CERTIFIED HEALTH & NUTRITION COUNSELOR ONLINE COURSE - SESSION 5:

- **DIGESTION, ABSORPTION, AND TRANSPORT**

Lynn, age one, is playing with her mother's necklace of glass beads. As one-year-olds do, she puts it in her mouth and chews on it. The necklace breaks, and Lynn puts the beads into her mouth one by one and swallows them. An hour later her mother finds her with only a few of the hundred beads left on the table. In a panic, her mother calls the doctor. "Doctor," she says, "my daughter has just swallowed a necklace!" "Don't panic," says the doctor. "What was the necklace made of?" "Glass beads," says the mother. "That's all right then," says the doctor. "You'll get them back. Just watch her diapers for a day or so."

One of the beauties of the digestive tract is that it is selective. Materials that are nutritive for the body are broken down into particles that can be assimilated into the bloodstream. Those that are not are left undigested and pass out the other end of the digestive tract. In a sense, the human body is doughnut-shaped, and the digestive tract is the hole through the doughnut. You can drop beads through the hole indefinitely, and they will never enter the body of the doughnut. Two days after Lynn swallowed them, her mother has recovered and restrung all the beads – and is again wearing the necklace.

The Problems of Digestion

Should you ever accidentally swallow a necklace, you would be protected from any serious consequences by the design of your digestive tract. The system solves many problems for you without your having to make any conscious effort. In fact, the digestive tract is the body's ingenious way of getting the nutrients ready for absorption. Let's consider the problems that are involved:

1. Human beings breathe as well as eat and drink through their mouths. Air taken in through the mouth must go to the lungs; food and liquid must go to the stomach. The throat must be arranges so that food and liquid do not travel to the lungs.
2. Below the lungs lies the diaphragm, a dome of muscle that separates the upper half of the major body cavity from the lower half. Food must be conducted through this wall to reach the abdomen.
3. To pass smoothly through the system, the food must be ground to a paste and must be lubricated with water. Too much water would cause the paste to flow too rapidly; too little would compact it too much, which could cause it to stop moving. The amount of water should be regulated to keep the intestinal contents at the right consistency.
4. When digestive enzymes are working on food, it should be very finely divided and suspended in a watery solution so that every particle will be accessible. Once digestion is complete and all the needed nutrients have been absorbed out of the tract into the body, only a residue remains, which is excreted. It would be both wasteful and messy to excrete large quantities of water with this residue, so some water should be withdrawn, leaving a paste just solid enough to be smooth and easy to pass.
5. The materials within the tract should be kept moving, slowly but steadily, at a pace that permits all reactions to reach completion. The materials should not be allowed to back up, except when a poison or like substance has been swallowed. At such a time the flow should reverse, to get rid of the poison by the shortest possible route (upward). If infection sets in farther down the tract, the flow should be accelerated, to speed its passage out of the body (downward).
6. The enzymes of the digestive tract are designed to digest carbohydrate, fat, and protein. The walls of the tract, being composed of living cells, are made of the same materials. These cells need protection against the action of the powerful juices that they secrete.
7. Once waste matter has reached the end of the tract, it must be excreted, but it would be inconvenient and embarrassing if this function occurred continuously. Provision must be made for periodic, voluntary evacuation when convenient.

The following sections show how the body solves these problems, with elegance and efficiency.

Anatomy of the Digestive Tract

The gastrointestinal (GI) tract is a flexible muscular tube measuring about 26 feet in length from the mouth to the anus. The voyage of the glass beads traces the path followed by food from one end to the other.

When Lynn swallowed the beads, they first slid across her epiglottis, bypassing the entrance to her lungs. This is the body's solution to problem 1: whenever you swallow, the epiglottis closes off your air passages so that you do not choke.

Next the beads slid down the esophagus, which conducted them through the diaphragm (problem 2) to the stomach. There they were retained for a while. The cardiac sphincter at the entrance to the stomach closed behind them so that they could not slip back (problem 5). Then one by one they popped through the pylorus into the small intestine, and the pylorus, too, closed behind them. At the top of the small intestine they bypassed the opening (entrance only, no exit) from a duct (the common bile duct), which was dripping fluids (problem 3) into the small intestine from tow organs outside the GI tract – the gallbladder and the pancreas. They traveled on down the small intestine through its three segments – the duodenum, the jejunum, and the ileum – a total of 20 feet of tubing coiled within the abdomen.

