>> Steve Langjahr: All right. So today is still November 8th, and this is lecture number 23. It's our last installment in this unit of study. Understand we've covered cardiovascular, respiratory, and now are completing our look at the so-called digestive system. We indicated early on that this system does much more than digestion. It's concerned with molecular and physical breakdown of food, secretion, absorption and motility. And that's where we're headed today. Let's back up a bit. We left you briefly in the stomach where we know hydrochloric acid is secreted. This helps to activate what enzyme there? Pepsin. And together, the process of proteolysis, and the breakdown of protein is at least begun. This acid also helps to kill bacteria, therefore minimizing the chance of infection. Then we move into the small intestine. And there, we find right away the deposition of sodium bicarbonate from the pancreas. This seems to be important because acid from the stomach will overflow into the duodenum, where it could harm or at least inhibit the enzymes that are being secreted there. So the function of this bicarb is to raise the pH, bring it close to neutrality. And that favors the activity of these many pancreatic enzymes. We concluded our remarks on Monday with a look at what is going on in the early and latter segments of the digestive tract. This diagram is not worth memorizing, but it's certainly worth appreciating that the things that are removed from the blood early in this system are put to use and then returned at the distal or latter segments of the digestive tract. So there's no net upset in electrolyte balance. There's no net upset in pH, provided there's opportunity for the return or reabsorption of these commodities. And so, we left you with that very common scenario of diarrhea. Remember that? If you have diarrhea, these things are going to move through too quickly and no opportunity for reabsorption. This will very definitely then impact electrolytes and also blood pH. So the proper speed of motility protects and ensures that these commodities are returned as they should be, so as not to disturb the homeostasis of pH and electrolytes. So where to go from here? We still have some secretions to consider. The pancreas is not alone, but rather the liver adds considerable benefits. Bile, as you know, is produced by the liver, and it's stored in the gallbladder. And bile has the following ingredients: number one, it contains bile salts and other emulsifiers. The most important emulsifier is lecithin. An emulsifier is something that helps liquefy fat. You might even know of lecithin because it's an ingredient in ice cream and peanut butter and candy bars, and it's there to keep the fat from separating. And indeed, that's what it does here. It helps break apart fat globules and helps make the cholesterol, which is the bulk of the bile constituent, helps liquefy and make more water-soluble the cholesterol. But the main reason that bile is the color that it is, is from the bilirubin that it contains. You've probably heard the term, maybe know a little bit about it, but bilirubin is a product derived from the breakdown of hemoglobin. In other words, the destruction of red blood cells, which commonly occurs all the time. Bilirubin has no function. It's essentially a metabolic waste product, and it's deposited here only to be put into the small intestine, where it exits the body in the feces. In fact, the color of your feces is largely due to the bilirubin that it contains. Bilirubin is dark green or yellow, and that serves to account for the

coloration of the feces. But bilirubin has no function; however, you probably have at least heard of it in a negative context, maybe because after all, when bilirubin builds up in the blood, it produces a symptom which is well known. What's that? Jaundice. And jaundice is not a disease. It's not even dangerous per se, at least to the adult, but it does color the skin and mucous membranes, and it's very easy to diagnose. Not so much of a concern for an adult, but in newborns, bilirubin can cross the blood brain barrier and, therefore, enter and damage the nervous system. So if you've heard of bilirubin, it might've been in a negative context. You might have had a child or known of a child that was jaundice and there was concern for his or her safety. So bilirubin does have a negative connotation especially in newborns. But mostly, bilirubin is simply a waste product, a byproduct of hemolysis and the breakdown of hemoglobin. The other and final ingredient in bile is cholesterol, which typically the body makes too much of or otherwise has too much of for one reason or another. And cholesterol, of course, is a steroid, yes? And therefore, it's not inherently water-soluble. What makes it water-soluble are the bile salts and other emulsifiers. But this is only noteworthy because in some individuals, cholesterol is particularly abundant here, and the anatomy of the biliary ducts may sometimes retard the release of bile. And if bile concentrates in the gallbladder, then cholesterol will precipitate there? And what do you call that when cholesterol precipitates here in this location? Gallstones. Gallstones are not uncommon, and many of you may have them, not particularly aware or suffering until they obstruct the pathway either at the biliary duct or the hepatopancreatic duct. So you must know people who have had