrations of other ions. These special fluids regulate the functioning of cells; the cells in turn regulate the composition and amount of the fluids. The entire system of cells and fluids remains in a delicate but firmly maintained state of dynamic equilibrium.

The maintenance of this balance is so important that it is credited with our ability and that of other animals to live on land. It is thought that we had single-celled ancestors that depended on the seawater they lived in to provide nutrients and oxygen and to carry away their waste. We have managed over the course of our 2-billion-year evolutionary history to internalize the ocean – to continue bathing our cells in a warm nutritive fluid that keeps them alive. The amounts of salts in our body fluids, and their temperature, are believed to be the same as in the ocean – not as it is now, but as it was at the time when our ancestors emerged onto land. The ocean has since become saltier, but we still carry the ancient ocean within us.

This session first introduces you to water itself; then to the minerals that contribute to salt balance, and then to the body's other major minerals.

Salt

Salt does not refer only to sodium chloride but also to ionic compounds.

Water in the Body

Water in the body is a river coursing through the arteries, capillaries, and veins, carrying a heavy traffic of nutrients and waste products. Water molecules also nestle inside the body's giant proteins, glycogen, and other macromolecules, helping to form their structure. It constitutes about 55 to 60 percent of an adult's body weight.

Water also serves many other functions:

- It participates actively in many chemical reactions.
- It serves as the solvent for minerals, vitamins, amino acids, glucose, and a multitude of other small molecules.
- It acts as a lubricant around joints.
- It serves as a shock absorber inside the eyes, spinal cord, and amniotic sac in pregnancy.
- It aids in the body's temperature maintenance.

The Constancy of Total Body Water

The total amount of water in the body remains constant, thanks to the delicate balancing mechanisms that regulate intake and excretion.

Thirst governs water intake; when you need water, you drink. The evidence from experiments with thirst points to the possibility that several mechanisms operate in its regulation. One is in the mouth itself. When the blood is too salty (having lost water but not salts), water is withdrawn from the salivary glands into the blood. The mouth becomes dry as a result, and you drink to wet your mouth. Another thirst mechanism is in a brain center, where cells sample and monitor the salt concentration in the blood. When they find it too high, they initiate impulses that travel to brain centers that in turn stimulate drinking behavior. The stomach may also play a role. Thirsty animals drink until nerves in their stomachs, known as stretch receptors, are stimulated enough to turn off the drinking. More must be learned about these mechanisms, but it is clear from what we know already that thirst is finely adjusted to provide a water intake that exactly meets the need.

Water

Water follows salt, moving in the direction of higher osmotic pressure.

Hypothalamus (hy-po-THAL-a-mus)
The brain center described here is the hypothalamus.

The mechanism of water excretion involves the brain and the kidneys. The cells of the hypothalamus, which monitor salt concentration in the blood, stimulate the pituitary gland to release a hormone, ADH, whenever the body's salt concentration is too high. ADH stimulates the kidneys to hold back (actually, reabsorb) water, so that it recirculates rather than being excreted. Thus the more water you need, the less you excrete. There are also cells in the kidney itself that are responsive to the salt concentration in the blood passing through them. When they sense a too-high salt concentration, they too release a substance. By a roundabout route, this substance also causes the kidneys to retain more water. This substance is the enzyme renin (REEN-in). Again, the effect is that when more water is needed, less is excreted.

These renal excretion mechanisms cannot work by themselves to maintain water balance unless you drink enough water. This is because the body must excrete a minimum amount of water each day -—the amount necessary to carry away the waste products generated by the day's metabolic activities. Above this amount (a minimum of about 500 milliliters a day), the amounts of water you excrete can be adjusted to balance you intake. The urine merely becomes more dilute. Hence drinking plenty of water is never a bad idea.

ADH (antidiuretic hormone)
ADH is a hormone that is released by the pituitary gland in response to high osmotic pressure of the blood. The kidney responds by reabsorbing water.

In addition to the obvious dietary source, water itself, nearly all foods contain water. In addition, water is generated from the energy nutrients in foods. Daily water intake from these three sources totals on the average about 2-1/2 liters (about 2-1/2 quarts). Similarly, in addition to the water excreted via the kidneys, some water is lost from the lungs as vapor, some in feces, and some from the skin. The losses of all of these also total about 2-1/2 liters a day on the average.

Liter
A liter is roughly the same size as a quart. A U.S. quart is a little smaller and a Canadian (imperial) quart a little bigger than a liter.

The Water Supply
When you draw water from the tap into a glass and drink it, it is not only water that you are drinking. Chlorine may have been added to it, to kill microorganisms that might otherwise convey disease. Fluoride may have been added to it, if your community has adopted fluoridation. In addition, it contains naturally occurring minerals, toxic heavy metals, live microorganisms, and a miscellany of organic compounds. Most people in the more developed countries take their water supply for granted and assume that is pure and safe. At the same time, they may be very much concerned over the presence of incidental additives in food. Actually, water may contain "incidental additives" of greater significance to human health than those in foods.

The quality of water varies, depending on the source. To learn about the water in your area, you may want to consult your local health department. The variables affecting water quality fall into four groups: minerals, heavy metals, microorganisms, and organic compounds. In addition, there are important questions to ask about water quantity.

Minerals in the Water Supply
The entire 20-odd major and trace minerals discussed in this session and the next are present in various ground waters in different concentrations. Often they make significant contributions as nutrients to the health of the people who drink the water. Few communities have yet analyzed their water supplies completely enough to state which mineral needs they may be helping to meet, but most at least have information about the major minerals.

The distinction between hard and soft water, which has some important health implications, is based on three of these minerals. Hard water usually comes from shallow ground, and it contains high concentrations of the cations calcium and magnesium. Soft water usually comes from deep in the earth, and its principal cation is sodium. Well water is hard or soft, depending on the area. Most people distinguish between these two types of water in terms of their practical experience. Soft water dissolves soap better and leaves less of a ring on the tub; hard water leaves a residue of rocklike crystals in the teakettle after a while, and turns clothes gray in the wash. Hence consumers often consider soft water to be the more desirable and may even purchase water-softening equipment, which removes magnesium and calcium and replaces them with sodium. However, as far as we know today, hard water seems to support health better.

Soft water can add appreciable sodium to people's diets, and it appears to contribute to a higher incidence of high blood pressure and heart disease in areas where it is used. The National Academy of Sciences has suggested a standard for public water allowing no more than 100 milligrams of sodium per liter. This limit would ensure that the water supply would add not more than 10 percent of the average person's total sodium intake. The American Heart Association has recommended a more conservative standard of 20 milligrams per liter, to protect heart and kidney patients whose sodium intakes must be restricted. At present, about half the U.S. population drinks water containing more than 20 milligrams per liter. Where snowy roads are salted, the salt running off into the water supply may raise its sodium content considerably higher than this.

Soft water also dissolves certain metals, such as cadmium and lead, from pipes. Cadmium is not an essential nutrient. In fact, it can harm the body, affecting at least some enzymes by displacing zinc from its normal sites of action. Cadmium has been found in high concentrations in the kidneys and urine of patients with high blood pressure and is suspected of having some causal connection with the condition. A normal intake of zinc may protect against cadmium-induced high blood pressure. Lead is another toxic metal, and the body seems to absorb it more readily from soft than from hard water – possibly because the calcium in hard water protects against its absorption.

