

World of Dairy Cattle Nutrition



INTRODUCTION

Most kids are taught to eat their fruits and vegetables. Why? Because they are good for you, and provide several essential vitamins and minerals for a healthy, balanced diet! It is just as important for a dairy cow to eat a balanced diet to live a long, healthy life. The basic difference between humans and cows is how our stomachs function.

Humans are **monogastrics**, meaning we have a single stomach digestive system. Pigs, cats and dogs are also monogastrics. The prefix “mono-” means “one.” Cows are **ruminants**, with a four-compartment stomach digestive system. The word “ruminant” comes from the Latin *ruminare*, which means “to chew over again.” They are able to digest plant-based feed by swallowing it, then regurgitating it, and chewing it again.

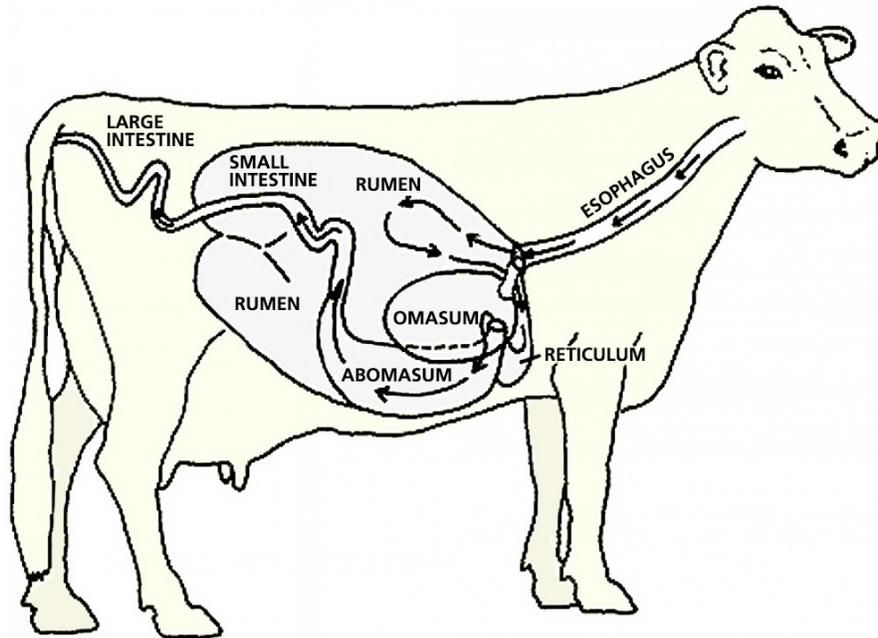




Table of Contents

Parts of the Digestive System	4
Essential Nutrients.....	8
Feedstuffs	13
Nutritional Needs.....	16
Balancing a Cow's Diet.....	19
EXERCISE: Required Nutrients	19
EXERCISE: Digestive System	20
EXERCISE: Determining Feed Values	21
#1: Determine the amount of dry matter a cow should be consuming.	21
#2: Determine the amount of dry matter a cow is consuming	21
#3: Determine the amount of protein a cow is consuming	21
#4: Determine the nutritional value the cow is getting from each feedstuff.	22

Parts of the Digestive System



Source: <http://www.extension.umn.edu/agriculture/dairy/feed-and-nutrition/feeding-the-dairy-herd/ruminant-anatomy-and-physiology.html>

MOUTH

You might not think of the mouth as a part of the digestive system, but it plays a very important role. Feed is chewed in the mouth, and mixed with saliva. Saliva helps lubricate the food for easier swallowing, provides a liquid base for nutrient digestion and bacterial growth, and acts as a buffer to maintain proper pH in the cow's rumen for fermentation. As much as 50 to 80 quarts of saliva can be produced by a cow a day.

ESOPHAGUS

When feed leaves the mouth, it travels down the esophagus with the help of a muscular movement called **peristalsis** that pushes feed along.

THE FOUR COMPARTMENTS OF A COW'S STOMACH

A cow's stomach is divided into four compartments: The reticulum, rumen, omasum and abomasum. The stomach and its contents make up 25 to 28% of a cow's total body weight.

Reticulum

The **reticulum** is sometimes called the “honeycomb” stomach because the inside surface has a honeycomb texture. The rumen and reticulum are not completely separate from each other. As food is digested it can move back and forth between the rumen and reticulum, often referred to jointly as the **reticulorumen**.



Photo courtesy of Dr. Karen Petersen, Univ. of Washington, Dept. of Biology

Rumen

The rumen is by far the largest stomach compartment, holding 40 to 50 gallons in a typical cow. The inside surface of the rumen is covered with **papillae**, finger-like projections that aid in nutrient absorption by increasing the surface area of the rumen. Feed undergoes a fermentation process while in the rumen.



Photo courtesy of Dr. Karen Petersen, Univ. of Washington, Dept. of Biology

Rumination: “Chewing Cud”

If you have ever watched a cow eat, you’ll notice she does not chew her food well. Don’t try this at home, because this is what makes our digestive systems different. She can eat fast and chew later. A typical cow will spend at least 8 hours a day ruminating, or what we commonly call “chewing her cud.” A cow will regurgitate a **bolus** of partially digested feed, often called the **cud**, through reverse peristalsis. The muscles in the esophagus that send food down can also send it back up. The cow will then re-masticate, or chew the food again, and then re-swallow it. **Eructation** also occurs during the rumination process, when a cow burps up gases produced in the rumen, created by bacteria and microorganisms as they digest the food.

Fermentation: “The bugs and the rug”

The rumen is like its own eco-system, home to billions of microorganisms. The environment is moist with a consistent temperature; no oxygen is present, and the standard pH is nearly neutral at 6.5. The rumen’s liquid and solid contents are mixed through a series of muscular contractions that occur roughly once to twice a minute in a healthy cow. If you put a stethoscope up to a cow’s side while she is ruminating, you will be able to hear these contractions as sort of a gurgling sound. Contents tend to settle into layers, with larger particles floating to the top and creating a rumen **mat**. Partially digested hay or other forages will settle into this thick mat. The fermentation process is in high gear in the mat, as microorganisms work to digest the forages, releasing gases as they work. The mat also acts as a screen, with liquid gushing through it every time the cow’s rumen contracts and stirs its contents. Once the feed is fermented to a point where it is small enough, it passes through the mat and moves on through the digestive system.