their gallbladder removed. And can you survive that. Of course. Because remember, the gallbladder makes nothing. What's the gallbladder do? It stores all of these commodities, which are produced, in fact, by the liver. So overall, bile helps to emulsify fat. That means it helps to liquefy fat in your diet and, therefore, enhances the action of that enzyme. What is that pancreatic enzyme that works on or hydrolyzes fat? L word, lipase. So just to put a fine point on it, bile salts help to liquefy fat, therefore making the job of lipase much more efficient. Next and not to be forgotten, mucous. Mucus is not produced by any particular organ, but rather all of the cells or many of the cells along the G.I. tract. We think of mucus too often as negative because we associate it with obstruction of airways. But we're not dealing here with the respiratory system. This is the digestive system. And mucus is uniformly important because it coats, it provides a chemical barrier to cell destruction. Mucus is then secreted throughout the G.I. tract. It is alkaline in pH, and it provides then a physical and chemical barrier to the very enzymes that are being secreted and added along the G.I. tract. With that said, what if you have some condition which leads to deterioration of this mucus? The breakdown of this mucus, would it be a good thing or a bad thing? Bad thing because it would cause ulceration, ulceration along the G.I. tract. And there are many types of ulcerations along the G.I. tract, a couple you may know of: Crohn's disease and ulcerative colitis, also known as UC. Actually, neither of these is related to mucus, but the idea of ulceration should be understood. Why is the breakdown of these cells anywhere along the G.I. tract a problem? If you're breaking down

these cells, are there blood vessels just below those cells, and can you then start bleeding into your G.I. tract, and can that lead to significant blood loss and, therefore, low EDV and low stoke volume and so forth? So ulceration, wherever it occurs, is not just painful, but it's also potentially life-threatening. A bleeding ulcer, wherever it might occur, is problematic and sometimes due to a failure or breakdown of this mucus barrier. So moving from the small intestine, still focusing on secretion and digestion. The large intestine really has little to do because most of the secretion and most of the digestion has already taken place where? Small intestine. And so, there is little or no enzymatic digestion going on in the large intestine, which begs the question, what then does the large intestine actually do. It really is a convenience organ, much like the stomach. Its function is to store, to compact, and to dehydrate the feces to minimize water loss and also to essentially make life more convenient. With that said, can you live without your large intestine? Yes. But obviously, you're going to lose a lot of water because among the things that are achieved in the large intestine, water return or water reabsorption. And as you may know from microbiology or just everyday reading, there are lots of bacteria which thrive and deserve our respect down here in the large intestine. Today, we actually have good names for them. What are they called? Probiotics. And people crave or otherwise eat yogurt or otherwise find these in various supplements. And they are important because among other things, they contribute to some vitamins, especially vitamin K, incidentally, which is largely produced by bacteria which reside in your large intestine. Now, of course, they have a somewhat embarrassing side effect. They produced gases, including hydrogen sulfide and methane. And this is of flatus. Most people just simply call it a fart. And I read the other day, and you can confirm this on Google, that all of us fart about 14 times a day. So if you're not up to your quota, my guess maybe you should start counting. I'm just joking, of course. But it is just a fact of life and nothing at all abnormal about it. Now we could make a momentary comment about this, but it's hardly worth it. It's interesting only in that it's a rather staggering list of statistics. On a given day, a given 24-hour day, your salivary glands produce a whole liter of saliva. Yeah. And your stomach is cranking out two liters of gastric juice. And then on top of it, three liters of mucus. Wow. And almost a liter of bile. This all adds up to 1.8 gallons of fluid, which is wow, surprising. What's important to emphasize is that these water-based commodities are not lost in the feces. Most of this H2O is going to be what? Reabsorbed, especially and mainly along the large intestine. So even though these things are produced in considerable volume, there is a great deal of conservation engaged to protect against the water loss and dehydration, which would otherwise result. So now, we just considered secretion and digestion. Let's go back to the beginning and take a different look at this system with an entirely different focus. Remember, digestion as a concept was only important as it allows what? Why do we need physical chemical digestion in order to bring about absorption? You cannot absorb molecules which are too large to be absorbed. So digestion and secretion make possible this actual payday here, which is the absorption of these nutrients. And motility supports this because unless things are moving faithfully and continually along this G.I.

