PROFESSOR: So today's lecture is going to be acid-base balance. First thing, couple of general statements. Basically, the water of the body serves the purpose of carrying mineral salts, electrolytes, okay. And of course, these dissociate or separate in the solution, and they go into positive and negatively charged ions. Of course, positively charged ions are cations and negatively charged ions are anions. An example of cations are sodium and potassium. And negatively charged ions, anions, chloride is a great example. And although there are cations present, anions present, basically the body fluids are electrically neutral. The neutrality results from a balance between the sum of the cations and the sum of the anions. Now, in certain diseases, the ion concentrations can vary. Usually the electrical neutrality is maintained.

Now, the distribution of water. Basically there are some disturbances of the body water that are associated with corresponding changes in electrolytes. And body water is basically about 70 percent, okay. So 70 percent of the body is going to be water weight. That is going to be distributed into the intracellular water, which is water within the cells. And then water outside the cells, we call that extracellular water. And the extracellular water, the water outside the cells, is going to be in the blood, in plasma, the lymphs, and also in the interstitial tissues or spaces. The interstitial tissues are the spaces in between the cells. There is was going to be water there. Basically, water accumulates or gets to the interstitial tissue by the -- through capillaries. So water can leave the capillaries and go into the interstitial tissue. Very often the amount of water that leaves the capillaries into the interstitial tissue is going to be dependent on the amount of protein in the blood. That's going to exert osmotic pressure, keeping water within the capillaries. The other force is going to be blood pressure. The higher the blood pressure, the greater the fluid -- the force of driving the fluid outside the capillaries. So the rule of thirds. Two-thirds of the body weight is H2O. Two-thirds of that is within the cells. And one-third of the water is extracellular in the tissues. So the adult female water content is 10 percent lower than adult male. Fluids and electrolytes diffuse freely between the intravascular space and the interstitial fluids. That's because the capillaries are permeable. They are permeable to the fluids; however, they are impermeable to protein. Protein cannot leave the capillaries if they are normal, healthy and they are not damaged. The interstitial fluid contains very little protein. The cell membrane separates the fluid within the cell from the...
fluid outside the cell or the interstitial fluid. Cell membranes are freely permeable to water; however, they are basically impermeable to sodium and potassium.

So the chief intracellular ions are going to be potassium and phosphate. The chief extracellular ions are going to be sodium and chloride. Now, does anybody know the normal level of sodium? What's the normal blood level for sodium? Anybody know? Around? Anybody have an idea? Anybody? So we're going to say it's basically about 142 milliequivalents to a milliliter. You don't have to know that for a test. I'm just using this as an illustration. So the concentration of sodium in the blood is around 142 millimeters. Probably normal lab might range something like 136 to 145. And the concentration of anions and cations is expressed in milliequivalents per milliliter. The concentration of potassium in the blood, okay, is roughly around four milliequivalents per milliliter. So there is a big concentration gradient between the amount of sodium in the blood and the amount of potassium in the blood. Now, the differences in concentration of ions on different sides of cell membranes result from metabolic activity of the cells. And the amount of sodium in the body determines the volume of extracellular fluid as the chief extracellular cations. Basically what they're saying is that sodium holds on to water. Sodium holds on to water. People have a problem with edema, swelling or accumulating fluid around the feet or the ankles, one of the things they'll do is they'll tell them to restrict their sodium. The sodium will hold on to water.

The amount of potassium in the body determines the volume of the intracellular fluids. Potassium is the major cation within the cell. In electrolyte disturbance, the primary concern is the concentration of the various ions and the relationship between the positively and negatively charged ions.

So let's see here. Unit of concentration can be expressed in the units that define the ability to combine with other ions. You guys don't have to really understand this. The equivalent weight -- when they talk about equivalent, it's the molecular weight. It's more chemistry. Divided by the valence. So sodium basically has a valence of one, and it's expressed as milliequivalents per milliliter. So there's a regulation of body fluid and electrolyte con, concentration. The amount of water and electrolytes in the body basically represents the balance between the amounts suggested and the amount excreted by the urine, the GI tract, perspiration, and also vaporized by the lungs. So disturbances in H2O balance. What is a disturbance? Typically you can have dehydration or overhydration. Dehydration is more common. What would cause the dehydration? Either inadequate intake, such as -- or excess loss. Now, so the excess loss, basically they have it reversed. It should be excess loss would be diarrhea or vomiting. Inadequate intake, comatose or a debilitated patients. As patients get older,
their thirst reflex may decrease, and as a result sometimes the older patients become dehydrated. When they become dehydrated, they don't produce enough urine to void, and they get residual urine in the bladder. They can get bladder infections and on and on. So dehydration is the most common. Overhydration is really much less common, and that might result from excessive fluid intake when there is compromise in renal function. If someone has severe kidney disease, they need to restrict their fluid intake. Or someone who basically is in the hospital and gets IV fluids and they administer too much in the way of IV fluids.