This fermentation process helps cows digest certain foods that humans cannot. Two examples are **cellulose** and **hemicellulose**, fibrous compounds found in plants (the “-ose” suffix is used in biochemistry to name saccharides, or sugars). The structures of these compounds make them impossible to digest without the help of special enzymes, **cellulase** and **hemicellulase** (the “-ase” suffix is commonly used to name enzymes). An enzyme is a compound that helps speed up changes in other materials, without being changed itself. These enzymes are only secreted by microorganisms, like the bugs that live in the rug. Without them, the cow wouldn’t be able to extract nutritional value, such as energy or protein, from the food she eats because it would be indigestible. Because of the work of these enzymes in the rumen, cellulose and hemicellulose are converted to **volatile fatty acids** (VFAs), such as acetate, propionate and butyrate, which are a source of energy.

Another marvel of the rumen microorganisms is their ability to turn **non-protein nitrogen (NPN)** sources into usable protein for the cow. They are generally more economical than plant or animal based proteins, and you commonly find NPN sources, like urea, used sparingly in a cow's diet. Most of the protein used by a cow is actually made in the rumen by microorganisms, known as **microbial protein**.

Omasum

The third stomach stop is the **omasum**, which primarily functions to absorb water. The omasum is also called manyplies because it is filled with many large leaves that resemble pages in a book. These layers of tissue increase surface area for water absorption. The omasum absorbs 60 to 70% of the water that enters it, or about 26 gallons of water a day.



Photo courtesy of Dr. Karen Petersen, Univ. of Washington, Dept. of Biology

Abomasum

The final stomach compartment feed travels through is the **abomasum**, sometimes referred to as the "true stomach" because it is most like the human stomach. The abomasum secretes a gastric juice which contains hydrochloric acid (HCl), causing it to be very acidic with a pH level of about 2. As a contrast, milk has a pH of 6.4 to 6.8.

pH Chart

	pH Level	Examples of pH Levels	
ACIDIC	pH = 0	Battery acid, strong hydrofluoric acid	
	pH = 1	Hydrochloric acid secreted by your stomach	
	pH = 2	Lemon juice, Vinegar	
	pH = 3	Grapefruit, Orange Juice, Soda	
	pH = 4	Acid Rain, Tomato Juice	
NEUTRAL	pH = 5	Black Coffee, Soft Drinking Water	
	pH = 6	Saliva, Urine	
	pH = 7	Pure Water	
	pH = 8	Sea Water	
	pH = 9	Baking Soda	
	pH = 10	Milk of Magnesia, Detergent	
	pH = 11	Ammonia Solution	
	pH = 12	Soapy Water	
	BASIC	pH = 13	Bleaches, Oven Cleaner
		pH = 14	Liquid Drain Cleaner

The abomasum also secretes two enzymes; pepsin and rennin. **Pepsin** is important for digesting and breaking down proteins. **Rennin** is only secreted in young animals and helps thicken milk so it can be digested by the calf.

ESOPHAGEAL GROOVE: A CALF'S BYPASS OF THE RUMEN & RETICULUM

	% OF TOTAL STOMACH	
	Newborn Calf	Adult Cow
Rumen	25%	80%
Reticulum	25%	6%
Omasum	10%	3%
Abomasum	40%	11%

The rumen and reticulum are not well developed in a newborn calf, so the **esophageal groove** diverts milk from the esophagus into the omasum. The esophageal groove is a muscular tissue that closes to form a tube when a calf begins to suck.

The development of the rumen and reticulum in calves is triggered by the consumption of hay and grain, when the fermentation process begins. As a calf eats more solid feed, the rumen gets larger, the wall thickens, and papillae form. The rumen and reticulum will normally be fully functioning by 6 to 9 months of age.

SMALL INTESTINE

The **small intestine** is the primary site of nutrient absorption in all animals. The average small intestine of a cow is 130 feet long and holds 10 gallons of partially digested feed (also called **digesta**). The inside surface of the small intestine is covered with **villi**, small finger-like projections which increase the surface area of the intestinal wall and aid absorption.

The small intestine is made up of three sections; duodenum, jejunum and ileum. The **duodenum** is the first section where secretions from the liver and pancreas enter. The small intestine itself also secretes several enzymes, primarily in the duodenum. These secretions help break down starches and carbohydrates into simple sugars which are easily absorbed. Examples of these enzymes are **amylase**, an enzyme that digests starch; **lipase**, and an enzyme that digests lipids or fats; and **peptidase**, an enzyme that digests proteins.

PANCREAS

The **pancreas** is a small gland located just below the abomasum. The juices secreted by this gland contain **buffers**, which help to neutralize the acidic stomach contents when they enter the small intestine. If the buffers weren't there to increase the pH to nearly neutral, the acid secreted in the abomasum would burn through the small intestine's lining.

In addition to secreting buffers, the pancreas secretes several types of enzymes and hormones. **Insulin** and **glucagon** are two examples of hormones secreted by the pancreas. Enzymes released by the pancreas each have a specific duty, like breaking down proteins into amino acids or converting starch into sugar, but all are important in making the nutrients in a cow's feed useable for her everyday functions and health.

LIVER

The **liver** secretes bile into the small intestine. **Bile** helps neutralize digesta as it enters the small intestine, and is important for the digestion of fats. Bile is stored in the gall bladder and is released into the intestine when needed.

The liver also plays an important role in converting certain absorbed nutrients into compounds that are more useful to the cow. One example is the conversion of propionate and lactate absorbed from the rumen into glucose. A cow needs glucose to make milk, and for use of her brain and central nervous system. The liver synthesizes nearly all of the glucose a cow needs every day, a process called **gluconeogenesis**.

LARGE INTESTINE

After digesta flows through the small intestine, where most of the nutrients are absorbed, it moves into the large intestine. The **large intestine** is a “sacculated organ,” meaning it contains sacs to accumulate and slow the passage of digesta, rather than being a simple tube. It is made up of the cecum and the colon. The main function of the large intestine is water absorption and waste storage, which will eventually leave the cow’s body as manure.

While not a primary site of digestion and absorption like the rumen, the large intestine is home to a population of microorganisms. These microorganisms ferment any remaining nutrients in the digesta, producing volatile fatty acids and microbial protein. The microbial protein produced here is lost in the feces, but the volatile fatty acids can be absorbed and used by the cow.

Essential Nutrients

The dairy cow is an impressive animal, but to keep her healthy, we must provide a perfect balance of nutrients for her to consume. We’ll break down her needs into categories of essential nutrients that are common to any living creature, including humans, to survive.