tract, then the efficiency of absorption is naturally going to suffer. So these two topics, these two activities are supporting each other in some way. And before we move into details, we need to revisit, remind you of the anatomy especially and mainly in the small intestine. Remember, despite the name small intestine, that's where most of the D word, digestion, and most of the A word, absorption, takes place. So naturally, we want to focus on the histology, the microbiology of these locations. So the small intestine is anything but smooth. It's certainly not like your desktop. It's more like shag carpeting. And it's thrown into ridges and valleys, which you might recall from anatomy, the plicae circulares, which is further made more complex by these microscopic valleys and ridges that are called villi, v-i-l-l-i. And so, indeed, the inner layer is very convoluted, anything but flat. And the purpose and reason for this is to increase surface area to maximize the A word, maximize absorption. If you stop to compare or ponder this, at least for me, it's a tempting analogy to compare this to a terrycloth towel. What makes a bath towel so absorbent? Well, I've got one over here, and we can put it under the TV camera here. This is just an ordinary terrycloth towel. And it doesn't look like much from a distance. But if we zoom in and get right down to it, we see that really what makes it so absorbent is that it's made up of countless loops and threads of fine cotton and, therefore, maximizing what? Maximizing the surface area. And so, even though this is a kind of far-fetched analogy, that's kind of how the small intestine looks, at least on a microscopic level. And, therefore, even though we say the small intestine is 20 feet in length, it's thousands of square feet of surface area made possible by these villi, multiple epithelial projections. To be exact, it's simple columnar epithelium, as shown here. And deep to that, we have blood vessels and lymphatics, blood vessels being capillaries and the lymphatics being lacteals. The lacteal is seen here in yellow, the capillaries in blue and red. You might recall from anatomy that the lacteals are important for absorbing fat. The capillaries absorb water-soluble materials, namely amino acids, carbohydrate products and so forth. So the point of this illustration is to show that the blood supply and the lymphatics supply is very near the surface, and absorption needs only to traverse the single cell layer, which is made of simple columnar epithelium. To say it another way, how many cells does a molecule of x, y or z have to go through before it finds its way into a capillary? One, one cell, and that's that single simple columnar epithelial cell. Going deep, going deep to this mucosal layer, we encounter the muscular layer. You might even remember that was called the tunica muscularis. But it's not a simple single layer at all. It's actually two layers, which are essentially concentric. And the innermost one is circular. That means it's organized like a slinky on the circumference of this. Remember, it's smooth muscle, and its function is to contract, not unlike that of smooth muscle found elsewhere. Did we speak of smooth muscle in bronchioles? Did we speak of smooth muscle in arterioles? And here, smooth muscle as well. This circular smooth muscle is designed not for peristalsis, but for constriction, actually narrowing the tube in a particular location. This helps to mix, m-i-x, mix things together. And that helps enhance digestion, later absorption. So the function of the circular sheet is mixing and

segmentation. Outside of the circular layer and running in a lengthwise or longitudinal way are the longitudinal sheets. These are the outermost smooth muscle layers, which basically bring about shortening of the tube and, therefore, an actual effort to advance things forward. Here's just a cardboard cylinder, and I've put on the surface some pink paper. This would illustrate the outer layer, which is L word. And then here, going in this fashion, is the innermost circular sheet. The innermost sheet basically just crimps and squeezes and segments. The longitudinal sheet contracts again in a wavic [phonetic] fashion and, therefore, actually produces a movement, which is known to you perhaps as peristalsis. This is not hard to visualize or appreciate. It's a bit like taking your hand around a garden hose. Got that idea? Hand around a garden hose. It's got water in it. And then just what? Squeeze down. What happens to the water? Spurts out. So the effort of the longitudinal layer brings about movement or propulsion, whereas contraction of the circular area basically just mixes and divides something we call segmentation of the contents. But do remember both of these are what sort of muscle? And, therefore, are they under the influence you think of the autonomic nervous system? Can they be modified by hormones or even, as we'll see in a moment, pressure and other factors? So, although these are quite capable of doing what they do, they're also subject to regulation. What I mean is their activity is not set. They can be accelerated or decelerated. And that means peristalsis can be slowed down or speeded up in ways that we're about to talk about. But still, fundamentally, what's the muscle? What kind of muscle? And smooth muscle is obviously not skeletal muscle. And that means it's capable of self-depolarization. And that's exactly what we see here. There are at strategic locations along the G.I. tract areas of smooth muscle, which are actually depolarizing and repolarizing at a particular set rate. And, therefore, these cells set the pace for the rest. What would you call a group of cells that is spontaneously depolarizing and repolarizing and, therefore, serves to set the pace for all the rest? They are called pacemaker cells. We've use that word before in the heart. And the meaning of the word is equally useful here. These are patches of smooth muscle cells, which are basically located in the circular or between the circular and longitudinal sheets. And their function is to spontaneously depolarize and repolarize; therefore, setting the inherent rhythm, the inherent contraction of the G.I. tract. And with that