Caution:
The examples just given show that the choice to install a water softener in your home may be unwise, especially if your family is heart disease prone. (One family we know solves the problem by connecting the water softener only to the hot-water line, then using hot water for washing and bathing, and only cold water for cooking and drinking.) These examples also show that the minerals in water interact in unpredictable ways. Someday we may be able to fortify our water with the ideal amounts of minerals for human consumption. But before that time arrives, we have much to learn about what is in the water already and what is ideal for humans.

Toxic Metals in the Water Supply

In the wilderness, water cycles rapidly through living systems, undergoing a natural purifying process in every cycle. Animal waste excreted into the earth is filtered out by the soil before the water arrives underground. Pollutants entering rivers quickly disappear back into the earth as the rivers flow along, leaving the water pure. But neither the earth nor its rivers can purify completely the heavily polluted water expelled as city sewage or industrial waste. Water leaving a factory may contain concentrations of toxic metals so high that some are still present when it is recycled to become drinking water. And if the water is cycled through the same factory again, it will contain still higher concentrations the next time around.

Human technology bears the burden of purifying water contaminated by human technology. The Public Health Service sets drinking water standards (upper limits for the amounts of toxic metals permitted in water), and public law distributes the responsibility for adhering to these standards among the industries and the water-processing plants.

The metals of greatest concern are mercury, cadmium, and lead. These metals may be absorbed in to the body, where they change cell membrane structure, alter enzyme or coenzyme functions, or even change the structure of the genetic material, DNA, causing cancer or birth defects. If they happen to alter the DNA in the germ cells (eggs or sperm), the changes (mutations) will become hereditary. When combined into complexes with organic compounds, these metals may be absorbed especially rapidly and may damage body tissue even more.

Mercury is one of the rarer elements in the earth's crust, but has been mined extensively for industrial use; and so it is present in our environment in unnaturally high concentrations. Much of it ends up in the water supply as mercury compounds. By far the most toxic of these is methyl mercury, which is efficiently (90 percent) absorbed in the GI tract and accumulates in red blood cells, the brain, and the nerves. In pregnant women, methyl mercury becomes concentrated in the growing fetus. Thus it can cause mental and physical defects in the newborn even though the mother has shown no symptoms.

Nerve damage occurs with mercury intakes as low as 300 micrograms per day, so the Food and Drug Administration (FDA) has set a limit of one-tenth that amount on the mercury levels in foods and drugs. (Monitoring mercury concentrations in water is a task of the public health agencies, such as the Environmental Protection Agency.) Two serious outbreaks of mercury poisoning have occurred in Japan, where people have eaten fish that grew near industrial plants that discharged mercury wastes into the water. Rising levels of environmental mercury have been observed in other industrial countries, including the United States.

Cadmium has its most toxic effects in the kidney, causing chronic renal disease; in the lungs, causing emphysema; and in the bones, causing osteoporosis and osteomalacia. It has been in commercial use since 1910 and has caused severe outbreaks of disease in Japan. Cadmium in contaminated water can be absorbed into vegetables and grains and so can find its way into human consumers of these foods.

Lead, another highly toxic materials, enters the water supply mostly by being captured in rain falling from atmospheres polluted with automobile exhaust. It is a metabolic poison that interferes with the action of several enzymes. Symptoms of mild lead poisoning include lowered hemoglobin, intestinal cramps, fatigue, and kidney abnormalities. These may be reversible if exposure stops. More severe exposure causes irreversible nerve damage, paralysis, mental retardation in children, abortions, and death.

These are only three examples of metal pollutants, but they are enough to illustrate how the purity of the water supply can be threatened by industrial use. Both government and consumer environmental protection groups have to be vigilant in detecting, reporting, and preventing dangerous levels of contamination, because our water is a vital resource.

Microorganisms in the Water Supply

Many harmless, even beneficial, bacteria dwell in the human digestive tract and are excreted into sewage. If these were the only inhabitants of sewage, there would be no concern about their presence in drinking water. But disease organisms are also excreted into sewage, and others are introduced into it by flies and other carriers. Before a sewage treatment plant releases its effluent into the water supply, it must reduce the bacterial count enough so that the further dilution that follows will make recycled water safe for human use.

An efficient secondary sewage plant may remove 99 percent of the bacteria in the water, which sounds pretty good for a start. But there are typically 10 million bacteria in a milliliter (1/5-teaspoon) of sewage. After 99 percent removal there will still be 100,000 bacteria left in each milliliter. Chlorination then kills another 99 percent, leaving 1,000 bacteria per milliliter. Most of these are harmless, and the few that are harmful can be diluted below the danger point if the water leaving the plant enters a large river. Alternatively, the facility may give the water tertiary treatment, sprinkling it over a large land area so that it will be filtered before reentering the general water supply.

High standards for sewage treatment in the developed countries ensure that most people have potable water, but for the rest of the world, microbial contamination remains the primary cause of human diseases and epidemics. Two of the most basic public health needs of the world's people are safe drinking water and an acceptable standard of waste disposal.

Sewage Treatment

The first step in sewage treatment allows the solids to settle out. This is primary treatment. Secondary treatment removes the suspended matter, including bacteria and some viruses. Tertiary treatment removes dissolved compounds, both organic and inorganic.

Potable (POTE-uh-bul)

Suitable for drinking.
Potare = to drink

Organic Compounds in the Water Supply

The fourth class of substances that may occur in water are the organic compounds from sewage, insecticides, petroleum-based and other industries, and other sources. Research on these substances is less than 20 years old, and few of them have been identified, but many are known to be toxic. Some cause birth defects, some are carcinogenic, some cause permanent alterations of the inherited genetic material. Many contain chlorine, and some may be formed during the chlorination of water. No information is available on the risks now presented by water containing these compounds; standards are only now being established, and new filtering systems may be called for if public water exceeds these standards. The study of organics in the water supply is an increasingly important research area.

In some regions, consumers have become sufficiently alarmed about their local water supplies to turn to buying bottled water for their personal consumption. The choice is an individual matter. However, in buying water, as in buying any other product, the consumer needs to be alert to fraudulent claims. Mineral waters from "famous spas" offer no known health advantages and may be undesirably high in sodium. On the other hand, bottled water sold in the United States must be tested by the producers once a year for safety and must meet standards set by the FDA for its contents of many chemical substances.

Water Quantity

The matter of water quantity still must be discussed. Is there enough to meet our needs? Water is an abundant natural resource, and until recently its availability has been unquestioned. But the use of water in the industrial countries is putting a strain on the supply. Used by agriculture for irrigating and by industry for transporting, dissolving, washing, rinsing, cooling, flushing away waste, and many other purposes, water in huge quantities is diverted from its original, ordinary uses. Processed and fast foods cost much more, in water, than do whole foods from the farm. In the future the water supply may limit human progress. It has been estimated, for example, that if the U.S. population increases by another 20 percent or so, the water supply will be unable to continue meeting all the demands placed on it. We will therefore have to compromise our living standards in order to meet the top-priority need for safe, pure water for human use.