Having traveled through these segments of the small intestine, the beads arrived at another sphincter (problem 5 again) – the ileocecal valve, at the beginning of the large intestine (colon) in the lower right-hand side of the abdomen. As the beads entered the colon they passed another opening. Had they slipped into this opening they would have ended up in the appendix, a blind sac about the size of your little finger. They bypassed it, however, and traveled along the large intestine up the right-hand side of the abdomen, across the front to the left-hand side, down to the lower left-hand side, and finally below the other folds of the intestines to the back side of the body, above the rectum.

During passage through the colon, water was withdrawn, leaving semi-solid waste (problem 4). The beads were held back by the strong muscles of the rectum. When it was time to defecate, this muscle relaxed (problem 7), and the last sphincter in the system, the anus, opened to allow their passage.

To sum up, the path followed by the beads is as shown in the box below. This is not a very complex route, considering all that happens on the way.

Epiglottis
↓
Esophagus
Diaphragm
Cardiac Sphincter
↓
Pylorus
↓
Common bile duct
↓
Duodenum, jejunum, ileum
↓
Ileocecal valve
Colon
↓
Appendix
↓
Rectum
↓
Anus

GI Tract

The GI tract is the gastrointestinal tract or alimentary canal; the principal organs are the stomach and intestines.
Gastro = stomach
Aliment = food

The Involuntary Muscles and the Glands

You are usually unaware of all the activity that goes on between the time you swallow and the time you defecate. As is the case with so much else that goes on in the body, the muscles and glands of the digestive tract meet internal needs without your having to exert any conscious effort to get the work done.

Chewing and swallowing are under conscious control, but even in the mouth there are some automatic processes you have no control over. The salivary glands squirt just enough saliva to moisten each mouthful of food so that it can pass easily down your esophagus (problem 3). After a mouthful of food has been swallowed, it is called a bolus.

At the top of the esophagus, peristalsis begins. The entire GI tract is ringed with muscles that can squeeze it tightly. Within these rings of muscle lie longitudinal muscles. When the rings tighten and the long muscles relax, the tube is constricted. When the rings relax and the long muscles tighten the tube bulges. These actions follow each other so that the intestinal contents are continuously pushed along (problem 5). (If you have ever watched a lump of food pass along the body of a snake, you have a good picture of how these muscles work.) The waves of contraction ripple through the GI tract all the time, at the rate of about three a minute, whether or not you have just eaten a meal. Peristalsis, along with the sphincter muscles that surround the tract at key places, prevents anything from backing up.

The intestines not only push but also periodically squeeze their contents at intervals – as if you had put a string around them and pulled it tight. This motion called segmentation, forces their contents backward a few inches, mixing them and allowing the digestive juices and the absorbing cells of the walls to make better contact with them.

Four major sphincter muscles divide the tract into its principal divisions. The cardiac sphincter prevents reflux of the stomach contents into the esophagus. The pyloric sphincter, which stays closed most of the time, prevents backup of the intestinal contents into the stomach and also holds the bolus in the stomach long enough so that it can be thoroughly mixed with gastric juice and liquefied. At the end of the small intestine, the ileocecal valve performs a similar function. Finally, the tightness of the rectal muscle is a kind of safety device; together with the anus, it prevents elimination until you choose to perform it voluntarily (problem 7).

Besides forcing the bolus along, the muscles of the GI tract help to liquefy it so that the digestive enzymes will have access to all the nutrients in it. The first step in this process takes place in the mouth, where chewing, the addition of saliva, and the action of the tongue reduce the food to a coarse mash suitable for swallowing. A further mixing and kneading action then takes place in the stomach.

Of all parts of the GI tract, the stomach has the thickest walls and strongest muscles; in addition to the circular and longitudinal muscles, it has a third layer of transverse muscles that also alternately contract and relax. While these three sets of muscles are all at work forcing the bolus downward, the pyloric sphincter usually remains tightly closed, preventing the bolus from passing into the duodenum. Meanwhile, the gastric glands release juices that mix with the bolus. As a result, the bolus is churned and forced down, hits the pylorus, and bounces back. When the bolus is thoroughly liquefied, the pylorus opens briefly, about three times a minute, to allow small portions through. From this point on, the intestinal contents are called chyme. They no longer resemble food in the least.