said, is your G.I. tract constantly in motion? Is it constantly contracting and moving things along 24/7? Of course. If you put a stethoscope on somebody's belly, can you hear things moving? If not, you've got problems because this is a nonstop thing. And material obviously then is being moved constantly from mouth to anus. So the pacemaker cells establish this basic pace, which then can be modified through the following influences. Item b then, peristaltic control. The first of many means to influence this basic rate comes from within the small intestine itself. A network of nerves called the myenteric plexus is basically sandwiched in between the circular layer and the longitudinal layer. And, in fact, this is called a nerve net because anatomically, it looks like the nerves are crisscrossed just like a kind of volleyball net. And this nerve net responds to the diameter of, that is the bulk within the small intestine. It responds to the pressure exerted by food and/or

gas. And think about it logically before we reveal what actually occurs. If we have an area where food is accumulating and, therefore, stretching the walls in that location, would you want the smooth muscle to relax and allow it to happen or contract and, therefore, help move things along? The latter. So this nerve net is sensitive to pressure, pressure as a result of food or gas, and basically leads to excitation of the smooth muscle, which helps to prevent obstruction or interruption in peristalsis. This is a spontaneous thing. It doesn't require the brain or any outside influence. The nerve net is essentially responding to the pressure of food and/or gas. We mentioned a moment ago, of course, that we would expect this smooth muscle to be controlled by the ANS. What's that? Autonomic nervous system. And so, would you expect and assume dual motor innervation? What does that mean, dual motor innervation? Sympathetic and parasympathetic. And before you jump to conclusions, I'm cautioning you. It's not as you might expect because sympathetic does not accelerate here. Sympathetic actually decelerates. Parasympathetic actually accelerates. And so, this effect, the autonomic effect, is going to determine the rate, that means the frequency, and to the degree of contraction and also the degree of secretion. So even though we are seemingly focused on motility, the autonomic nervous system also affects secretion. And here are, of course, the familiar relationships. Sympathetic, acting on beta-2 adrenergic receptors, will actually slow down. Slow down what? The P word, peristalsis, but also the S word, right there, secretion. So sympathetic action will slow peristalsis. It'll also decrease secretion of materials, enzymes along the G.I. tract. And naturally, you'd expect, and you'd be right, that parasympathetic acting through cholinergic receptors has the direct opposite. Meaning it does what to peristalsis? Speeds it up, makes it stronger, and also enhances the S word, enhances secretion. Indeed, this is reminded in the catchphrase for parasympathetic. We know the catchphrase for sympathetic. That was fight or flight. A catchphrase for parasympathetic was rest and digest or feed and breed, and so suggesting its positive influence on rate and secretion along the G.I. tract. So these influences are exerted on the smooth muscle and the intestinal lining. They are linked to and controlled by the hypothalamus and, therefore, under the influence of any number of so-called external receptors. That statement might be vague, but remember, the hypothalamus is part of the brain and, therefore, it's in the sense in touch with any and all activities in the brain or coming to the brain. Do we have a lot of extra internal stimuli which you know influence the brain? Certainly. We have visual stimuli. We have auditory stimuli. We have olfactory stimuli. We have gustatory stimuli. Where am I going with this? If you're driving down a lonesome highway and you see a billboard for Jumbo Jack, okay, McDonalds, fill in your favorite, and normally it's not a black-and-white billboard. I've never seen that. It's always full color with dewy lettuce and dewy tomatoes and dripping secret sauce and so forth. And why go to all the expense, the color, you know, photography? Like, whoa, whoa, whoa. Your eyes are on that and you're already imagining, you know, how wonderful it tastes and smells and feels in your mouth. And, you know, you just can't wait for the next offramp because, you know, your stomach is starting to growl. Is there a connection between

your brain and your gut? Yeah. And it operates through the what? The hypothalamus. So this fact is not lost on advertising, that is people know that color photography and all sorts of other stimuli can get you to think about and, therefore, purchase their product. Mentioned this earlier. Why do theaters pop their own popcorn? Why don't they just bring it in in the truckloads from the outside? They pop it right there because what? The minute you come in, smell, you make those connections. All right. Got to have some of that. Never mind that it's $10 a bag. Got to have it. So this is psychology, but it's also physiology, working through the hypothalamus. Now those are fairly familiar and easy enough to relate to. There are some hidden influences on peristalsis, hidden in the sense that they may not be familiar or otherwise common knowledge. And these are so-called G.I. hormones, gastrointestinal hormones. Important to emphasize this word "hormone," not an enzyme. Enzymes, as you know, are proteins, which are catalysts, organic catalysts, which break down or otherwise are involved in digestive processes. But these aren't enzymes. They're what? And the definition of a hormone, quite different. A hormone is a chemical compound produced here, wherever that is, and then goes into the bloodstream and then has its effect somewhere else, right. So hormones are produced here, circulate and have an effect somewhere else. That's the inherent definition of a hormone. Now the hormones we're about to list here are certainly probably not on your radar. That is, they're probably not hormones you've heard of because their action is limited to the G.I. tract. What's curious about these hormones