This course is about individual nutrition and has dealt little with the economic and ecological problems of worldwide supply and demand. This discussion of water brings those problems into the foreground. To continue surviving and to maintain a desirable quality of life in an increasingly crowded and complicated world may mean making some hard choices in the near future.

The Body's Salts

Session 1 listed the major minerals; the following table shows the amounts found in the body. As you can see, the most prevalent are calcium and phosphorus, the chief minerals of bone (discussed later). Four of the major minerals – potassium, sodium, chlorine, and (again) phosphorus – strongly influence the water balance. These form salts that are abundant in the body fluids.

Major Minerals	Amount in grams	Trace Minerals	Amount in grams
Calcium	1,150	Iron	2.4
Phosphorus	600	Manganese	0.18
Potassium	210	Copper	0.09
Sulfur	150	Iodide	0.024
Sodium	90		
Chloride	90		
Magnesium	30		

In the table above, the amounts of minerals are in a 60-kilogram human body. The major minerals are those present in amounts larger than 5 grams (a teaspoon). A pound is about 454 grams; thus only calcium and phosphorus appear in amounts larger than a pound. There are more than a dozen trace minerals, although only four are shown here.

To understand how cells regulate the amount of water they contain; it is necessary to take a closer look at the minerals as ions, the form in which cells use them for water regulation. Cell membranes are freely permeable to water molecules, which are neutral, and which flow in and out of cells all the time. Yet the cells never lose all their water nor do they overfill. Along the evolutionary path they have contrived a method of keeping their water constant; they do this beautifully by employing the salts to assist them. They make use of the principle that water follows salt

Chemists use the term salt to include many inorganic substances, not just ordinary table salt. The chemist refers to table salt as sodium chloride, NaCl. In this salt, sodium and chlorine atoms are bound together by strong electrostatic forces in a rigid crystalline structure. Outwardly, the crystals exhibit no electrical charge. However, when dissolved in water, the rigid structure relaxes. Some of the sodium moves about freely as positively charged ions, and some of the chloride also dissociates and moves about as negatively charged ions. The salt thus reveals itself as a compound composed of charged particles. The positive ions are cations; the negative anions.

A salt that partly dissociates in water, as sodium chloride does, is known as an electrolyte. Since the fluids of the body are composed of water and partly dissociated salts, they are electrolyte solutions.

Electrolyte solutions are always electrostatically balanced. There is no such thing as a test tube filled with sodium ions. Sodium ions are always positively charged, and they cannot exist apart from negatively charged ions. Therefore, in any fluid with dissolved electrolytes there will always be the same number of positive and negative ions. If an anion enters a cell, a cation must accompany it or another anion must leave so that electroneutrality will be maintained.

Salt

A compound composed of charged particles (ions). Exceptions: a compound in which the cations are H^+ is an acid; a compound in which the anions are OH^- is a base.

Cation (CAT-eye-un)
A positively charged ion.

Anion (AN-eye-un)
A negatively charged ion.

Na = sodium
Cl = chlorine

Chloride
The ionic form of chlorine.

Dissociation
Physical separation of the ions in an ionic compound. A salt that partly dissociates in water is an electrolyte.

Electrolyte Solution
A solution that can conduct electricity.

Water Balance
We stated above that water follows salt. More precisely, there is a force that moves water into a place where a solute, such as sodium chloride, is concentrated. This force is known as the osmotic pressure of a solution. Water flows toward the higher osmotic pressure. The substances dissolved in the water that create this pressure are the solutes (SOLL-yutes). This force can operate only if the divider separating the two fluid solutions is permeable to water but not permeable (or less freely permeable to the solute.

You have seen this force at work if you have ever salted a lettuce salad an hour before eating it. When you come back to the salad, the lettuce was wilted and there was water in the salad bowl. The high concentration of salt (and therefore low concentration of water) on the outside of the lettuce cells caused water to move out of the cells. They collapsed (the lettuce wilted), and the water puddled in the salad dish. Sugar would have caused the same reaction. There is one way you could have prevented this (here's a cooking lesson for the novice). You could have coated the lettuce lightly with oil before salting it or put salad dressing on it. The oil would have acted as a barrier against the salt, keeping it from attracting water out of the lettuce.

The divider between the water inside and outside a cell is the cell membrane. The cell cannot pump water directly across its membrane, but it does have proteins in its membrane that can attach to sodium ions and move them from one side of the membrane to the other. When these sodium pumps are active, they pump out sodium faster than it can diffuse into the cell. Water follows the sodium. When potassium pumps are active, they pump in potassium, and water follows this ion. By maintaining a certain amount of sodium outside and potassium inside, the cell can exactly regulate the amount of water it contains.

Electrolyte Solutions
Other terms used to describe electrolyte solutions: isotonic (having the same osmotic pressure as a reference solution), hypertonic (having a higher osmotic pressure than a reference solution), and hypotonic (having a lower osmotic pressure than a reference solution). The salty water on the outside of the lettuce cells is hypertonic to the water inside the cells, so it attracts water out of the cells. Saline (salt) solutions used in the hospital are made isotonic to human blood.

Semipermeable
The cell membrane is semipermeable – that is, more permeable to some substances (such as water) than to others (such as sodium and potassium). This is the condition necessary for osmotic pressure to operate.

Acid-Base Balance
The body uses its ions not only to help maintain water balance but also to help regulate the acidity (pH) of its fluids. Some of the electrolyte mixtures in the body fluids, as well as the proteins, protect the body against changes in acidity by acting as buffers – substances that act to neutralize newly introduced acids or bases.

Surprisingly, although one person may eat more or less of certain minerals than other person, the body's total content of electrolytes remains very nearly constant. The job of regulating the body's salt population is largely delegated to the kidneys, under the supervision of several monitoring systems, notably the adrenal and pituitary glands. The net effect of all the homeostatic balancing systems is to help ensure that output balances intake. A person who eats a lot of table salt, for example, excretes more sodium and chloride in his urine than one who eats only a little. Thus, except for a transient rise immediately after ingestion, the body's total electrolytes remain constant, and it is the composition of the urine that is affected by what you eat.

Some foods are classed as acid-formers, others as base-formers, depending on the amount of acid they donate to the urine after their metabolism. It has been thought (but it is not clear) that their acid-forming or base-forming nature derives partly from the balance of mineral salts they contain. The distinction becomes important when kidney stones form; because excesses of many metabolites flow through the kidneys on their way to being excreted (some are excluded from absorption and leave the body with the feces). Some stones tend to form in acid, others in basic solutions, so when a person has a tendency to form kidney stones, she is advised to eat the foods least likely to aggravate that tendency. She is instructed, then, to eat either an acid-ash or an alkaline-ash diet.

Acid Forming Foods	**Base-Forming Foods**
Meat, fish poultry	Milk
Eggs	Vegetables
Cheese	Fruits (except cranberries, prunes, and plums)
Grains (breads and cereals)	
Fruits (cranberries, prunes, and plums only)	

Diseases of the kidney more serious than stones impair the body's ability to regulate its fluid and electrolyte balances. To keep the renal patient alive, in addition to many medical procedures, the physician may order adjustment of the patient's electrolyte input from food. The burden then falls on the dietitian to calculate a diet that precisely specifies sodium, potassium, calcium, water, and many other constituents.