Gastric Glands

Gastric glands are exocrine glands in the stomach wall that secrete gastric juice into the stomach.
Gastro = stomach

Chyme (KIME)

Chyme is the semiliquid mass of partly digested food expelled by the stomach into the duodenum

Organs that Secrete Digestive Juices

1. Salivary glands
2. Gastric glands (stomach)
3. Pancreas
4. Liver
5. Intestinal glands
6.

Gland

A gland is a cell or group of cells that secretes materials for special uses in the body. Glands may be exocrine glands, secreting their materials "out" (into the digestive tract or onto the surface of the skin) or

endocrine glands, secreting their materials “in” (into the blood).
Exo = outside
Endo = inside
Krine = to separate

Salivary Glands
The salivary glands are exocrine glands.

Bolus (BOH-lus)
A bolus is the portion of food swallowed at one time.

Peristalsis (peri-STALL-sis)
Peristalsis is successive waves of involuntary muscular contraction passing along the walls of the intestine.
Peri = around
Stellein = wrap

Segmentation
Segmentation is a periodic squeezing or partitioning of the intestine by its circular muscles.

Miniglossary of GI Terms

- **Epiglottis (epp-ee-GLOTT-iss)** - The Epiglottis is the cartilage in the throat that guards the entrance to the trachea and prevents fluid or food from entering it when a person swallows.
  Epi = upon (over)
  Glottis = back of tongue
- **Trachea (TRAKE-ee-uh)** - The trachea is the windpipe.
- **Esophagus (e-SOFF-uh-gus)** - The esophagus is the food pipe.
- **Cardiac Sphincter (CARD-ee-ack SFINK-ter)** - The cardiac sphincter is the sphincter muscle at the junction between the esophagus and the stomach.
  Cardiac = the heart
- **Sphincter** - A sphincter is a circular muscle surrounding and able to close a body opening.
  Sphincter = band (binder)
- **Pylorus (pie-LORE-us)** - The pylorus is a sphincter muscle separating the stomach from the small intestine.
  Pylorus = gatekeeper
- **Duodenum (doo-oh-DEEN-um, doo-ODD-num)** - The duodenum is the top portion of the small intestine (about “12 fingers’ breadth” long, in ancient terminology).
  Duodecim = twelve
- **Jejunum (je-JOON-um)** - The jejunum is the first two-fifths of the small intestine beyond the duodenum.
- **Ileum (ILL-ee-um)** - The ileum is the last segment of the small intestine.
- **Ileocecal (ill-ee-oh-SEEK-ul) valve** - The Ileocecal valve is a sphincter muscle separating the small and large intestines.
- **Colon (COAL-un)** - The colon is the large intestine. Its segments are the ascending colon, the transverse colon, the descending colon, and the sigmoid colon.
  Sigmoid = shaped like the letter S (sigma in Greek)
- **Appendix** - The appendix is a narrow blind sac extending from the beginning of the colon; a vestigial organ with no known function.
- **Rectum** - The rectum is the muscular terminal part of the intestine, from the sigmoid colon to the anus.
- **Anus (AY-nus)** - The anus is the terminal sphincter muscle of the GI tract.

The Process of Digestion

One person eats nothing but vegetables, fruits, and nuts; another, nothing but meat, milk, and potatoes. How is it that they wind up with essentially the same body composition? It all comes down to the fact, of course, that the body renders food – whatever it is to start with – into the basic units that carbohydrate, fat, and protein are composed of. The body absorbs these units and builds its tissues from them. The final problem of the GI tract is to digest the food.

For this purpose five different body organs secrete digestive juices; the salivary glands, the stomach, the small intestine, the liver, and the pancreas. Each of the juices has a turn to mix with the intestinal contents and promote their breakdown to small units that can be absorbed into the body.