1. Water
2. Energy
 - a. Carbohydrates
 - b. Protein
 - c. Fats
3. Vitamins
4. Minerals

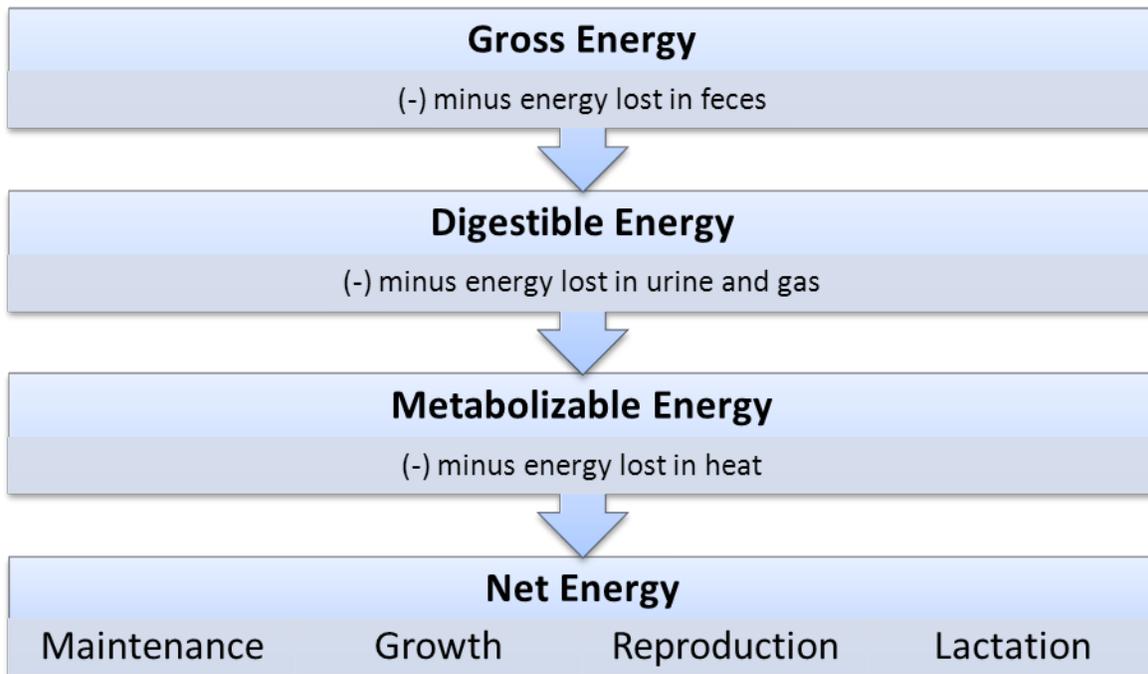
WATER

Water is the most important nutrient for dairy cattle, so cows must have free access to a high quality water supply at all times. Approximately 71 to 73% of a cow’s non-fat body weight is water. In the cow’s body, water helps break down the food she eats, transports nutrients through her system, helps chemical reactions occur, and helps maintain a normal body temperature.

Cows drink two to three times more water than the amount of food they eat. Water intake increases during hot weather and with increasing milk yield. For example, a dairy cow producing 100 pounds of milk a day loses 87 pounds of water in the milk (as 87% of milk is water). While most of the water a cow consumes comes from drinking water, some is found in the feed she consumes. Corn silage, for example, is commonly 65 to 75% water. A cow will also get a small amount of water from chemical reactions that occur in her body, and water molecules are released.

ENERGY

After water, energy is the primary nutritional need. **Energy** is defined as the capacity to do work. Cows need energy to do things like produce milk, grow, maintain their large body frame and support pregnancy. Energy is available from three dietary sources: proteins, carbohydrates and fats. Fats provide the most energy per pound of feed, with protein and carbohydrates next.



The **maintenance requirement** of a cow is the energy needed just to maintain her body. This requirement must be met before any growth, milk production or pregnancy can occur.

Think of athletes such as marathon runners and the high amount of energy they need to run long distances. Before they would run a race, they might do something called “carb-loading.” That is, loading up on carbohydrates, like pasta, as a source of energy, to ensure they have enough energy to finish the race. Now, think about a cow that is producing a lot of milk. She needs extra energy to do so. If you wanted to increase the energy in a cow’s diet, you might feed her more corn silage, corn, or beet pulp.

Energy is measured in **calories**. Any packaged food you see in a grocery store will have “Nutrition Facts” printed on the label. That will tell you how many calories are in the food you eat. The total amount of energy, or calories, in food is determined by the amount of heat it releases when it is burned. The same concept applies to cow feed.

Not all energy that a cow eats will end up actually providing her with usable energy. Some of it is indigestible, and some will be wasted.

Gross energy is the total amount of energy ingested by a cow. That, minus the energy is lost in the cow’s feces is **digestible energy**. For example, forages are less digestible than grains, meaning more of their energy is lost in feces. After accounting for the energy lost in urine or gases, such as methane, we have the **metabolizable energy**. Finally, some energy is lost as heat during chemical reactions that occur in the cow’s body, and the ending amount of energy with everything considered is **net energy**.

In the end, it is the net energy that a cow can use for her maintenance, growth, pregnancy and lactation. This is important to understand in finding the most efficient and economical diet to feed a cow.

CARBOHYDRATES

Carbohydrates are the primary component found in livestock feeds and are a source of energy. Carbohydrates are made up of carbon (C), hydrogen (H) and oxygen (O), and are the main energy compound in plants. Plant tissues are high in carbohydrates such as starch, cellulose and hemicellulose. When a cow consumes carbohydrates, the ruminal microorganisms release enzymes that break them down into **monosaccharides** or “simple sugars.” The monosaccharides are then converted by the microorganisms into volatile fatty acids. Volatile fatty acids are absorbed across the wall of the rumen and small intestine and then can be used by the cow as energy.

PROTEIN

Protein is found in the highest concentration of any nutrient, except water, in all animals and most living things. Thousands of different proteins have many different functions in a cow’s body. Proteins provide structural components of things like muscle, hooves, bone and blood. Several hormones are proteins, including insulin and bovine somatotropin. Additionally, the enzymes important in digestion, absorption and metabolism are all proteins.