It is not known whether any regulating system other than the kidneys governs the body's salt contents. We have thirst, to govern our intake of water, but do we have a salt hunger to govern our intake of sodium? Salt hunger is well known in plant-eating animals like cattle, which will travel long distances to a salt lick when they have been depleted of sodium. The tongue, in both animals and humans, is equipped with taste receptors that respond only to the salty taste. Animals know instinctively when to seek this stimulus, but humans may seek it when they have no need. Future research may determine whether a true salt hunger operates in humans.

Buffer

A substance or mixture capable in solution of neutralizing both acids and bases and thereby capable of maintaining the original acidity of the solution.

Renal Calculi (REE-nul CAL-kyoo-lie)

Kidney stones are deposits of mineral and other salts that have crystallized within the kidney. Technically, they are termed renal calculi.
Renal = of the kidney
Calculus = a small stone

Acid Ash Diet

A diet of acid-forming foods (foods that, if burned to ask, would be found to contain acid-forming minerals). Such a diet contributes to acidity of the urine, because the kidney collects the excess acid-forming minerals into the urine for excretion.

Alkaline Ash Diet

A diet of base-forming foods.

Taste Receptors

There are four kinds of taste receptors on the tongue: those sensitive to salt, sweet, sour, and bitter flavors.

Water and Salt Imbalances

The activity of the kidneys in regulating the body's contents of sodium and water is remarkable. Sodium is absorbed easily from the intestinal tract, then travels in the blood, where it ultimately passes through the kidneys. The kidneys filter all the sodium out, then with great precision return to the bloodstream the exact amount needed. Normally, the amount excreted equals the amount ingested that day. About 30 to 45 percent of the body's sodium is thought to be stored on the surface of the bone crystals, where it is easy to recover if the blood level drops.

When the blood level of sodium rises, as it does after a person eats heavily salted foods, the thirst receptors in the brain are stimulated. The fluid intake increases to make the sodium-to-water ratio constant. Then the extra water is excreted by the kidneys along with the extra sodium.

Thus you are well protected from imbalances of water and electrolytes. Technically, these kinds of imbalances are known as fluid-and-electrolyte imbalances. However, you may be thrown into situations for which your kidneys, thirst instinct, and cell membranes cannot compensate. This is the case when large amounts of fluid and electrolytes are suddenly lost. Vomiting, diarrhea, heavy sweating, burns, wounds, and the like may incur such great fluid losses that a medical emergency results.

The details of electrolyte balance are among the most important ones that medical students must learn. Mastery of these details is appropriately left to them and to their medical associates. For the general reader and the student of nutrition, it is necessary only to appreciate the importance of this balance and the principles by which it is maintained and to be aware of the situations that threaten it. When any of these gets out of control, the appropriate action is to call the doctor. Water and salts, which we take for granted and usually ignore, are more vital to life than any of the other nutrients considered in this course.

Sodium, Other Minerals, and High Blood Pressure

The body has to maintain a certain blood pressure to sustain the lives of its cells. The pressure of the blood against the walls of the arteries ensures that fluids carrying nutrients and oxygen move out of the arteries into the tissues to deliver their cargo. By the time blood reaches the veins, much of its fluid has exited, and the concentration of cells and solutes in the remaining blood is at a maximum. Fluids from the tissues, attracted by the concentrated plasma, then seep back into the veins, now carrying carbon dioxide and other waste materials. Thus the cells' needs for supply and removal of materials are met. The blood pressure also helps ensure good filtration of wastes into the urine as blood passes through the kidneys.

When the blood pressure falls, the lives of all the body's cells are threatened. The kidneys detect the lowered pressure and immediately set in motion a mechanism to raise the blood pressure again

Normally, this response of the kidneys is highly adaptive. In dehydration, for example, a "water deficiency" exists. By constricting the blood vessels and conserving water and sodium, the kidney-initiated mechanism ensures that blood pressure is maintained until more water can be drunk.

Sometimes, however, t he kidneys are fooled. They experience a "water deficiency" when there is none. Then they raise the blood pressure with harmful effects – a maladaptive response. Most often, the cause is atherosclerosis (hardening of the arteries), which deprives the kidneys of water just as if there were a water deficiency. In response to poor circulation of blood fluid, the kidneys raise the blood pressure and the heart has to pump extra hard to push the extra fluid around against resistant arteries. Added weight (obesity) raises the pressure further, and the extra adipose tissue means miles of extra capillaries through which the blood must be pumped. The combination of high blood pressure, obesity, and hardened arteries is deadly.

In 10 percent of cases, hypertension is caused by recognized kidney disease, and is called secondary hypertension, but in 90 percent, the cause is unknown. The vast majority of cases are called essential hypertension, meaning that the disease process must be primary.

The mineral sodium has been implicated so strongly in the causation of high blood pressure that many people have been led to believe it alone is to blame. Findings such as these incriminate sodium (but withhold judgment for a moment):

1. Populations with high intakes of sodium have more high blood pressure (for example, the Japanese).
2. Populations that eat little or no salt have normal blood pressure (even some vegetarian groups in our society).
3. Severely restricting sodium reduces high blood pressure; adding sodium back to the diet restores high blood pressure.
4. A nationwide program to control blood pressure, including sodium reduction, has seemed to lower blood pressure in many individuals.
5. People in areas with soft water have higher (average) blood pressure than people in areas with hard water.
6. Genetically sodium-sensitive strains of animals are known; their blood pressure is greatly affected by dietary sodium, some humans (perhaps 20 percent) are genetically sensitive also.

Blood pressure regulation is not simple, however. Other factors are involved. Items 1 and 2, above, show correlations, not evidence of cause. With respect to Item 3, people with normal blood pressure usually do not show an increase when fed large amounts of salt. With respect to Item 4, drugs were used to lower blood pressure, and the independent effect of sodium restriction, if any, is unknown. As for Item 5, who is to say that it is the sodium in soft water that accounts for the difference? Perhaps it is some other mineral; or perhaps the minerals in hard water protect against high blood pressure.

The only findings that seem to hold up strongly are that some people are sensitive to sodium and tend to have high blood pressure, and that they can lower it by reducing their salt intakes. Since not all those people know who they are (and you can't tell by "feel" when you have high blood pressure) some authorities contend that the whole population should be encouraged to reduce its salt intakes. The government's Dietary Goals, the Dietary Guidelines for Americans and the Canadian government's guidelines all recommend reducing sodium intakes based on this assumption.

We'll come back to sodium shortly, but first, what are the other diet-related factors that affect blood pressure? Obesity is one, as already mentioned. Several other minerals are also involved – notably, potassium, calcium, magnesium, and cadmium.

When sodium is retained in the body, potassium is traded for it. Even subjects with normal blood pressure, if fed very large quantities of sodium, ultimately show a rise in blood pressure – but at the same time, their potassium excretion is increasing. Fed potassium simultaneously with the sodium, they do not have a rise in blood pressure.

Population studies show sodium being traded for potassium in a different sense. People who eat many foods high in sodium (processed foods, for example), necessarily eat fewer potassium-containing foods (such as fruits and whole vegetables) at the same time.