Saliva contains not only water and salts, but also amylase, an enzyme that breaks bonds in the straight chains of starch. The digestion of starch thus begins in your mouth. In fact, you can taste the change if you choose. Starch has very little taste, but some maltose is released, conveying a subtly sweet flavor that you may associate with malted milk. If you hold a piece of starchy food like white bread in your mouth without swallowing it, you can taste it getting sweeter as the enzyme acts on it. Saliva also protects the tooth surfaces and linings of the mouth, esophagus, and stomach from attack by molecules that might harm them.

Digestion in the Mouth

Carbohydrate	Starch/amylase/maltose
Fat	No chemical action
Protein	No chemical action
Vitamins	No chemical action
Minerals	No chemical action
Water	Added
Fiber	No chemical action

Gastric juice is composed of water, enzymes, and hydrochloric acid. The acid is so strong (pH 2 or below) that if it chances to reflux into the mouth, it burns the throat. The strong acidity of the stomach prevents bacterial growth and kills most bacteria that enter the body with food. It would kill the cells of the stomach as well, but for their natural defenses. To protect themselves from gastric juice, the cells of the stomach wall secrete mucus, a thick, slimy, white polysaccharide that coats the cells, protecting them from the acid and enzymes that would otherwise digest them (problem 6).

Saliva

Salifa is the secretion of the salivary glands; the principal enzyme is salivary amylase.

Amylase (AM-uh-lace)

Amylase is an enzyme that hydrolyzes amylose (a form of starch). An older name for salivary amylase is ptyalin (TY-uh-lin).

Hydrolyze (HIGH-dro-lize)

To hydrolyze is to split by hydrolysis.

<u>Caution</u>:

It should be noted here that the strong acidity of the stomach is a desirable condition – television commercials for antacids notwithstanding. A person who overeats or who bolts her food is likely to suffer from indigestion. The muscular reaction of the stomach to unchewed lumps or to being overfilled may be so violent as to cause regurgitation (reverse peristalsis, another solution to problem 5). When this happens, the overeater may taste the stomach acid in her mouth and think she is suffering from “acid indigestion.” Responding to TV commercials, she may take antacids to neutralize the stomach acid. The consequence of this action is a demand on the stomach to secrete more acid to counteract the neutralizer and enable the digestive enzymes to do their work. So the consumer ends up with the same amount of acid in her stomach but has had to work against an antacid to produce it.

Antacids are not designed to relieve the digestive discomfort of the hasty eater. Their proper use is to correct an abnormal condition, such as that of the ulcer patient whose stomach or duodenal lining has been attacked by acid. Antacid misuse is similar to the misuse of diuretics. To avoid falling into the same trap as our misguided consumer, remember that what such a person needs to do is to chew food more thoroughly, eat it more slowly, and possibly eat less at a sitting.

Gastric Juice

Gastric juice is the secretion of the gastric glands. The principal enzymes are rennin (curdles milk protein, casein, and prepares it for pepsin action), pepsin (acts on proteins), and lipase (acts on emulsified fats).

A pH of 2

A pH of 2 is 1,000 times stronger than a pH of 5.

Mucus (MYOO-cuss)

Mucus is a muco-polysaccharide (relative of carbohydrate) secreted by cells of the stomach wall. The cellular lining of the stomach with its coat of mucus is known as the mucous membrane. (The noun is mucus; the adjective is mucous.)

Pepsin

Pepsin is a gastric protease. It circulates as a precursor, pepsinogen, and is converted to pepsin by the action of stomach acid.

All proteins are responsive to acidity; the stomach enzymes work most efficiently in a fluid of pH 2 or lower. However, salivary amylase, which is swallowed with the food, does not work in acid this strong, so the digestion of starch gradually ceases as the acid penetrates the bolus. In fact, salivary amylase becomes just another protein to be digested; its amino acids end up being absorbed and recycled into other body proteins.

The major digestive event in the stomach is the hydrolysis of proteins. Both the enzyme pepsin and the stomach acid itself act as catalysts for this reaction. Minor events are the hydrolysis of some fat by a gastric lipase, the hydrolysis of sucrose (to a very small extent) by the stomach acid, and the attachment of a protein carrier to vitamin B_{12}.