Proteins are made up of long chains of **amino acids** that have been linked together. Amino acids contain carbon (C), hydrogen (H), oxygen (O), and nitrogen (N), and some other compounds, and are known as the “building blocks of protein.” Combinations of these elements form 22 different amino acids, and various combinations of those amino acids are bonded to form various types of protein. Enzymes secreted by the abomasum, pancreas and small intestine break these bonds to separate the amino acids and allow them to be absorbed by the cow’s body. Proteins can’t be absorbed, but amino acids can.

Amino acids can be divided into two groups; essential and non-essential. The difference is that **essential amino acids** are not produced by the cow’s body, so she needs to get them from her diet. **Non-essential amino acids** are produced by cells in the body and are not needed in the cow’s diet.

The essential amino acids are:

- Arginine
- Histidine
- Isoleucine
- Leucine
- Lysine
- Methionine
- Phenylalanine
- Threonine
- Tryptophan
- Valine

First Limiting Amino Acid Concept – It’s as easy as apple pie

Each protein made by a cow requires a specific combination of amino acids. If an amino acid is in short supply, it cannot be replaced by another without completely changing the end product. The amino acid supplied in the smallest amount required for protein synthesis is known as the **first limiting amino acid** because it limits the amount and type of protein that can be made.

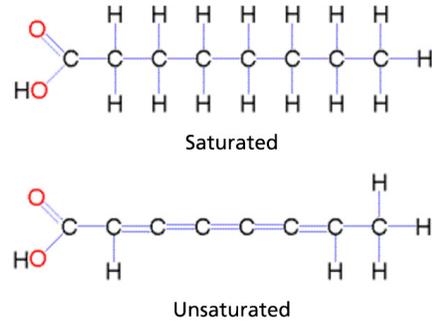
Each unique amino acid is like a different ingredient in a recipe. Instead of a protein, imagine you are making an apple pie. The recipe for one apple pie calls for ½ cup butter, 1 cup flour and 4 cups of apples, but you want to make two pies, so you’ll need 1 cup butter, 2 cups flour and 8 cups of apples. You have 1 cup of butter and 2 cups of flour, but you only have 6 cups of apples. So apples are the first limiting ingredient that only allows us to make one apple pie (you are two cups short for the second pie), and the extra butter and flour are wasted, just as the extra amino acids are wasted. You can’t substitute cherries for apples, even if you had them on hand, just like you couldn’t use a different amino acid to build a certain protein.

In dairy cow diets, **lysine** and **methionine** are the most common limiting amino acids because common feeds like corn, corn silage and soybean meal are relatively low in these amino acids compared to the quantities needed for milk production.

FATS

Fats, or lipids, are high in energy, and are found in many common feedstuffs. Oilseeds, such as whole cottonseed or whole soybeans, or animal fats, are common sources of fat in a cow's diet. Fat is a very important part of young calves' diets because of the amount of energy they need to grow. It is also essential for absorption of fat-soluble vitamins.

Fats can be classified as either saturated or unsaturated, which is determined by the chemical structure. A **saturated fat** is fully saturated with hydrogen atoms and does not contain double bonds between carbon atoms. **Unsaturated fats** contain double bonds, so they do not have the maximum number of hydrogen atoms. During rumen fermentation, most of the unsaturated fats are converted to saturated fats, which is why most of the fat found in milk and meat we consume is saturated fat.



VITAMINS

Vitamins are essential for sustaining a healthy life for cows and humans alike. Each vitamin has a number of functions. They are needed for normal growth, and enable many critical processes that take place in the body. Some play a role in absorption and metabolism of carbohydrates, proteins, fats, and minerals. Others are important for brain function, resistance to infection, fertility, and the digestive system.

The major storage site for vitamins is the liver. Most vitamins are bound to specific proteins. The presence of vitamins in milk is important because it is often a sole source for newborn animals. **Colostrum**, a cow's first milk after calving, is especially high in vitamin content to ensure the calf gets adequate nutrition early in her life.

Vitamins are divided into two categories: water-soluble vitamins and fat-soluble vitamins.

Water-soluble vitamins are not stored in the body tissue, so they must be provided in the diet daily for humans. In a cow, the rumen microbes synthesize enough of these vitamins to meet her nutritional requirements. Since a calf's rumen doesn't fully function until later in her life, water-soluble vitamins must be fed as part of her diet when she's young.

Many water-soluble vitamins function primarily as cofactors of enzymes. A **cofactor** is a substance that is required for an enzyme to function properly.

Water Soluble Vitamins

Vitamin	Also Known As
Ascorbic Acid	Vitamin C
Thiamin	Vitamin B ₁
Riboflavin	Vitamin B ₂
Niacin	
Pyridoxine	Vitamin B ₆
Pantothenic Acid	
Folic Acid	Vitamin B ₉
Cyanocobalamin	Vitamin B ₁₂
Biotin	
Choline	
Inositol	
Para-aminobenzoic acid	PABA

There are four **fat-soluble vitamins**: Vitamins A, D, E and K. They can be stored in large volumes in a cow's body fat for months. This means providing a cow too much of these vitamins can also lead to toxicity. Vitamins A, D and E are commonly supplemented in lactating cow diets.

Fat Soluble Vitamins and their Functions

Vitamin	Functions
A	Vision and maintains epithelial cells (lining the body surface and cavities)
D	Calcium absorption and bone deposition
E	Metabolic antioxidant
K	Blood clotting

MINERALS

Minerals are divided into two classes: macrominerals and microminerals. **Macrominerals** (the prefix "macro-" means "large"), are present in cows part in larger proportions – greater than 100 parts per million. **Microminerals**, are found in smaller quantities – less than 100 parts per million (the prefix "-micro" means small). Like vitamins, minerals play a variety of important roles, and need to be fed in just the right amounts to prevent either deficiency or toxicity.

Macrominerals in Cattle Nutrition and their Functions

Mineral	Functions	Deficiency Signs
Calcium (Ca)	bone structure, nervous system activity, blood clotting	rickets, osteoporosis, slow growth
Phosphorus (P)	bone structure, metabolic functions	poor reproduction, poor growth
Chlorine (Cl)	regulation of osmotic pressure and pH in body fluids	lack of appetite, rapid loss of weight, decline in milk production, uncoordinated movements
Magnesium (Mg)	bone structure, nervous system activity	grass tetany, irritability, convulsions
Potassium (K)	nervous system activity, regulation of osmotic pressure and pH in body fluids	emaciation, listlessness, poor performance
Sodium (Na)	nervous system activity, regulation of osmotic pressure and pH in body fluids	abnormal eating behavior, urine licking
Sulfur (S)	acid base balance, ruminal growth	poor appetite, unthrifty appearance, dullness of hair coat and hair loss



Feedstuffs

“Feedstuffs” is a common term for things we might feed cows. We will break them down into three categories.