So disturbance of electrolyte imbalance. Yes?

STUDENT: (Inaudible)

PROFESSOR: Yeah, in that basically dehydration was common. Inadequate intake, the cause for intake adequate would be the comatose patient or debilitated. The excessive water loss would be through diarrhea or vomiting. They reversed that.

So disturbances of electrolyte balance, conditions that can produce water imbalance also can disturb electrolyte composition. So the depletion of electrolytes. I mentioned vomiting and diarrhea, sodium and potassium are lost. Excessive use of diuretics can affect the electrolyte balance. Excessive diuresis and diuretic acidosis. With juvenile diabetics, we talked about that. With juvenile diabetics, they will have a lot of glucose in the urine. What that does is it acts as a diuretic, and the glucose holds on to some of the water and so they end up with excessive diuresis or renal tubular disease. The renal tubules are damaged, and as a result they don't re-absorb the electrolytes as they should. Diuretics promote excretion of salt and water. And the way diuretics work, they work by impairing the reabsorption of these substances. So patients with heart failure, liver cirrhosis, kidney disease would be at risk for that. Uncontrolled diabetes, they have excessive loss of water in the urine from the diuretic glucose. In renal tubular disease what happens is the regenerating renal tubules, they've been injured and they're starting to regenerate, starting to heal, and they cannot conserve electrolytes and water.

Acid-base. We talked about electrolytes. Now acid-base. The body produces large amounts of acid from normal metabolic processes such as a breakdown of protein, glucose or oxidation of fat. And basically the body fluids remain slightly alkaline. Normal range is 7.38 to 7.42. You can see it's a tight range. The regulatory mechanisms are designed to maintain the pH. They maintain the pH through the buffer system. The buffer system is carbonic acid and sodium bicarb. The major buffer system is the acid in the salts. So let's see. Acids can be eliminated to help maintain a normal pH. So the blood -- the purpose of the blood buffers are to resist pH change. And the lungs and the kidneys are the two most important organs when it comes to
acid-base balance. The lungs are responsible for the carbonic acid concentration, and the kidneys are responsible for the bicarb concentration. Now, carbonic acid is -- results from CO2 with water. So you end up with carbonic acid which is an H2CO3. Anybody here not have chemistry? Okay. So if you take away, you see H2CO3, and then if you take away one hydrogen, all right, that's going to be, therefore, leaving us with HC03, which is bicarb. So sodium and bicarb is a salt. It's a salt of the acid, carbonic acid. And the sodium and bicarb freely dissociate, so therefore you have your bicarb molecule that very easily can pick up a hydrogen, and then you end up with H2CO3. Then what happens is in the lungs, the H2CO3 can dissociate with H2O and CO2. CO2 then can be blown off the lungs. So that's how the body can regulate the pH. The kidneys control the bicarb concentration. They can excrete it. They can absorb it. So there is a balance between the sodium bicarb and the carbonic. Of course, the carbonic acid is going to make things a little more acidic. The sodium bicarb is going to make it a little more basic. The sodium bicarb is under the kidney control, and the carbonic acid is under the respiratory control. And by that we mean the lungs.

So the purpose of the blood buffer system is to minimize change in hydrogen ion by converting strong acids and bases into weaker ones. Weak acid and its salt and weak base and its salt. Respiratory control of the lungs basically is for carbonic acid. So as I said, carbonic acid is basically CO2 in plasma. Now, when people hyperventilate, that means they breath in rapidly and they take deep breaths. They are going to blow off CO2. They blow off CO2. So very often -- well, not very often, but sometimes people have an anxiety reaction, they hyperventilate. They take real deep breaths; they breath fast. As a result what is a side effect of hyperventilation? People like this, when they hyperventilate, what happens? That can become lightheaded; that's one thing much. And another thing typically? Anybody? Anybody ever hyperventilate before?