Digestion in the Stomach

Carbohydrate	Minor action
Fat	Minor action
Protein	Pepsin/HCL/Smaller polypeptides
Vitamins	Minor action
Minerals	No chemical action
Water	Added
Fiber	No chemical action

Intestinal Juice

Intestinal juice is the secretion of the intestinal glands; contains enzymes for the digestion of carbohydrate and protein and a minor enzyme for fat digestion

Pancreatic (pank-ree-AT-ic) Juice

Pancreatic juice is the exocrine secretion of the pancreas, containing enzymes for the digestion of carbohydrate, fat, and protein. (The pancreas also has an endocrine function, the secretion of insulin and other hormones.) Juice flows from the pancreas into the small intestine through the pancreatic duct.

By the time food has left the stomach, digestion of all three energy nutrients has begun. But the action really gets going in the small intestine, where three more digestive juices are contributed. Glands situated in the intestinal wall secrete a watery juice containing all three kinds of digestive enzymes – carbohydrases, lipases, and proteases – and others as well. In addition, both the pancreas and the liver make contributions by way of ducts leading into the duodenum. The pancreatic juice also contains enzymes of all three kinds, plus others.

Food evidently needs to be digested completely. The sharing of the task by several organs underscores the body's determination to get the job done. If the pancreas fails, the intestine can still do its share; if the intestine fails, the pancreas can substitute, at least in part. Such distribution of labor is seen in nature whenever the job to be done is absolutely vital, as it is in this case.

In addition to enzymes, the pancreatic juice contains sodium bicarbonate. The pancreatic juice joins the intestinal contents just after they leave the stomach, and the bicarbonate neutralizes the acidic chyme as it enters the small intestine. From this point on, the contents of the digestive tract are at a neutral or slightly alkaline pH. The enzymes of both the intestine and the pancreas work best at this pH.

Bile, a secretion from the liver, also flows into the duodenum. The liver secretes this material continually, but it is needed only when fat is present in the intestine. The bile is concentrated and stored in the gallbladder, which squirts it into the duodenum on request. Bile is not an enzyme but an emulsifier; it brings fats into suspension in water so that enzymes can work on them. Thanks to all these secretions, all the energy nutrients are digested in the small intestine.

When the Pancreas Fails
When the pancreas fails, fat digestion is seriously impaired, since the intestine has no major lipase.

Bicarbonate
Bicarbonate is an alkaline secretion of the pancreas, part of the pancreatic juice. (Bicarbonate also occurs widely in all cell fluids.)

Bile
Bile is an exocrine secretion of the liver (the liver also performs a multitude of metabolic functions). Bile flows from the liver into the gallbladder, where it is stored until needed.

Gallbladder
The gallbladder is the organ that stores and concentrates bile. When it receives the signal that fat is present in the duodenum, the gallbladder contracts and squirts bile down the bile duct.

Digestion in the Small Intestine

Carbohydrate	All carbohydrates/Enzymes/Monosaccharides
Fat	All fats/Bile/Emulsified fats
Protein	Emulsified fats/Enzymes/Monoglycerides or glycerol and fatty acids
Vitamins	No chemical action
Minerals	No chemical action
Water	Added
Fiber	No chemical action

Caution:
Most proteins are broken down to dipeptides, tripeptides, and amino acids before they are absorbed. With this in mind, you will be in a position to refute certain untrue claims made about foods – for instance, "Don't eat Food A. It contains an enzyme B that will harm you." Any enzyme you eat becomes but one among thousands of different proteins in your digestive tract. Except for the digestive enzymes whose design prevents them from being digested while they work, enzymes you eat are simply proteins that are broken down to amino acids identical to those from the other proteins you eat. Your body cannot tell the source of a particular amino acid any more than it can tell where its vitamin C comes from. Don't be fooled by claims that imply that enzymes you eat will not be digested by the body.

Intestinal Flora
The bacterial inhabitants of the GI tract are known as the intestinal flora.
Flora = plant growth

Minerals and Vitamins
Some minerals and vitamins are slightly altered during digestion. Iron is reduced in the stomach acid to its ferrous state; Vitamin B_{12} is picked up by a carrier, intrinsic factor.