is that they're produced by the G.I. tract and have an effect on the G.I. tract. But nevertheless, they're hormones. So these are hormones which are secreted by cells along the intestinal tract, especially the small intestine, and they have their effect after moving through the bloodstream. The have an effect here or there along this same system. There's a whole list of these. And you can go to your book or otherwise dig them out. But we're just going to give you three, the top three. And the first of those three was actually the first to be discovered. It's called gastrin. And gastrin was a good name because it apparently, what's it say here, it responds to. That means it reacts to protein arriving in the stomach. Now read no further and just think with me. If protein arrives in the stomach, what reaction or response would be appropriate? What would you want to be done if food, especially protein, arrives there in the stomach? Well, read on. This hormone, which responds to the presence of protein, actually promotes, that means causes, gastric secretion. That means the release of hydrochloric acid and pepsin, and also facilitates and steps up G.I. what? G.I. motility. Now this should make perfect sense. And although it might be surprising, this is for efficiency. Here's what I'm saying. Would it make sense for the stomach to secrete hydrochloric acid and pepsin 24/7? No, that wouldn't make sense because a lot of times, there's nothing in the stomach. So this is a way to synchronize, to synchronize and control the release of these products only when what arrives? Only when, in this case, protein actually arrives. So gastrin is a chemical signal which steps up the release of hydrochloric acid and, therefore, also mixes and brings these things together. So the significance of this and all these hormones is basically just to improve the efficiency, the

performance of this G.I. tract, which otherwise would be very inefficient. The next of three hormones that we'll mention is called secretin. It responds from acid, hydrochloric acid, which has come over into the small intestine. I mean, after all, where is this acid made? Stomach. Is it going to be pushed into the small intestine? Yes. So what would you hope or expect should happen when this acid moves out of the stomach and into the small intestine? What reaction would be appropriate? What do we want to do to this acid now that it's out of the stomach and moving along the small intestine? Well, here you are. The presence of acid, which has now arrived in the duodenum, will stimulate the release of this hormone. What is it? And secretin actually targets the pancreas, causing it to release HCO3. What's that? Bicarbonate. And at the same time, increase mixing and motility of the G.I. tract. Does this make sense? Is it logical? Is it purposeful? Is it a good thing? And so, what's the significance of this hormone? Think about it. If you didn't have that hormone, would acid still come over from the stomach? And what wouldn't happen would be the release of bicarbonate. And that would set the stage for what? Now we've got acid in the small intestine, which is much less equipped to deal with that. And that acid would breakdown, breakdown through the mucous layer and probably cause that dreaded condition, the U word, ulcers. And interestingly and not without some significance, this hormone is inhibited by nicotine. Just FYI. So let's put those ideas together. Nicotine found in cigarette smoke. So a smoker is obviously going to be inhibiting his or her release of? Secretin. Therefore, minimizing the release of? Therefore, setting the stage for or at least making it more likely that? We're going to have some ulcers. So I'm not saying smoking causes ulcers, but smoking certainly would aggravate an existing ulcer because, remember, if you don't neutralize that hydrochloric acid, then it's only going to be a loose cannon in the small intestine. Finally on this list of just three is CCK, which is actually pronounced cholecystokinin. Chole is a word for gallbladder. So is cysto. Kinin is something that stimulates. So it's a busy word, which we'll just reduce to CCK. It responds to what? Responds to the arrival of peptides and fats where? In the duodenum. And this hormone, well, let's stop and just sort of speculate. If peptides, which are small proteins, and fats arrive in the duodenum, what response would be appropriate? What do we want to happen now that these things have come into the small intestine? What are the agents involved in dealing with fat or, for that matter, peptides? Is there an enzyme that we know is involved in the hydrolysis of fat? And is there an emulsifier that we spoke of? So reading on, we find that this hormone stimulates the contraction of? The gallbladder. So let's stop there. If you contract the gallbladder, what's going to squirt out? What comes out? Bile. And bile contains the emulsifiers, which will help liquefy this f-a-t and, therefore, enhance the action. Reading on, this same hormone also stimulates the release of pancreatic enzymes. And what are the pancreatic enzymes? Well, we have those to break down peptide fragments. We have lipase for fat, and certainly we have even amylase. So this is making good sense because it helps time, it helps to synchronize the action of the gallbladder and the pancreas to the arrival of these things at that location. Read on. It also improves intestinal motility. Okay, that's good. It mixes