STUDENT: (Inaudible)

PROFESSOR: I noticed. I noticed. I'm glad. What happens when people hyperventilate? They may get lightheaded, but something else happens, too.

STUDENT: They pass out.

PROFESSOR: No, not pass out. Before they pass out. What happens to their hands and feet? They get numb and tingling, right, absolutely. Hyperventilate. They get lightheaded, they get numbness and tingling in their fingers. What is the treatment for people who hyperventilate? What do you have them do?

STUDENT: Blow in a paper bag.

PROFESSOR: Right. Why do you do that?

STUDENT: (Inaudible)

PROFESSOR: That's exactly right. So when they exhale the
CO2 into the bag, and when they take a breath in, the CO2 comes in. So therefore, you're gradually the CO2 levels so that they achieve a more normal level. As a result the symptoms and the numbing or the tingling in the extremities is reduced. So with respiratory control, as I mentioned -- of carbonic acid. So hyperventilation, lower CO2 and carbonic acid in the plasma. Decreased or inadequate ventilation will raise the CO2 in the carbonic acid in the plasma.

The kidney controls the bicarb concentration. The kidneys are able to selectively re-absorb filtered bicarb, and they can manufacture bicarb to replace amounts lost in the buffering acids from metabolic processes. In any buffer system, the pH depends on the ratio of bicarbonate to carbonic acid. Normal ratio is 20 parts of sodium bicarb to one part carbonic acid. That is not significant; you don't have to know that.

So disturbances in acid-base balance. You either have acidosis or alkalosis. Acidosis refers to an increase in blood pH. It's more acidic. It results from an excess of carbonic acid and decreased bicarb. Then with alkalosis, you have the reverse. The pH shifts to a more basic (), and it results from a decrease in the carbonic acid and an increase of bicarb.

Now, if you are going to classify acid-base disturbances as either metabolic, respiratory, and then acidosis or alkalosis. Metabolic usually refers to disturbances in relationship to the kidney sometimes indirectly. Respiratory disturbances refers to the carbonic acid. So metabolic acidosis, what does that come from? It comes from increased acid being generated, and as a result with the amount of increased acid generated it exceeds the body's buffering capacity. The body really can't neutralize all of it and becomes slightly more acidic. Then as the bicarb tries to neutralize the excess acid, the bicarb and the plasma falls from being consumed, and as a result you have an acidic situation, metabolic acidosis. When does this occur? It occurs with ketosis. People have high ketone levels such as diabetic ketoacidosis. Also in uremia when people have kidney disease and they have high () levels. Remember the kidneys are involved in production of bicarb and the reabsorption of bicarb. So in metabolic acidosis, how can the body compensate? It can compensate by hyperventilating. By hyperventilating, it lowers the PCO2. The pressure of carbon dioxide refers to the pressure within the LV line. So they can hyperventilate and therefore they can breath off, okay, the CO2. And as a result hopefully there's going to be increased bicarb production by the kidneys.

So here is a diagram of what we were talking about. The diagram of the acid-base balance in metabolic acidosis. The things get shifted towards the more acidic side. And then with the formation of additional bicarb hopefully by the kidney and blowing off CO2, we'll get a more neutral pH.

With respiratory acidosis what happens is there's going to be inefficient excretion of CO2 by the lungs. As a result --
now, people maybe who are in a coma, people who don't -- or elderly, they have respiratory problems, they may not be able to blow off CO2 as well as they should. As a result they become -- they develop respiratory acidosis. The kidney will then compensate by increasing production of bicarb.

So here you have a once again the diagram, okay, of respiratory acidosis, hopefully compensation by forming additional bicarb by the kidney.

In respiratory alkalosis, you have reduced H2CO3, which is carbonic acid. And it results from hyperventilation. With the hyperventilation you get a relative excess of bicarb, and then hopefully the compensation is the kidneys respond by excreting more of the bicarb. Here is your diagram here.

So basically the diagnostic evaluation of acid-base balance, you need to do laboratory studies. You want to know the blood pH. You want to know the partial pressure of CO2 in the blood and the bicarb.

(End of class.)

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I hereby certify that the foregoing transcription is a true and accurate verbatim record of the recorded proceedings.

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