The intestine, being neutral, permits the growth of bacteria. In fact, a healthy small intestine supports a thriving bacterial population that normally does the body no harm and may actually do some good. Bacteria in the GI tract produce a variety of vitamins; two of them (biotin and vitamin K) may, on occasion, be of significance to the person surrounding the GI tract. (For example, we sometimes rely on some of the vitamin K our bacteria have produced for us.) Provided that the normal intestinal flora are thriving, infectious bacteria have a hard time getting established and launching an attack on the system.

The small intestine – and in fact the entire GI tract – also manufactures and maintains a strong arsenal of defenses against foreign invaders. Several different kinds of defending cells are present there and confer specific immunity against intestinal diseases.

The story of how food is broken down into nutrients that can be absorbed is now nearly complete. All that remains is to recall what is left in the GI tract. The three energy nutrients – carbohydrate, fat, and protein – are the only ones that must be disassembled to basic building blocks before they are absorbed. The other nutrients – vitamins, minerals, and water – are mostly absorbable as is. The function of undigested residues, such as some fibers, is not to be absorbed but rather to remain in the digestive tract, mainly to provide a semisolid mass that can stimulate the muscles of the tract so that they will remain strong and perform peristalsis efficiently. Fiber also retains water, keeping the stools soft, and carries bile acids, sterols, and fat with it out of the body.

Absorption in the Small Intestine

Carbohydrate	Almost completely absorbed (as basic units)
Fat	Almost completely absorbed (as basic units)
Protein	Almost completely absorbed (as basic units)
Vitamins	Almost completely absorbed
Minerals	Mostly absorbed
Water	Remains
Fiber	Remains

The process of absorbing the nutrients into the body presents its own problems, to be discussed in the next section. For the moment, let us assume that the digested nutrients simply disappear from the GI tract as soon as they are ready. Virtually all are gone by the time the contents of the GI tract reach the end of the small intestine. Little remains but water, a few dissolved salts and body secretions, undigested materials such as fiber, and an occasionally glass bead. These enter the large intestine (colon).

In the colon, intestinal bacteria degrade some of the fiber to simpler compounds. The colon itself actively retrieves from its contents the materials that the conservative body is designed to recycle – much of the water and the dissolved salts (problem 4).

Absorption in the Colon

Minerals	Reabsorbed
Water	Some reabsorbed
Fiber	Some digested by bacteria; some remains

The Problem of Absorption

Problem: Given an elaborate production in which 1,000 actors are on stage at once, provide a means by which all can exit simultaneously. This is the problem of absorption. Within three or four hours after you have eaten a dinner of beans and rice (or spinach lasagna, or steak and potatoes) with vegetable, salad, beverage, and dessert, your body must find a way to absorb some two hundred thousand million, million, million amino acid molecules one by one, and an equivalent number of monosaccharide, monoglyceride, glycerol, fatty acid, vitamin, and mineral molecules as well.

For the stage production, the manager might design multiple wings that all the actors could crowd into, a dozen at a time. A mechanical genius might somehow design moving wings that would actively engulf the actors as they approached. The absorptive system is no such fantasy; in 20 feet of small intestine it provides a surface whose extent is comparable to a quarter of a football field in area where the nutrient molecules can make contact and be absorbed. To remove them rapidly and provide room for more to be absorbed, a rush of circulation continuously bathes the underside of these surfaces, washing away the absorbed nutrients and carrying them to the liver and other parts of the body.

The Absorptive System

The small intestine is a tube about 20 feet long and an inch or so across. Its inner surface looks smooth and slippery, but viewed through a microscope, it turns out to be wrinkled into hundreds of folds. Each fold is covered with thousands of nipple-like projections, as numerous as the hairs on velvet fabric. Each of these intestinal projections is a villus. A single villus, magnified still more, turns out to be composed of hundreds of cells, each covered with microscopic hairs, the microvilli.

The villi are in constant motion. Each villus is lined by a thin sheet of muscle, so that it can wave, squirm, and wriggle like the tentacles of a sea anemone. Any nutrient molecule small enough to be absorbed is trapped in the microvilli and drawn into the cells beneath them. Some partially digested nutrients are caught in the microvilli, digested further by enzymes there, and then absorbed into the cells.