things up. And here's something somewhat paradoxical. It what? Reduces gastric contraction. Now that's odd. It even seems impossible because this same hormone stimulates contraction here, but it inhibits contraction here. Whoa. Now stimulating contraction of the intestine make sense because that'll at lease mix things up and help in the breakdown of these products. But why would you want to inhibit gastric contraction? Well, essentially, it's this. We want to act on this stuff, but we don't want the stomach to continue to contract because it takes time to do this, right. So hold off please. Give us some time. We'll work [inaudible]. Hold off on that. We're going – Get the idea? So even though it improves intestinal motility, it's prudent for it to block or reduce gastric contraction, therefore allowing time, t-i-m-e, for the action of these enzymes on the material. And finally and interestingly, it suppresses appetite. It causes something called satiety. Satiety is that sense of being full. And that might make some sense because after all, our fats and peptides pretty high on the caloric index. Yeah. So, in fact, historically, when this hormone was discovered, people got all excited, not everybody, but scientists did because anything that can do that, anything that can do that will be the Holy Grail of research because anything that can suppress what? You got a weight loss product that would really sell. So for a while, there was a lot of excitement. Turns out, it didn't work as a pharmacological agent, but it certainly connects with your own experience. In terms of cuisine, in terms of food that you eat, what are the kinds of food that give you that satiety, that sense of fullness? Carbs? No. Fats? Yeah. So a fatty meal tends to make you feel not only like you're full, but it tends to want to make you go to sleep. I don't know. Check it out this Thanksgiving and see what you – Sort of a little experiment on the side. I know after Thanksgiving, I just want to go to bed. In other words, that fat causes a high level of cholecystokinin, which, among other things, suppresses appetite and makes you sleepy. So moving along. Where do we go from here? We've talked about motility enough. Let's finish it up with absorption. After all, that's the purpose of this system. And we can start – Actually, we can skip the mouth. Why is there little absorption going on in the mouth? Well, food doesn't spend that much time there. And even if you kept food in there for eight hours just as an experiment, nothing much would happen. It's not really set up for absorption. And so, let's move right down to the stomach. Actually, that doesn't accomplish much absorption, and for the same reason as it's not very common in the mouth. The stomach is not really designed for absorption. Maybe 2%, but the reason that it's not geared up for absorption is that it's really not anatomically designed to do that. There's no special transport mechanism in place. Most molecules at this point are too big and/or too polar. And, therefore, they just don't get absorbed. So this puts into question the importance of the stomach. And we already dismissed it as not very important at all. In other words, people think the stomach is important in digestion. That's not true. Is it important in absorption? No. So its importance is mainly as a holding tank, a holding tank which at least begins the process of protein hydrolysis. But you can live without a stomach, and many people do. Really? Are there people who actually pay money to have their stomach, their perfectly good stomach removed or at least largely reduced in size? Yeah.

And this is a popular, one of many popular sort of bariatric procedures because if you shrink the size of your stomach, guess what? You can't eat as much because you just don't have the room to do it. People try, and, in fact, they can overcome that with years of cramming food down there. In other words, that tiny little golf ball of a stomach can be stretched out over time if you're really serious about it, and some people are. But after all, if you're going to reduce the size your stomach, why not take advantage of that. Anyway, don't get me started on that. So in short, stomach, not so much absorption. The only thing that the stomach is actually very good at absorbing is alcohol. And that's almost just a coincidence. Alcohol is non-polar and, therefore, can be readily absorbed in the blood supply of the stomach. And this is common knowledge. That is, on an empty stomach, do you tend to get inebriated quicker with a beer or two? Now some of you say, well, I don't know. I've never actually had any alcohol, but some of you have. So you can testify to the fact that an empty stomach does promote absorption of alcohol pretty quick, which is neither here nor there, but let's move on. Number two, the small intestine is where 98% of the absorption occurs because this is where 98% of the digestion occurs. But let's keep in mind what has to happen first. Before we can have absorption, we have to have digestion. And that would include the following. Everything that we eat that we call carbohydrate is going to be broken down, hydrolyzed one way or another to simple sugars, and those simple sugars are now available for absorption. There are two mechanisms for absorption. One is facilitated diffusion, which we discussed in unit one. The best-known carbohydrates, the best-known simple sugar in this category is fructose. Facilitated diffusion, does that use a carrier? Yes. Does it go up a concentration gradient? No. So this is limited to moving from a high concentration to a low concentration. Surprisingly, but yet maybe not so much, glucose is also a simple sugar. But in this location at least, it is transported by active transport. And just to remember, what is the beauty or advantage of active transport over something called facilitated diffusion? It can go against a concentration gradient. So even though the blood sugar level might be high, glucose is still going to leave the gut and still go into the blood, even though it might be high. This is, of course, natural and appropriate because is glucose a valuable commodity? Would we want any glucose to remain in the feces? No. So there's very little glucose in the feces because all of it has been absorbed by active transport. This is logical and good, except in diabetics where it still works, but it's no longer good. I hate to jump out of context, but what's the number one symptom of an uncontrolled diabetic? High blood sugar. And in that case, would you want glucose to come from the food into that already high area? No. But it's going to happen anyway. So this doesn't know the patient has diabetic conditions. But my point is this is active transport, which uses energy and moves against a concentration gradient. The same can be said for amino acids, and the same argument can be used. Would you want amino acids to be in the feces? I mean, no. I mean, after all, where did these amino acids come from? They came from protein. Where'd that come from? The food. That was expensive food. So why break it down only to poop it away? I mean, doesn't make any sense. So this is