- Forages
- Energy concentrates
- Protein supplements

FORAGES

Forages include the stem and leafy parts of a plant and are generally higher in fiber. They are more bulky, and provide less digestible energy than concentrates. Common forages include baled hay, haylage, and corn silage.

Making Hay

In the United States each year, 140 million tons of dried hay are made. Approximately 50% of that is alfalfa hay. We harvest and preserve hay when fields yield more than we can use in the summer time, saving it for times when we can't access adequate forage in the fields or pastures in the winter time. If you've ever had more cucumbers than you want or need ready in the garden and decided to make pickles out of what you couldn't eat at the time, you know what we mean.

Crops should be harvested when they are at their optimum nutritional value. The maturity of a forage crop harvested for hay has a dramatic impact on its nutritional value.

Making high quality hay also requires an optimum moisture content of 15 to 18%, to minimize leaf loss and prevent the hay from spoiling when you store it. The leaves contain more protein and carbohydrates compared to the stems. After the hay is cut, proper curing, which includes raking the hay and allowing it to get plenty of sunshine, will bring the moisture content down before baling.

Relative Feed Value (RFV) is a common measurement of how good the hay is as feed for your cows. Values above 100 indicate higher quality hay with greater digestibility.



Silage

Making silage out of grasses, alfalfa, corn or sorghum is a great way to preserve crops when drying isn't feasible, but it also makes good cow feed. Like hay, it is important to harvest the crop at proper moisture and maturity. The biggest difference is harvesting the crop at a higher moisture content, and storing it in an oxygen-free environment. Limiting oxygen helps the feed ferment and preserve properly. Packing the silage tightly into whatever storage method used is critical to limiting oxygen exposure, preventing mold from growing and the silage quality from deteriorating. For most crops, a dry matter content of 25 to 35% is optimal for silage making.

While sight and smell are commonly used to assess the quality of silage on the farm, testing the pH is more accurate. Generally, good silage should have a pH of 4.2 or less.

Corn silage is by far the most popular silage in the U.S. Some corn seed varieties are even designed to produce ideal corn for making silage.

ENERGY CONCENTRATES

A cow will get energy from feedstuffs that contain readily available carbohydrates, fats and oils. Known as "high-energy" feedstuffs, these components contain greater than 70% total digestible nutrients (TDN) and are high in net energy content. High-energy feed generally has low protein content, less than 20% crude protein (CP).

The energy concentrates in a ration are commonly referred to as "grain." **Cereal grains** come from plants that are grown primarily for their seeds, which we harvest as grain. This includes things like corn, wheat, oats, barley, rye and sorghum.

High-energy feeds can also come in a liquid form. Molasses is the most common one fed to dairy cows, while some farms are now feeding liquid milk by-products such as whey.

Beet pulp is a commonly fed dry by-product of sugar beets, while in some areas of the country cows are fed other by-products of citrus, bakery waste or potatoes as an energy source.

Fats and oils can be added to a cow's diet to boost her energy intake. They are highly digestible and can help reduce dustiness and increase palatability. A small amount of fat may be added to lactating dairy cow diets, but it is very important in young calves' diets.

PROTEIN SUPPLEMENTS

Protein supplements are generally defined as having 20% or more crude protein (CP).

Some proteins come from plants. Soybean meal is the predominant plant protein fed. It is categorized as an oilseed meal, which refers to the process where oils are extracted from the seeds. Corn gluten meal (a by-product of wet corn milling) and distillers grains (a byproduct of ethanol or alcohol production) are other common protein sources today.

Manufactured Non-protein Nitrogen (NPN) such as urea can also be fed to ruminants, but too much can decrease palatability and how much a cow will want to eat. A good rule of thumb is, not more than one-third of total Nitrogen should come from urea or other NPN sources and in complete feeds; ideally it should be 2% or less.

Determining Nutritional Value of Feeds

Taking samples of different feeds and running tests gives a good estimate of the nutrition they provide.

Proximate analysis is the most common analysis run on feed samples and will tell you the feeds' content of dry matter, crude protein, crude fat, crude fiber, ash and nitrogen-free extract.

- **Dry Matter:** The amount of material left after the water is removed from the feed
- **Crude Protein:** Total protein, as determined by the amount of nitrogen in the feed
- **Crude Fat:** Total fat
- **Crude Fiber:** Total fiber, as determined by the amount of less digestible carbohydrates in the feed (hemicellulose, cellulose and lignin)
- **Ash:** Inorganic materials, including minerals
- **Nitrogen-Free Extract:** Readily available carbohydrates

Another common test gives more accurate information about the feed's fiber and how well it will be digested – the Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) methods. **NDF** includes the cell walls, while **ADF** includes the cell contents. NDF commonly reflects a feed's bulk and can determine how much a cow can fit in her digestive system. ADF is closely associated with the digestibility of feed.



Nutritional Needs

FEEDING CALVES

The health and vigor of a calf at birth depends mostly on the nutrition of the cow 60 days before birth, when the developing calf gains 70% of its birth weight. Cows that are properly fed and immunized against harmful pathogens produce higher quality colostrum when the calf is born. Again, **colostrum** is the first milk a cow produces after calving. Calves are born without a functioning immune system, so the importance of feeding the calf colostrum at birth cannot be over emphasized. Colostrum supplies the calf antibodies it needs to stay healthy from the start. Calves should receive a minimum of two quarts in two feedings in their first 12 hours of life.



The First 2 Months

A calf's rumen does not start functioning normally until she is about 60 days old. This makes it necessary to feed a young calf milk or milk replacer. A calf that is bottle fed milk will activate the esophageal groove when it lifts its head up and begins sucking, which diverts milk from the rumen into the omasum and abomasum. This is why bottle feeding is preferable over bucket feeding at that early age. Also, the more frequently calves are fed at an early age, the more efficient their growth will be. Most people will feed calves twice a day, in the morning and evening, but adding a third feeding can be beneficial.

Milk Replacers

Milk replacer comes in a dry, powder form and is generally mixed with warm water. It is typically mixed with a ratio of 1 pound of milk replacer to 1 gallon of water. The amount of mixed milk replacer fed to a calf should not exceed 8% of the calf's body weight. When feeding milk replacer, be sure to always follow the instructions on the packaging carefully.