Once a molecule has entered a cell in the villus, the next problem is to transport it to its destination elsewhere in the body. Everyone knows that the bloodstream performs this function, but you may be surprised to learn that there is a second transport system – the lymphatic system. Both of these systems supply vessels to each villus. When a nutrient molecule has crossed the cell of a villus, it may enter either the lymph or the blood. In either case, the nutrients end up in the blood, at least for a while.

Villi (VILL-ee, VILL-eye)
Villi are singular villus, which are fingerlike projections from the folds of the small intestine.

Microvilli (MY-cro-VILL-ee, MY-cro-VILL-eye)
Microvilli are singular microvillus, which are projections from the membranes of the cells of the villi.

Surface Features of the Small Intestinal Wall
1. Five folds in each wall of the small intestine. Each is covered with villi.
2. Two villi. Each villus is composed of several hundred cells.
3. Three cells of a single villus. Each cell is coated with microvilli.

Lymph (LIMF)
Lymph is the body's interstitial fluid, between the cells and outside the vascular system. Lymph consists of all the constituents of blood that can escape from the vascular system; it circulates in a loosely organized system of vessels and ducts known as the lymphatic system.

A Closer Look at the Intestinal Cells
The cells of the villi are among the most amazing in the body, for they recognize, select, and regulate the absorption of the nutrients the body needs. (Thanks to these cells, glass beads never enter the body proper to lodge in inconvenient places, but the cells can make far more sophisticated distinctions than this.) A close look at these cells is worthwhile, because it will help to explode a number of common misconceptions about nutrition.

Each cell of a villus is coated with thousands of microvilli, which project from its membrane. In these microvilli and in the membrane lie hundreds of different kinds of enzymes and "pumps," which recognize and act on different nutrients. For example, the enzyme lactase, which breaks apart the disaccharide lactose (milk sugar), lies within the cells' microvilli. The presence of lactase at the cell surface ensures the efficient absorption of this sugar, because as soon as it is broken into its component parts (glucose and galactose), those parts are easily contacted by the nearby pumps, which move them into the interior of the cell. This arrangement makes it easy for a newborn infant to absorb and use milk sugar, even though his gastrointestinal tract may in some ways still be immature.

Enzymes for cleaving dipeptides and tripeptides also lie in the surface structures of the intestinal cells. Whole proteins – long polypeptides – are digested to chains a few amino acids in length out in the fluid of the intestine, but once they have been rendered into dipeptides and tripeptides, these fragments are contacted and trapped by the microvilli, where the last steps of digestion occur. The cells' enzymes then can deliver the final products – amino acids – directly to the pumps, which carry them into the interior of the cells.

There is nothing random about this process. The anatomical arrangement guarantees not only digestion but also delivery of its products into the body. Digestion and absorption are coordinated.

An additional refinement of the system for digesting and absorbing protein gives a further reason for not tampering with it. The amino acid transport systems are not specific for individual amino acids but for groups of them. For example, there is one pump for the basic amino acids and another for the neutral ones. Each group of amino acids with similar structures shares a transport system. This means that competition can occur. The amino acids within a group can interfere with each other's absorption.

Normally, no problems arise with this arrangement. Food proteins deliver balanced assortments of amino acids to the GI tract, digestion occurs slowly, fragments are delivered in leisurely fashion to the microvilli, and the final steps of digestion and absorption occur without much mutual interference. If, however, a person takes pure amino acids rather than protein, the competition for carriers is more severe, and some amino acids are lost. If the person still more foolishly presumes to decide that she needs certain specific amino acids and takes an overdose of one, she may precipitate a deficiency of the others that share its carrier. If the lost amino acids are essential ones, the net effect will be to reduce her total supply of usable protein.

Caution:
Some people believe that eating predigested protein (amino acid preparations such as the "liquid protein" products sold to dieters) saves the body the work of having to digest protein, so that the digestive system won't "wear out" so easily. Nothing could be further from the truth. As a matter of fact, whole proteins are better absorbed and utilized, even by the body of a very sick, malnourished person, than are hydrolyzed amino acid mixtures. This surprising finding has come to light through actual experiments, not through the exercise of reasoning from what was known before. It has proven wrong the claims of advertisers who try to sell hydrolyzed amino acid preparations to athletes, sick people, dieters, and others. The "best" protein is food protein.