Calcium and magnesium are implicated because of the hard water versus soft water observation already mentioned above. It has also been reported that calcium in the blood is low in people with high blood pressure. The contaminant cadmium is leached from pipes into water, especially soft water, and may contribute to high blood pressure. Other factors mentioned have been chloride, alcohol, and protein.

Still, the use of highly salted foods probably contributes to hypertension for those who have a genetic tendency to develop it anyway. How many people this represents is a much-debated question, but one in five seems to be a conservative estimate. Black Americans are significantly more at risk than other groups. It is possible that, by the age of 65, as many as three out of four people have high blood pressure. This being the case, perhaps we should all curtail our sodium intakes, as the authorities mentioned earlier suggest.

There is certainly no sodium shortage in the diet. Foods almost always include more salt than is needed. Intakes vary widely, especially because of cultural differences in diets. Orientals, who liberally use soy sauce and monosodium glutamate (MSG or accent) for flavoring, consume about 30 to 40 grams of salt per day; most people in the United States average about 6 to 18 grams per day. Vegetarians, depending on their food preferences, can consume much less

The Dietary Guidelines recommend that we limit our sodium intake to not more than 5 grams of added salt a day (that is, salt added by manufacturers and consumers above and beyond that already in the food as grown). In practice, this would mean avoiding highly salted foods and removing the salt shaker from the table.

Persons who wish to avoid salt need to know that what they pour from the salt shaker may be only a third of the total salt they consume. One-fourth to one-half comes from processed food, to which salt is added as a preservative and flavoring agent. This makes eating something of a guessing game because labels do not necessarily declare the sodium contents of foods. The serious sodium-avoider must stay away from fast-food places and Oriental restaurants and stop using many canned, frozen, and instant foods at home. (On a positive side, unprocessed, whole foods are lower in sodium – and higher in potassium – than most people realize.)

Processed foods don't always taste salty. Most people are surprised to learn that a serving of cornflakes contains more sodium than a serving of cocktail peanuts – and that a serving of chocolate pudding contains still more.

Avoiding sodium is hard to do, not only because sodium is often hidden, but also because foods are far less tasty without salt. With practice, however, people can learn to enjoy the flavors of many unsalted foods and, where species are needed, to make liberal use of sodium-free spices like those listed in the table below. If you persist long enough (say, two months) in eating a low-salt diet, your taste threshold for salt will actually change so that your preferred level is lower.

In summary, the person who wishes to use diet to prevent high blood pressure should probably not only reduce sodium intake but emphasize positive actions as well:

- Eat plenty of fresh fruits and vegetables, because they are rich in potassium.
- Be sure to eat a balanced diet, including good food sources of calcium and magnesium.
- Maintain ideal weight.
- Be moderate in the use of alcohol.

Hypertension

High blood pressure. People sometimes confuse hypertension with stress, but hypertension is an internal and stress an external condition. Stress may cause hypertension in sensitive people, however.

Secondary Hypertension

Secondary hypertension is high blood pressure caused by kidney disease (10 percent of cases). Primary, or essential, hypertension is of unknown origin (90 percent of cases) and can cause kidney disease.

“High” Blood Pressure

“High” blood pressure is defined differently for different purposes. Here, if the higher of the two numbers is over 140 or if the lower is over 90, it is considered to be too high.

Blood Pressure Regulation

Renin from the kidney splits the plasma protein angiotensinogen to form angiotensin I; in the presence of another enzyme, angiotensin I is activated to angiotensin II, which acts as a vasoconstrictor and also stimulates aldosterone secretion. The net effect is to raise blood pressure.

Salt

5 grams salt is about 2 grams sodium
1 gram salt = 1/5 tsp.
Estimated safe and adequate daily dietary intake of sodium (Committee on RDA) 1.1-3.3 grams (1,100-3,300 mg)

To Avoid Too Much Sodium:

- Learn to enjoy the unsalted flavors of foods.
- Cook with only small amounts of added salt.
- Add little or no salt to food at the table.
- Cut down on:
    - Foods prepared in brine, such as pickles, olives, and sauerkraut.
    - Salty or smoked meats, such as bologna, corned or chipped beef, frankfurters, ham, luncheon meats, salt pork, sausage, smoked tongue.
    - Salty or smoked fish, such as anchovies, caviar, salted and dried cod, herring, sardines, smokes salmon.
    - Snack items such as potato chips, pretzels, salted popcorn, and salted nuts and crackers.
    - Bouillon cubes; seasoned salts (including sea salt); soy, Worcestershire, and barbecue sauces.
    - Cheeses, especially processed types.
    - Canned and instant soups.
    - Prepared horseradish, catsup, and mustard.

Read Labels

You may be surprised to learn that some processed foods that contain no table salt and don’t taste salty have lots of sodium. Look for the word soda or sodium or the symbol Na on labels. Examples are sodium bicarbonate (baking soda), monosodium glutamate, most baking powders, disodium phosphate, sodium alginate, sodium benzoate, sodium hydroxide, sodium propionate, sodium sulfite, and sodium saccharin. – USDA

Sodium-Free Spices and Flavorings

Allspice	Onion Powder
Almond Extract	Paprika
Bay Leaves	Parsley
Caraway Seeds	Pepper
Cinnamon	Peppermint Extract
Curry Powder	Pimiento
Garlic	Rosemary
Garlic Powder	Sage
Ginger	Sesame Seeds
Lemon Extract	Thyme
Mace	Turmeric
Maple Extract	Vanilla Extract
Marjoram	Vinegar
Mustard Powder	Walnut Extract
Nutmeg	

Calcium

Unlike sodium, calcium is not so abundant in the diet, and deficiencies are widespread in human societies. The price you pay for neglecting to obtain enough calcium throughout early and middle life is extensive degeneration of the skeleton in old age – adult bone loss, which leads to crippling deformities, irreparable fractures, and even death. Nearly all people suffer some bone loss as they grow older, and it causes serious fractures in about one of every three people over 65. It is therefore urgent to understand the necessity of obtaining adequate calcium in food from the early years on throughout adulthood.

The urgency of obtaining enough calcium has to be learned through education, because the body sends no signals saying it is deficient. Most nutrient deficiencies make themselves known by way of symptoms that can be felt or seen, such as pain, skin lesions, tiredness, and the like. But a developing calcium deficiency is utterly silent; it becomes apparent only when a hip or pelvic bone suddenly shatters into fragments that cannot be reassembled. No evidence of a developing calcium deficiency can be found in a blood sample, because blood calcium remains normal no matter what the bone content may be. Nor does depletion of bone calcium show up in an x-ray until it is so far advanced as to be virtually irreversible.

There is a lacy network of calcium-containing crystals inside the bones. These are the deposits in the body's calcium bank, which are drawn on whenever the supply from the day's diet runs short. Invested in savings during the milk drinking years of childhood, these calcium deposits provide a nearly inexhaustible fund of calcium; 99 percent of the body's calcium is stored in the bones.

The other 1- percent of the body's calcium is in the blood and body fluids, where its concentration is tightly controlled by a system of hormones and vitamin D. Whenever the blood calcium concentration rises too high, these agents promote its deposit into bone. Whenever the blood concentration falls too low, the regulatory system acts in three locations to correct it:

- Intestine: increase calcium absorption.
- Bone: increase calcium release.
- Kidney: reduce calcium excretion.