Milk replacers can contain 10 to 25% fat. In colder weather, a minimum of 20% fat milk replacer should be fed. Many milk replacers are medicated, which means they contain antibiotics.

High quality, clean water should be offered to all calves, even during the liquid feeding stage, to improve growth and dry matter intake.

Calf Starter

When a calf is one week old, offer a calf starter. A calf starter is often a texturized feed that includes pellets and corn and can be drizzled with molasses to make it appealing for the calf to eat. She might not eat it right away but keep a fresh, clean offering of starter available to her at all times.

Along with the starter, good-quality alfalfa hay should be offered in small quantities. All of this will help her rumen develop properly.

Weaning

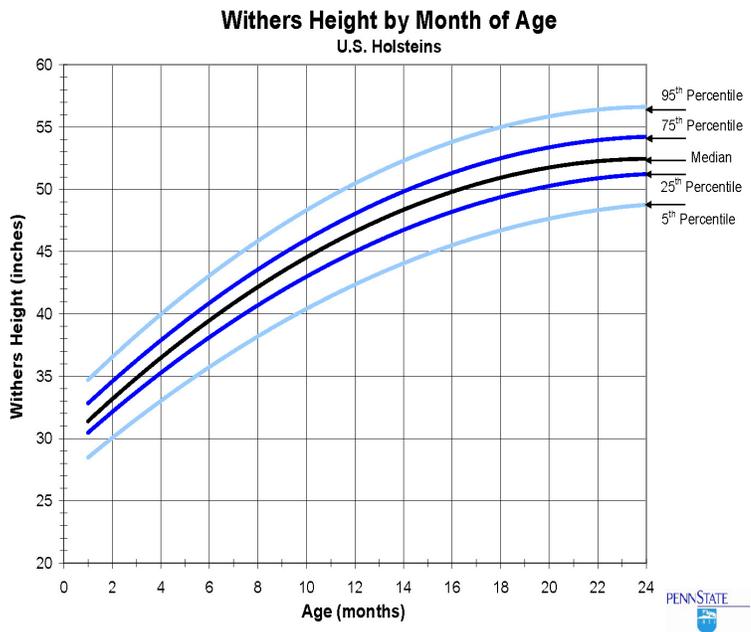
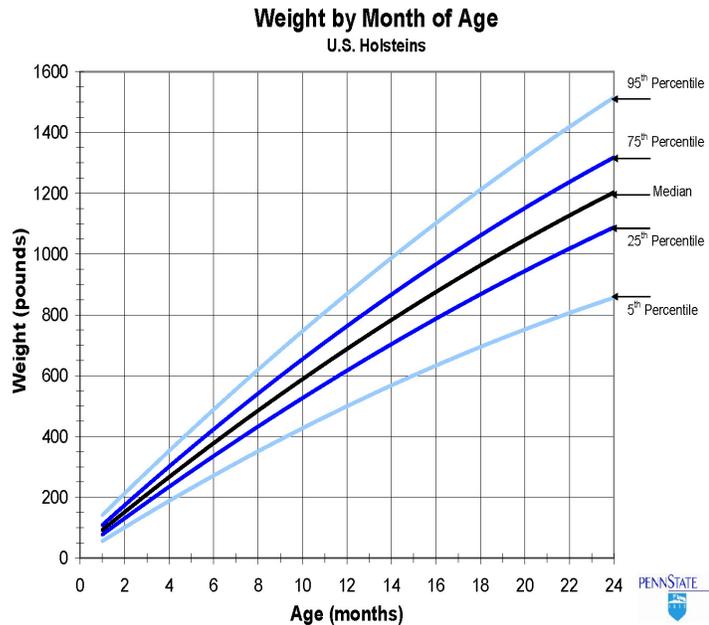
Weaning is the process of taking a calf off of milk, and transitioning her to water. This usually occurs between 6 to 8 weeks old. Weaning should take place when the calf is eating about 4 pounds of starter a day, in addition to hay and milk replacer. Before weaning, calves should be moved from individual hutches to small group pens. If possible, group calves by size to ensure their specific nutritional needs are met and to prevent bullying.

FEEDING HEIFERS

Once a heifer is growing well, she should be gaining close to 2 pounds a day. As we get into feeding growing heifers to prepare them for breeding, it is time to seek the help of a professional to formulate a proper diet, often called a **ration**. Developing a heifer ration takes careful calculation and can vary depending on the variety of feedstuffs available and their quality. One key parameter to follow – ensure that the total feed intake (dry matter) does not exceed approximately 3% of her body weight. Also, a ration for a growing heifer should not exceed 50% moisture, so limiting silage and supplementing her diet with dry hay is a good idea.

It is helpful to group heifers of similar age and size together to ensure their nutritional needs are met. As a heifer nears breeding age, she may need a nutritional boost to support ovulation and conception.

It is common to evaluate average daily gain of heifers and to plot the weights and heights on a graph for comparative purposes. Heifer growth charts usually identify ranges of growth by breed. A spreadsheet is available from Penn State that uses mature size and herd goals for age at first calving to generate a growth chart, which means heifer performance is compared to the growth required to meet herd goals, not to a breed standard. For additional resources please visit the following link: <http://extension.psu.edu/animals/dairy/nutrition/heifers/monitoring-heifer-growth/customized-dairy-heifer-growth-chart>.



Bred Heifers

From the time a heifer is bred to 60 days prior to calving, the ration should be designed for growth and minimal fat deposition. Once she nears calving, a “pre-fresh” ration should be fed. This helps transition her to the diet she’ll be receiving once she has calved and enters the milking herd. It will prepare her rumen microbe population, support the growing fetus, and support the heifer’s growth and preparation to begin lactating.

During the last 60 days of gestation, a heifer needs to supply 75% of the calcium that her calf will have at birth. This proves how critical it is that a proper ration is calculated every step of the way to ensure the heifer and her calf’s nutritional needs are met.

FEEDING LACTATING COWS

As you have already learned, a dairy cow’s nutritional needs vary tremendously through her lifetime. This is where the assistance of a professional dairy nutritionist will prove helpful. At peak milk production, a cow may need 3 to 10 times as much protein and energy as she did during late gestation. The goal of any good dairy feeding program is to meet the cow’s nutritional needs, minimize weight loss, and maintain health.

A cow’s lactation and gestation cycle can be divided into five phases.