When hydrolyzed proteins (that is, predigested mixtures of amino acids) are consumed, there can be no coordination of digestion and absorption. The amino acids arrive en masse, presenting the intestine with the problem of trying to absorb them all at once. At first, floating free in the intestinal fluid, they exert an attractive force (remember that charged molecules attract water), so that excess fluid is drawn into the GI tract, causing at least discomfort, and at worst cramping, nausea, and diarrhea. On the other hand, when whole food proteins are delivered to the intestine they are systematically and gradually cleaved to pieces that can be digested and absorbed in sequence. The amino acids that flow into the body also arrive in sequence, perhaps even in the sequence needed to build protein in the cells.

In general, it is unwise to try to second-guess the body. It has evolved over millions of years to derive its nutrients efficiently from foods. How could we presume, after five minutes of listening to a salesman or fad diet promoter, that we can improve on this natural capacity?

This is not to say that some food proteins can't be improved by amino acid supplementation. A plant protein of very poor quality may be better utilized by the body if the limiting amino acids are added to it. In this instance, adding amino acids provides a balance closer to what the body needs. This theory has been scientifically tested and confirmed – for example, in growth experiments on children.

The preceding discussion has illuminated some aspects of the absorption of carbohydrates and protein but has said nothing about lipids. The absorption of lipids differs in that pumps are not involved. Cell membranes dissolve lipids easily because they are made largely of lipid themselves. After the triglycerides have been digested to monoglycerides or to glycerol and fatty acids, for example, they simply diffuse across the cell membrane. The cell retains them by reassembling them.

As you can see, the cells of the intestinal tract wall are beautifully designed to perform their functions. Further refinement of the system is that the cells of successive portions of the tract are specialized for different absorptive functions. The nutrients that are ready for absorption early are absorbed near the top of the tract; those that take longer to be digested are absorbed farther down. Thus the top portion of the duodenum is specialized for the absorption of calcium and several B vitamins, such as thiamin and riboflavin; the jejunum accomplishes most of the absorption of triglycerides; and vitamin B12 is absorbed at the end of the ileum. Medical and health professionals who deal with digestion learn the specialized absorptive functions of different parts of the GI tract so that, when one part becomes dysfunctional, the diet can be adjusted accordingly.

The rate at which the nutrients travel through the GI tract is finely adjusted to maximize their availability to the appropriate absorptive segment of the tract when they are ready. The lowly "gut" turns out to be one of the most elegantly designed organ systems in your body.

Release of Absorbed Nutrients

Once inside the intestinal cells, the products of digestion must be released for transport to the rest of the body. The water-soluble nutrients (including the smaller products of lipid digestion) are released directly into the bloodstream. For the larger lipids and the fat-soluble vitamins, however, access directly into the capillaries is impossible because they are insoluble in water. The cells assemble the monoglycerides and long-chain fatty acids into larger molecules, triglycerides. These triglycerides and the other large lipids (cholesterol and the phospholipids) are then wrapped in protein to form chylomicrons. Finally, the cells release the chylomicrons into the lymphatic system. They can then glide through the lymph spaces until they move to a point of entry into the bloodstream near the heart.

Transport of Nutrients into Blood

Water-soluble nutrients	
Carbohydrates	
Monosaccharides	Directly into blood
Lipids	
Glycerol	Directly into blood
Short-chain fatty acids	Directly into blood
Medium-chain fatty acids	Directly into blood
Proteins	
Amino acids	Directly into blood
Vitamins	
Vitamins B and C	Directly into blood
Minerals	Directly into blood
Fat-soluble nutrients	
Lipids	
Long-chain fatty acids	Made into triglycerides
Monoglycerides	Made into triglycerides
Triglycerides (in lipoproteins)	To lymph, then blood
Cholesterol (in lipoproteins)	To lymph, then blood
Phospholipids (in lipoproteins)	To lymph, then blood
Vitamins	
Vitamins A, D, E, K	To lymph, then blood

CERTIFIED HEALTH & NUTRITION COUNSELOR ONLINE COURSE - SESSION 5 **– 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 is the purpose of bile?

2. What is chyme?

3. Describe the process of eating from the time you chew your food to the time your eliminate.

4. Do you use antacids? If so, when do you use them?

5. What pH is the natural pH of the urine?