Thus blood calcium returns to normal.

To say that food calcium never affects blood calcium is not to say that blood calcium never changes. In fact, sometimes blood calcium does rise above normal, causing a condition known as calcium rigor. When this happens, the muscle fibers contract and cannot relax. Similarly, calcium levels may fall below normal in the blood, causing calcium tetany – also characterized by uncontrolled contraction of muscle tissue, due to a change in the stimulation of nerve cells. These conditions do not reflect a dietary lack or excess of calcium; they are caused by a lack of vitamin D or by glandular malfunctions that result in abnormal amounts of the hormones that regulate blood calcium concentration.

On the other hand, a chronic dietary deficiency of calcium or a chronic deficiency due to poor absorption over the course of years can diminish the savings account in the bones. Because this is an important concept, we repeat: it is the bones, not the blood, that are depleted by calcium deficiency.

Calcium Regulators

The regulators are hormones from the thyroid and parathyroid glands, as well as vitamin D. One, parathormone, raises blood calcium. Others, calcitonin and thyrocalcitonin, lower it by inhibiting release of calcium from bone. The hormone-like vitamin D raises blood calcium by acting at the three sites listed.

Calcium Rigor

Harness or stillness of the muscles caused by high blood calcium.

Calcium Tetany

Intermittent spasms of the extremities due to nervous and muscular excitability caused by low blood calcium.

Roles of Calcium

The calcium that circulates in the body fluids plays many roles. Some calcium is found in close association with cell membranes, where it appears to be essential for their integrity. It helps to regulate the transport of other ions into and out of cells. It is essential for muscle action and so helps maintain the heartbeat. Calcium must be present between nerve and nerve, and between nerve and muscle, for the transmission of nerve impulses; and when it enters cells, it delivers important messages to intracellular receptors.

Calcium must also be present if blood clotting is to occur, because it is one of the 14 factors directly involved in this process. (The other 13 are proteins; vitamin K is needed, too, for the synthesis of some of these proteins.) Calcium also acts as a cofactor for several enzymes.

As for the calcium in bone, it plays two important roles. One, as already mentioned, is to serve as a bank to prevent alteration of the all-important blood calcium concentration. And the bones, of course, hold the body upright and serve as attachment points for muscles, making motion possible.

Cofactor

A mineral element that, like a coenzyme, works with an enzyme to facilitate a chemical reaction.

Calmodulin (cal-MOD-YOU-lin)

Calcium is over 1,000 times more concentrated outside of cells than inside, and normally, it can't get in. When it does, however (for example when an electrical impulse arrives along a nerve, altering the membrane), it finds molecules of the protein calmodulin waiting inside. Calcium binds to calmodulin, changing its shape. Now, calmodulin activates other proteins, which take action. Thus calcium has "delivered" the message transmitted along the nerve, and the appropriate action is taken (calcium, meanwhile, is rapidly expelled from the cell by membrane pumps).

Calcium is abundant; so is calmodulin. The reaction is one of the fastest in the body. Even hormones cannot work so fast.

Calcium Deficiency

The disease rickets has been mentioned in connection with vitamin D deficiency. Often in rickets the amount of calcium in the diet is adequate, but it passes through the intestinal tract without being absorbed into the body, leaving the bones undersupplied. Vitamin D deficiency, by depressing the production of the calcium-binding protein, is the most common cause of rickets. In children, the failure to deposit sufficiency calcium in bone causes growth retardation, bowed legs, and other skeletal abnormalities. In adults, the disease may set in after a normal childhood during which calcium intake and absorption were adequate, and after the skeleton has become fully calcified. Prolonged inadequate calcium uptake during adulthood, often due to vitamin D deficiency, may cause the gradual and insidious removal of calcium from the bones. The result is altered composition or reduced density of the bones in old age, which makes them fragile.

Many older people are severely afflicted with osteoporosis. The causes seem to be multiple, but inadequate storage of calcium during the growing years is a factor always in the background. This fact underscores the importance of prevention: drink plenty of milk while you are young to have strong bones in later life, and continue drinking milk throughout adulthood, to avoid losing calcium.

A net calcium loss occurs in many adults, especially women after menopause or hysterectomy, suggesting that hormonal changes are responsible. Many minerals and vitamins are required to form and stabilize the structure of bones, including magnesium, fluoride, vitamin A, and others. Any of these may be essential for preventing osteoporosis. One obvious line of defense, however, is to maintain a lifelong adequate intake of calcium.

Rickets

The calcium deficiency (or vitamin D deficiency) disease in children.

Osteomalacia

Altered composition of the bones is reflected in osteomalacia, the condition in which the bones become soft. Osteomalacia is sometimes called adult rickets.

Osteoporosis (oss-tee-oh-pore-OH-sis)

Reduced density of the bones results in osteoporosis – literally, porous bones. Session 15 shows that exercise, too, is important in the prevention of osteoporosis.

Food Sources of Calcium

The recommended intake of calcium, arrived at by way of balance studies, is 700 to 800 milligrams (0.7 to 0.8 grams) per day for adults in both the United States and Canada. Adults can stay in balance on intakes lower than this if they adapt over a long period of time to lower intakes, and the World Health Organization recommends only 400 to 500 milligrams per day for adults. However, high protein intakes increase calcium excretion, and in the United States and Canada, where diets are rich in protein, 700 to 800 milligrams for adults and 1,200 for pregnant and lactating women seems to be a protective recommendation. Authorities are considering raising this recommendation to 1,000, or even 1,200, milligrams a day for women over 50.

Calcium is found almost exclusively in a single class of foods – milk and milk products. For this reason, if for no other, members of this group must be included in the diet daily or wise substitutions must be made. Because a cup of milk contains almost 300 milligrams of calcium, an intake of 2 cups of milk provides a good start towards meeting the amount recommended for an adult for a day. A pregnant or lactating woman should have 3 to 4 cups; and an older woman, 3 cups. The other dietary food that contains comparable amounts of calcium is cheese.

One slice of cheese (1 ounce) contains about two-thirds as much calcium as a cup of milk. (Cottage cheese, however, is a poor source.) For people who don't drink enough milk, dark-green leafy vegetables have been thought to be an important calcium source, but the calcium binder – oxalate – renders the calcium in most greens except broccoli unabsorbable. (Greens are still a valuable source of riboflavin, folacin, vitamin A, iron, and other nutrients, however.)

The absurdity of attempting to meet calcium needs in any way other than by consuming two or more servings a day of these foods can be demonstrated by listing the amounts of some other foods you would have to consume instead:

- 6 heads of iceberg lettuce
- 10 cups of cooked green beans
- 12 oranges or eggs
- 20 cups of strawberries

For most people, then, the obvious way to meet calcium needs is to include milk and milk products in the diet daily. This is especially important for pregnant and lactating women, older women, and children in the growing years (their calcium balance must be positive to permit good skeletal growth). Adults concerned with feeding children who dislike milk may find it helpful to learn how to conceal milk in foods. Ice cream, ice milk, and yogurt are acceptable substitutes for regular milk, and puddings, custards, and baked goods can be prepared in such a way that they also contain appreciable amounts of milk. Powdered skim milk, which is an excellent and inexpensive source of protein, calcium, and other nutrients, can be added to many foods (such as cookies and meatloaf) in preparation. For children with a milk allergy, a calcium-rich substitute such as fortified soymilk must be found. Butter and cream contain negligible calcium, because calcium is not soluble in fat.