active transport, meaning that it moves against a concentration gradient. Now fats are handled quite a bit differently. Fats come from, of course, many dietary sources, but they are hydrolyzed ultimately into fatty acids and glycerol. And this turns out to be absorbed not by active, but by passive means, from a high concentration in the gut to a relatively low concentration in the lacteals. Notice that word. This is an anatomical fact. Fat molecules do not go directly into the bloodstream. They go first into the lacteals, and then they worked their way through the thoracic duct into the liver and so forth. That's just an anatomical fact. And, of course, what enhances the breakdown of fat is not only lipase, but just to remind you, it's also a function of the emulsifiers, the bile salts, which are secreted by the gallbladder and important in the process of digesting fat. This remark here is just an interesting comment that bile salts, which work early in the G.I. tract up by the duodenum, are not eliminated in the feces. They're actually reabsorbed in the final segments. So bile salts are recycled. That means reused over and over again. This diagram comes from your book, and it's not really worth memorizing or anything, but it's a kind of graphic, pictorial look at what we're talking about. Here's a very large fat droplet. Remember, fat is by definition not soluble in water. And so, the first things that act upon fat are bile salts, including lecithin. And so, now this big droplet is broken down into tiny pieces. This is still fat though. It's a bit like taking a bowling ball and hitting it with a sledgehammer until you have a bunch of pieces. It's still a bowling ball, but it's just small pieces. Now these small, much smaller particles of fat can be acted upon by lipase. And what does lipase do? It breaks down fat into fatty acids and glycerol. And so, now these products of hydrolysis will be absorbed. That means they'll move passively into the intestinal cell. But here's the interesting thing, and it's paradoxical. What do I mean? We went to all this trouble to break down fat into what? Into fatty acids and glycerol. And then on their way through the columnar epithelial cell, they reform into what? Fat. And that's just because it can't be helped. So it's odd that we went to all this trouble to break fat down into fatty acids and glycerol, only to have them recombine and form fat and, therefore, make them unable to be absorbed in the blood, but they are at least welcomed and absorbed by the lacteals. So this is kind of the odd truth about fat. Nevertheless, it's absorbed. And that occurs mainly in the small intestine. What else is worthy or noteworthy in the absorption category are vitamins. By definition, vitamins are those things that are necessary for proper metabolism. We mentioned early on that vitamins come in two forms. Maybe you know this from other classes. There are those vitamins that are soluble in water. They're called water-soluble. And those that are not, those are called fat-soluble. So let's speak a bit about vitamins. Even though we're not going to get terribly specific, let's treat it as a broad category for discussion. Almost all vitamins are absorbed passively. That means from a high concentration in the gut to a low concentration in the bloodstream or lymphatic system. And the water-soluble vitamins are obviously dependent upon water. That is, if water doesn't get absorbed, they don't get absorbed. And those vitamins include all of the B vitamins, well, most of the B vitamins and vitamin C. Then there are the fat-soluble vitamins, and the same comment

applies. They are by definition what? Fat-soluble; therefore, fat doesn't get absorbed. Guess what? They don't get absorbed. In other words, fat-soluble vitamins depend upon fat absorption for their own absorption. And why is that important? Well, anything that would block fat absorption would, therefore, block the absorption of these vitamins. And although there are specific and important functions for each of these, which vitamin in this list anyway has meaning for us in this particular unit? Which vitamin did we zero in on or had something to say about? Vitamin K. So there, you can piece together a scenario. If we block fat absorption, we're going to minimize the absorption of vitamin K, among others. And that would inhibit or otherwise have repercussions on what? The production of prothrombin and, therefore, less chance for coagulation. So naturally trifling with these vitamins has repercussions. And you could make a case for any of these vitamins because they have their own specific important biological functions. As you know, maybe vitamin D, very important in calcium absorption and, therefore, bone health and on and on. Now the exception to everything we just said is the curious B vitamin called B12. Unlike the other B vitamins, it is not absorbed passively, but rather is the only known vitamin that depends upon active transport. And why that is, I don't know, but it is nevertheless true. Vitamin B12 has to combine with a so-called intrinsic factor, which is actually made by the stomach and, therefore, enables its active transport later in the G.I. tract. Now why is this important? Well, you can put together another scenario. Where's this intrinsic factor come from? The stomach. So what about these folks, what about somebody who's removed some of their stomach? They're not going to have much of this what? Intrinsic factor; therefore, they're not going to be able to absorb vitamin B12. Okay, so what? Well, the missing fact or information from our story is that vitamin B12 is very important in producing precursors to DNA synthesis, all right. So what? Here's the story. No intrinsic factor, no absorption of? No absorption of vitamin B12; therefore, cells can't make DNA. And DNA replication is necessary for the M word. What's that? M word, m word, mitosis. All right, so back up. No intrinsic factor, no absorption of B12, no synthesis of DNA, no M word. And what tissue is so dependent on cell division to