1. First 10 weeks of lactation: Peak milk production occurs and body stores are used to make up for the deficits in nutrient intake.
2. Next 10 to 20 weeks: A cow’s energy intake meets her requirements and she is consuming her maximum amount of dry matter intake.
3. Later lactation: Intake exceeds requirements for production and body stores rebuild in preparation for the next lactation.
4. Dry period: Final regain of body weight and involution followed by regeneration of secretory tissue in the udder (typically 6-8 weeks).
5. Close-up dry period: When you would start preparing a cow for lactation (1-3 weeks before calving – also known as the transition period).

As you can see, monitoring a cow’s weight is very important. A **body condition scoring system** is used in the dairy industry to help provide standards. Individual cows are rated on a scale of 1-5, with 1 very thin and 5 excessively fat. A body condition score of 3.5 at calving is ideal for high milk yield and reproductive performance. The cow should also be at this condition when she goes dry.

A cow’s weight fluctuates based on her energy balance. Negative energy balance means she is not getting enough energy in her diet, so she will likely lose weight as she resorts to taking from her body stores. A positive energy balance means she is maintaining or gaining weight. Cows in this stage have greater conception rates.

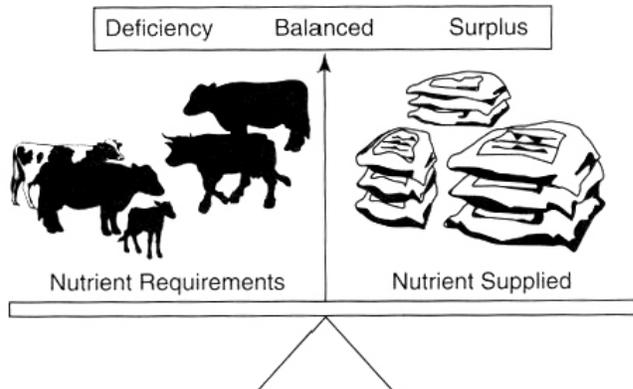
Maximizing dry matter intake as soon as possible will help attain and maintain a positive energy balance as well as high milk production. Dry matter intake will likely reach 3.5 to 4.5% of the cows’ body weight, and higher producers will commonly reach closer to 5%. Having readily available access to feed will also drive dry matter intake. A high producing cow should have access to feed 18 to 20 hours a day.

If feeding ration components individually, a minimum of four offerings a day, alternating between forages and concentrates, is ideal. If feeding a Total Mixed Ration (TMR), lactating cows may also be divided into larger feeding groups, based on stage of lactation or the amount of milk they are giving. Again, grouping ensures the cows’ nutritional needs are met more closely.

Water is critically important for cattle to ensure optimal production. A fresh, clean and abundant supply should always be available. In group housing, one watering station should be allowed for every 20 to 25 cows.

Balancing a Cow's Diet

In its simplest form, you can think of balancing a ration as ensuring the nutrient requirements are equal to the feed nutrients. A ration that is not balanced will be either in surplus or deficiency, which can negatively affect the health of the animal.



Ration formulation may be visualized as the simple process of "balancing" nutrient requirements with feed nutrients.

Formulating a ration is something many will and should leave to a professional nutritionist. But, it is good to understand some basic ways used to determine feed values.

Take some time to look at the "Nutrition Facts" label on packaged foods you eat. It contains the nutritional value of the food, like calories (energy), fat, carbohydrates and protein. It also shows you what percent of the daily recommended value of each will be supplied by consuming that food. Complete feeds that come in bags will have a similar label, only it is up to you to make sure you are feeding the

animal the appropriate amounts for proper nutrition.

The nutrition value of individual feeds is the basis for formulating a ration. In the U.S., the National Research Council (NRC) publishes "Nutrient Requirements of Domestic Animals." This publication includes reliable animal nutrient requirements, as well as the nutrient make-up of common feeds. If you plan to feed hay or silage, it is a good idea to have them tested by your nutritionist to get more specific information on its nutrient value.

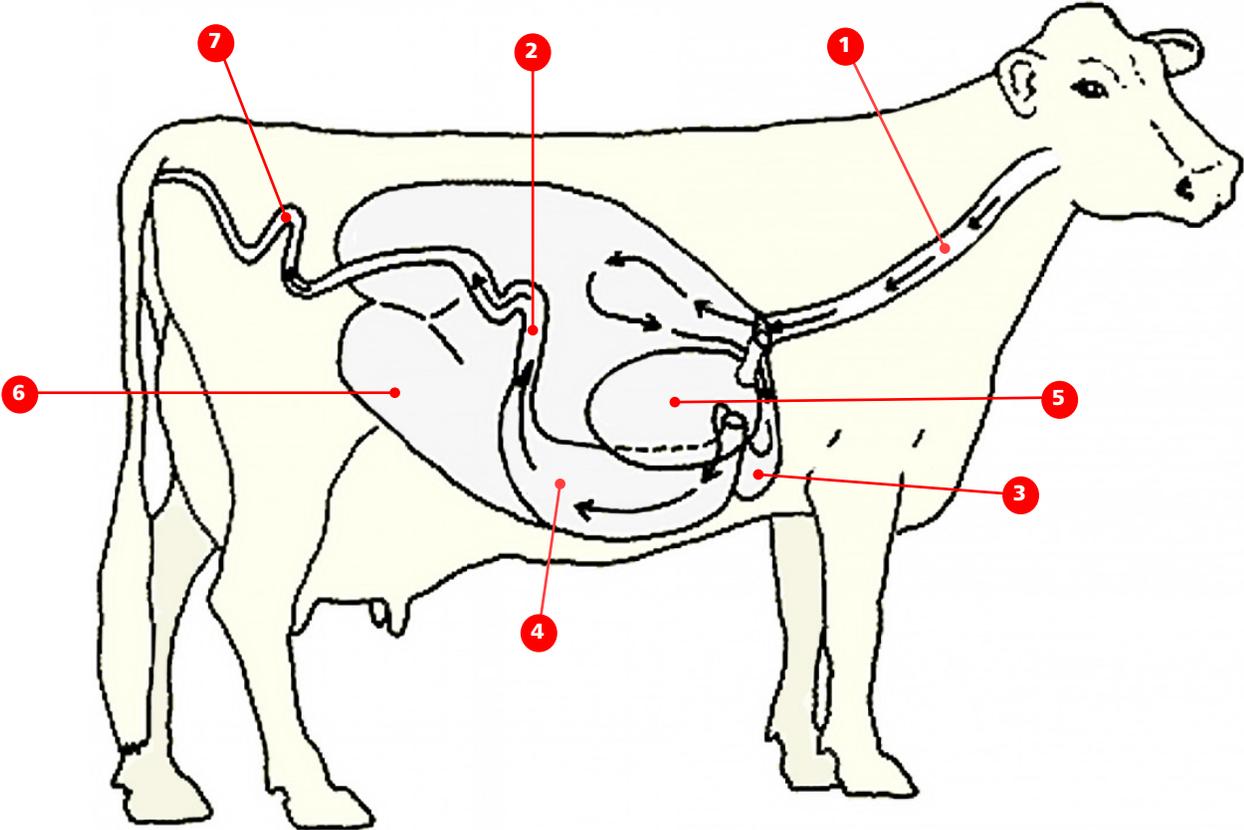
EXERCISE: Required Nutrients

Answer the following questions regarding nutrients.