The word daily should be stressed with respect to food sources of calcium. Because of its limited ability to absorb calcium, the body cannot handle massive doses periodically but instead needs frequent opportunities to take in small amounts.

Many factors affect calcium absorption. The stomach's acidity favors it by helping to keep calcium soluble. Vitamin D aids in calcium absorption by helping to make the necessary calcium-binding protein. (It is no accident that milk is chosen as the vehicle for fortification with vitamin D.) The lactose in milk also seems to facilitate calcium absorption by a mechanism as yet unknown. Calcium levels are lower in breast milk than in cow's milk, but babies absorb calcium better from breast milk, possibly because of its higher lactose content.

Some foods contain binders that combine chemically with calcium (and other minerals such as iron and zinc) to prevent their absorption, carrying them out of the body with other wastes. For example, phytic acid renders the calcium, iron, and zinc in certain foods unavailable; oxalic acid binds calcium and iron; and uronic acid binds calcium. Phytic acid is found in whole grains; oxalic acid in beets, rhubarb, and dark green leafy vegetables; and uronic acid in the fiber of grains, fruits, and vegetables. Fiber in general seems to hinder calcium absorption, so the higher the diet is in fiber, the higher it should be in calcium. This fact in now way affects the overall value of high-fiber foods. Whole grains, legumes, greens, other vegetables, and fruits are nutritious for so many reasons that no one should hesitate to include them in menu planning.

Milk Allergy

The most common food allergy; caused by the protein in raw milk. Milk allergy is sometimes overcome by cooking the milk to denature the protein, sometimes "cured" by abstinence from and gradual reintroduction to milk.

Binders

Chemical compounds occurring in foods that can combine with nutrients (especially minerals) to form complexes the body cannot absorb. Phytic (FIGHT-ic) and oxalic (ox-AL-ic) acids are examples of such binders.

Caution:
The amount of calcium recommended for the daily diet is so great that is won't fit in a single pill that can be swallowed. To make it absorbable, the manufacturers combine the calcium into a large organic salt such as calcium gluconate or calcium lactate, making an extremely bulky pill. To get 600 milligrams of calcium in this salt you would have to take six pills that might each be the diameter of a quarter and the thickness of four quarters. You therefore never find significant amounts of calcium in vitamin-mineral supplements of the type that are to be taken once a day. Many vitamin-mineral supplements do contain some calcium, however.

There are to ways to read a label. Once is to read what it contains, and the other is to read how much. A list of the ingredients in a pill that contains calcium might mislead unaware consumers into believing that their calcium needs would be met by the pill. However, often the label lists the calcium content of each pill as 20 milligrams. Only when you compare this amount with the recommended intake (800 milligrams) do you realize that you would have to take 40 of these pills a day to meet your calcium needs. This discussion should remind you that you should always use a yardstick when reading nutrient amounts of labels.

It is important to remember, too, that pills do not supply the relative amounts of nutrients that are in the best balance for your overall health. A typical calcium supplement, for example, is labeled with the instructions to take six a day. Yet six of these pills a day supply less than 50 percent of the recommended intake of calcium and 500 percent of the vitamin D – and vitamin D is toxic in excess. (Vitamin D is added to the pill to enhance the absorption of calcium.)

In contrast, 2 cups of skim milk fortified with vitamins A and D would supply the following percentages of the nutrients an adult man needs: calcium, 60 percent; vitamin D, 50 percent; protein, 40 percent; vitamin A, 50 percent; thiamin, 12 percent; and riboflavin, 50 percent; plus 24 grams of carbohydrate in the form of lactose. Calcium absorption is enhanced by several of these other nutrients. Once again, a point made previously is relevant; there are fringe benefits to eating a nutrient in a natural food as opposed to a purified nutrient preparation.

The Four Food Group Plan Recommends Daily Milk Servings

Children under 9	2-3 cups
Children 9-12	3+ cups
Teenagers	4+ cups
Adults	2 cups
Pregnant women	3+ cups
Lactating women	4+ cups
Older women	3 cups

The body is able to regulate its absorption of calcium by altering its production of the calcium-binding protein. More of this protein is made if more calcium is needed. Thus you will absorb more when you need more. This system is most obviously reflected in the increased absorption by a pregnant woman, who absorbs 50 percent of the calcium from the milk she drinks instead of only 30 percent, as she formerly did. Thus her body's calcium intake almost doubles, even if her food intake does not change at all. Similarly, growing children absorb 50 to 60 percent of ingested calcium; when their growth slows or stops (and their bones no longer demand a net increase in calcium content each day), their absorption falls to the adult level of about 30 percent.

Child Can't or Won't Drink Milk

If allergic to cow's milk protein	If lactose-intolerant	If unexplained intolerance or dislike
Boiled Milk	Enzyme-treated milk	Emphasis on foods containing the nutrients of milk
And/or	And/or	Last resort
Milk cooked into foods	Smaller portions of milk more often	Nutrient supplements
And/or	And/or	
Goat's milk	Yogurt and other fermented dairy products	

An important relationship exists between calcium and phosphorus. Each is better absorbed if they are ingested together. Authorities differ on the ratio that might best favor health, but it seems probable that most would agree on a 1:1 ratio; perhaps any ratio from 3:1 to 1:3 is all right.

Protein also affects calcium status, as already mentioned, but not by affecting absorption. The higher the diet is in protein, the greater the amount of calcium excreted. This is why people in the United States and Canada are told to ingest more calcium than people in countries whose protein intakes are lower.

Caution:
A generalization that has been gaining strength throughout this course is supported by the information given here about calcium. A balanced diet that supplies a variety of foods is the best guarantee of adequacy for all essential nutrients. All food groups should be included, and none should be overused. Calcium is found lacking wherever milk is under-emphasized in the diet – whether through ignorance, simple dislike, lactose intolerance, or allergy. By contract, iron is found lacking whenever milk is overemphasized, as session 11 shows.

Phosphorus

Phosphorus is a mineral in second largest quantity in the body. About 85 percent of it is found combined with calcium in the crystals of the bones and teeth. There it occurs as calcium phosphate, one of the compounds in the crystals that give strength and rigidity to these structures.

The concentration of phosphorus in blood plasma is less than half that of calcium; 3.5 milligrams per 100 milliliters of plasma. But as part of one of the body's major acids (phosphoric acid), it is found in all body cells. It is a part of DNA and RNA, the genetic code material present in every cell. Thus phosphorus is necessary for all growth, because DNA and RNA provide the instructions for new cells to be formed.

Phosphorus also plays many key roles in energy transfers occurring during cellular metabolism. Many enzymes and the B vitamins become active only when a phosphate group is attached. (The B vitamins, you will recall, play major roles in energy metabolism.) ATP itself, the energy carrier of the cells, contains three phosphate groups and uses these groups to do its work.