restore or replace cells on a daily basis? Bone marrow. That's what I'm thinking of. And what does red bone marrow make? All right. So now we can piece this whole thing together. Where are we going? If you can't make red blood cells, what's the simple street name for that? There is a street name. It's called anemia, right. And so, this is actually called pernicious anemia, which is traceable to a lack of this intrinsic factor. Now you might say, well, okay, that's not a problem. I'll just go buy some vitamin B12. Well, you can. But remember, without what, without the what? You're not going to absorb it anyway. So save your money. If you've ever been diagnosed with pernicious anemia, they're not going to give you a pill for this, but they are necessarily going to give you B12. And B12 can't be taken orally because of the basic problem, which is linked to the intrinsic factor. So how do you get B12 in the body if not through the mouth? Injection, an intramuscular injection. So B12 is a bit of a curiosity, but nevertheless important for cell mitosis, including, among others, the RBCs. Finally now,

the large intestine. We visited that a moment ago with little attention to its secretion because not much is secreted there, other than mucus. And so, we have little to say here too. That is, its function is relegated to water absorption and also electrolyte absorption, especially the following: sodium. What's that next one? Potassium and CA plus 2. That's calcium. All of these are controlled not by passive means, but what? Active means. Now that needs to be emphasized and appreciated because what's the beauty of active transport, the one that you know? Active transport can go against a concentration gradient. Okay, that's good. The other thing about active transport is that it can be adjusted. We can ratchet it up. We can ratchet it down. And, therefore, at times, sodium is reabsorbed a lot; at times, it's not. And so, really, if we reflect on those ideas, the large intestine doesn't just sit there and allow things to happen. It actually regulates the uptake, the absorption and, therefore, the concentration of these electrolytes, provided it has time to do that. And that's worth stressing again. If things are moving through quickly, what's not going to happen? If motility is too rapid, this just isn't going to have time to happen. So even though we've not finish this, what is the devastating effect of diarrhea? We're not going to have opportunity to absorb or control these electrolytes. And also, therefore, we're not going to have opportunity to sufficiently return what? Water. Because water in the end is absorbed just as it always is, by osmosis. And we make this remark, osmosis follows the active absorption of solutes, including in mainly these electrolytes. So simply put, if the electrolytes are not being absorbed, then what's not going to follow or be absorbed as a consequence is water. So needless to say, this would disturb electrolyte and water balance and can be considerably problematic, which incidentally is exactly what happens, through no fault of their own, in people who have had to have their large intestine removed. Why would you take your large intestine out? Well, you wouldn't. But why do some people live regrettably without a large intestine? Cancer. And, therefore, as you know, they have an appliance which is stuck on their abdomen, and they're constantly defecating into a bag. It's called a colostomy bag. Now never mind the lifestyle that that obviously involves. Are there issues there? Are you jeopardizing electrolyte and water balance? Number one problem. So you can see that the large intestine deserves our respect if only for these two things. And then finally, we mentioned already these pro, what are the probiotics, which live down here and crank out, among other things, important vitamins like vitamin K. The reason this is worth mentioning is that many people over indulge in anti, antibiotics. And that's because they're uneducated. That is, they'll go in with a viral head cold and they'll insist on what? I've got to have antibiotics. And the practitioner says, well, you know, this is not a bacterial disease. This is a viral disease. Sorry. I'm not leaving here without antibiotics. And so, we prescribe what? Antibiotics. Does it do them any good? No. But it kills off these what? These resident bacteria. Not only that, and I hate to get way off track, but this obviously stimulates the advanced evolution of these bacteria. So do the bacteria evolve and develop resistance to these antibiotics, and are we in a world of trouble already because of that? Yeah. Well, anyway, sorry. So the vitamins produced here by the bacteria are

useful. The most important one is vitamin K, which we've already stressed. Now finally, and I don't know if it's on here or not. I guess it's not. There are a lot of materials that arrive in the large intestine which are not digestible and, therefore, form the bulk of what we call feces. Actually, a lot of people think of feces as waste products, but they're really not. They're mostly things that couldn't be digested or actually cells of your G.I. tract, including a lot of bacteria. What's my point? We hear a lot about fiber. Is fiber good? Well, fiber includes soluble and insoluble commodities that can't be digested, and fiber creates bulk, b-u-l-k. And, therefore, the large intestine has something to do, namely to move it along. Diet low in fiber tends to create problems with motility, but it also tends to allow the cells of the large intestine to be exposed to materials, carcinogens, mutagens, which otherwise might be absorbed by the fiber, right. So what's the link I'm trying to make? What is a prevailing kind of cancer that's related to or at least connected to fiber in the diet? Colon cancer. And why is colon cancer on the rise in this country? Because we eat stuff which doesn't have a lot of F word, fiber. Fiber is a physical barrier to the absorption and contact of these toxins on the cells of the G.I. tract. So that's just a final footnote on the importance of fiber in the diet and the action on the large intestine. So we are done. And yeah, we have a decent ten minutes or so. So let's take advantage of it.