- 1. What is the function of feeding carbohydrates to a dairy cow?**
- 2. Why is feeding protein important to the dairy cow?**
- 3. Energy is available from three dietary sources. One of these is fats. Give an example of a fat often fed to a dairy cow.**
- 4. Why is fat important in a dairy cow's diet?**
- 5. Give an example of a vitamin not stored in the body tissue of a dairy cow?**
- 6. What role does Vitamin A serve in a cow's diet?**
- 7. Give an example of a macromineral used in dairy cattle nutrition?**
- 8. What is the function of calcium in a cow's diet?**

EXERCISE: Digestive System

Label parts of a cow's digestive system



___ Abomasum
___ Esophagus
___ Large Intestine

___ Omasum
___ Reticulum

___ Rumen
___ Small Intestine

EXERCISE: Determining Feed Values

#1: Determine the amount of dry matter a cow should be consuming.

QUESTION:

How much dry matter should a 1,600 pound cow consume a day with a desired intake of 3.5% of body weight?

#2: Determine the amount of dry matter a cow is consuming

QUESTION:

If you feed a cow 10 pounds of 70% dry matter high-moisture shelled corn, how many pounds of dry matter is she consuming in the corn?

#3: Determine the amount of protein a cow is consuming

Sample Feed Tag

Brand X
COMPLETE DAIRY FEED
18% for Lactating Cows

GUARANTEED ANALYSIS

Crude Protein (Min.)	18%
Crude Fat (Min.)	4.5%
Crude Fiber (Max.).....	8%

INGREDIENT LIST

FEEDING DIRECTIONS

Manufactured by
Brand X Feed Mill
Anytown, USA

50 Lb. Net Weight (22.68 kg)

QUESTIONS:

If you feed a cow 10 pounds of 18% Complete Dairy Feed (see sample tag), knowing it is 90% dry matter, how many pounds of protein is she consuming in the Dairy Feed? Then, determine the amount of protein on a dry matter basis.

#4: Determine the nutritional value the cow is getting from each feedstuff.

Feed	# as fed	% Dry Matter	# Dry Matter	% Crude Protein on as fed basis	# Crude Protein
Corn Silage	50	34%	17	3%	1.5
Alfalfa Haylage	50	42%	21	8%	4
High-Moisture Corn	15	78%	11.7	5.50%	0.825
Soybean Meal	5	90%	4.5	40%	2
Diet summary	120		54.2		8.325

QUESTIONS:

Using the sample diet above, answer the following:

How many pounds of alfalfa haylage is a cow being fed each day?

How many pounds of dry matter is the cow consuming a day?

What percent protein is the high-moisture corn?

On an as-fed basis, how many pounds of protein are provided in the corn silage?

REFERENCES:

Livestock Feeds and Feeding, 6th edition, Richard O. Kellems & D. C. Church, c. 2010.

University of Pennsylvania Extension. "Monitoring Dairy Heifer Growth."

ANSWER KEY

REQUIRED NUTRIENTS

1. Carbohydrates provide most of the cow's energy and they release enzymes that break microorganisms down into simple sugar stimulating rumen synthesis
2. Protein is important for structural components such as blood, bone and muscle tissues and amino acids bond together forming proteins which allow them to be absorbed by the body
3. Cottonseed or soybeans
4. Fat provides the most energy per pound of feed improving energy status and helps with reproductive performance
5. Vitamin C, B1, B2, B6, B9, B12 or PABA
6. The purpose of Vitamin A is to help with immunity, gene regulation and vision
7. Calcium, phosphorus, chlorine, magnesium, potassium, sodium or sulfur
8. Calcium helps with bone structure, creates activity in the nervous system and prevents blood clots

DIGESTIVE SYSTEM

1. Esophagus
2. Small Intestine
3. Reticulum
4. Abomasum
5. Omasum
6. Rumen
7. Large Intestine

#1 DETERMINING FEEDS VALUES

$16 \text{ (for a 1,600 pound cow)} \times 0.035 \text{ (desired intake \% of body weight)} = 56 \text{ pounds Dry Matter (DM)}$

#2 DETERMINING FEEDS VALUES

$10 \text{ (pounds of silage on an as fed basis)} \times 0.70 \text{ (percent dry matter)} = 7 \text{ pounds Dry Matter (DM)}$

#3 DETERMINING FEEDS VALUES

$10 \text{ (pounds of Dairy Feed on an as fed basis)} \times 0.90 \text{ (percent dry matter)} = 9 \text{ pounds Dry Matter (DM)}$

$9 \text{ (pounds of dry matter)} \times 0.18 \text{ (percent protein in the feed)} = 1.62 \text{ pounds of protein on a dry matter basis}$

#4 DETERMINING FEEDS VALUES

50 pounds alfalfa hay

54.2 pounds of dry matter each day

5.50% protein in the high-moisture corn

.825 pounds crude protein in the corn silage



Holstein Foundation Workbook Contribution Form

Our series of Holstein Foundation workbooks are provided free of charge as an educational resource for dairy youth and adults around the world. The development of these workbooks is supported by contributions from generous individuals who believe in the Holstein Foundation's mission of promoting and supporting programs that provide leadership for the dairy industry. If you would like to make a gift to help ensure we can continue providing these resources, please complete this form and return it to the address below. Donations may also be made with a credit card online at www.holsteinfoundation.org.

Full name, as you would like to be recognized for your gift:

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Preferred Email Address _____

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A note will be sent to the family of the above individual, notifying them of your gift.

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