Some lipids contain phosphorus as part of their structure. These phospholipids help to transport other lipids in the blood; they also reside in cell membranes, where they affect transport of nutrients into and out of the cells. The phosphate ion also helps in one of the blood's most important buffering systems.

Animal protein is the best source of phosphorus, because phosphorus is so abundant in the energetic cells of animals. The recommended intakes for phosphorus are the same as those for calcium: 700 to 800 milligrams per day for adults. Deficiencies are unknown.

Chlorine

The element chlorine occurs as a poisonous gas, but when it combines with sodium in salt, it is not poisonous but is part of a life-giving compound. It occurs in salt as the negative chloride ion.

The chloride ion is the major negative ion of the fluids outside the cells, where it is found mostly in association with sodium. Chloride can move freely across membranes and so is also found inside the cells in association with potassium. Its role in balancing the pH of the blood has already been described.

In the stomach, the chloride ion is part of hydrochloric acid, which maintains the strong acidity of the stomach. The cells that line the stomach continuously expend energy to push chloride into the stomach fluid. One of the most serious consequences of vomiting is the loss of acid from the stomach, which upsets the acid-base balance.

A chlorine compound is added to public water to reduce its bacterial count before it flows through pipes into people's homes. The compound turns to the deadly poisonous gas chlorine, kills dangerous microorganisms that might otherwise spread disease, and then evaporates, leaving the water safe for human consumption. The addition of chlorine to public water is one of the most important public health measures ever introduced in the developed countries and has eliminated such water-borne diseases as typhoid fever, which once ravaged vast areas, killing thousands of people.

The estimated safe and adequate daily dietary intake of chloride from the Committee on RDA is 1,700-5,100 mg.

Potassium

Potassium is critical to maintaining the heartbeat. The sudden deaths that occur in severe diarrhea and in children with kwashiorkor may often be due to heart failure caused by potassium loss. As the principal positively charged ion inside body cells, it plays a major role in maintaining water balance and cell integrity. When water loss from the body involves sodium loss, the ultimate damage comes when potassium is pulled out of the cells and excreted. Dehydration is especially scary, because potassium deficiency affects the brain cells early, making the victim unable to perceive that she needs water.

During nerve transmission the muscle contraction, potassium and sodium briefly exchange places across the cell membrane. Nerve and muscle cells, then, are especially rich in potassium, but all cells must contain some. Potassium is also known to play a catalytic role in carbohydrate and protein metabolism, but the exact nature of this role is not known.

A deficiency of potassium from getting too little in the diet is unlikely, but high-sodium diets low in fresh fruits and vegetables make it a possibility. Abnormal conditions such as diabetic acidosis or loss of large volumes of water can cause potassium deficiency. One of the earliest symptoms is muscle weakness.

Gradual potassium depletion can occur when a person sweats profusely day after day and fails to replenish his potassium stores. A study of this effect shows that up to about 3 grams of potassium can be lost in a day. The average diet in this country supplies about 1.5 to 2.5 grams. The authors of one study recommend that a person who sweats heavily and often should eat five to eight servings of potassium-rich foods each day.

Caution:
It has been pointed out several times previously that there are advantages to eating foods instead of taking supplements. Salt tablets contain sodium and chloride, but foods contain a multitude of minerals. The body evolved in dependence on foods, not supplements. Also, men who think fruit is only for dainty ladies might take note that because of the potassium it contains, fruit may do more for these muscles than meat.

Potassium supplements are not advisable except when prescribed, because too much potassium is as dangerous as too little. Even salt substitutes containing potassium should be avoided, especially by heart patients except as recommended by a physician.

Estimated safe and adequate daily dietary intake of potassium according to the Committee on RDA is 1,875 – 5,625 mg (1.9 – 5.6 grams).

Potassium-rich foods include bananas and many other whole, fresh fruits; orange juice and many other fruit juices; and potatoes, tomatoes, and many other vegetables.

Sulfur
Sulfur is present in all proteins and plays its most important role in determining the contour of protein molecules. Sulfur helps the strands of protein to assume a particular shape and hold it – and so to do their specific jobs, such as enzyme work. Some of the amino acids contain sulfur in their side chains; once built into a protein strand, one of these amino acids can link to each other by way of sulfur-sulfur bridges. The bridges stabilize the protein structure. Skin, hair, and nails contain some of the body's more rigid proteins, and these have a high sulfur content.

There is no recommended intake for sulfur, and no deficiencies are known. Only if a person lacks protein to the point of severe deficiency will he lack the sulfur-containing amino acids.

Methionine and Cysteine
Amino acids containing sulfur are methionine and cysteine. Cysteine in one part of a protein chain can bind to cysteine in another part of the chain by way of a sulfur-sulfur bridge. Two cysteine molecules linked this way are called cystine.

Magnesium
Magnesium barely qualifies as a major mineral. Only about 1-3/4 ounces of magnesium are present in the body of a 130-pound person, most of it in the bones. Bone magnesium seems to be a reservoir to ensure that some will be on hand for vital reactions regardless of recent dietary intake.

Magnesium also acts in all the cells of the soft tissues, where it forms part of the protein-making machinery and where it is necessary for the release of energy. Its major role seems to be as a catalyst in the reaction that adds the last high-energy phosphate bone to ATP. Magnesium also helps relax muscles after contraction and promotes resistance to tooth decay by holding calcium in tooth enamel.

A dietary deficiency of magnesium does not seem likely, but deficiency may occur as a result of vomiting, diarrhea, alcohol abuse, or protein malnutrition; in postsurgical patients who have been fed incomplete fluids into a vein for too long; or in people using diuretics. A severe deficiency causes tetany, an extreme and prolonged contraction of the muscles very much like the reaction of the muscles when calcium levels fall. Magnesium deficit is also thought to cause hallucinations experienced by alcoholics during withdrawal.

Recommended intakes of magnesium are 300 to 350 milligrams a day for adult males, 250 to 300 for females. Good food sources include nuts, legumes, cereal grains, dark-green vegetables, seafoods, chocolate, and cocoa. The kidney acts to conserve magnesium; the magnesium not absorbed is excreted in the feces.

CERTIFIED HEALTH & NUTRITION COUNSELOR ONLINE COURSE - SESSION 10 **– QUESTION & ANSWERS**

NAME: ____

ADDRESS: ____

PHONE: ____

FAX: ____

E-MAIL: ____

Please be sure to fill out the information above, complete the test and e-mail or fax it back to us at iridology@netzero.net or 425-955-4639. We will grade your question & answer session and will let you know if we have any questions or concerns.

1. What percentage of the body's weight is water?

2. Which water is rich in calcium and magnesium?

3. Name three toxic heavy metals that industrial waste may add to the water supply.

4. What controls microbial contamination in the water supply?

5. What are the principal electrolytes in the body fluids?

6. What is a normal pH of the body fluids?

7. What is atherosclerosis?

8. Ten percent of hypertension cases are attributed to ______________________________.

9. The 1- percent of calcium found in body fluids helps maintain what?

10. Calcium deficiency may be caused directly by what?

11. Calcium deficiency diseases are which 3 diseases?

12. What is a negative chloride ion?

13. Which mineral is primarily involved in the working of nerve and muscle cells?

14. A deficiency in magnesium causes ____________.