Chapter 7

Nutrition: Energy Yielding Nutrients

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Introduction
An optimal diet is one that supplies the necessary nutrients in adequate amounts to maintain, repair, and grow tissue without providing excess energy that the body stores in the form of adipose tissue. Human nutritional needs are relative to individual genetic predisposition; affected by normal variations in nutrient digestion, absorption, and assimilation; needed to meet specific requirements for energy expenditure of physical activity; and influenced by individual dietary practices and preferences.

These four factors indicate that there is no single, universal diet for optimal nutrition (26; 36; 50; 51). However, careful evaluation of food consumption, coupled with food intake planning in accordance with sound nutritional guidelines, will result in general and specific improvements in overall health, fitness, and performance.

Nutrients are divided into six classes and two subcategories. Carbohydrates (CHO), proteins, and lipids are individually classified and categorized as energy-yielding nutrients. The non-energy-yielding category includes the other three classes of nutrients: vitamins, minerals, and water. Each plays a vital role in the proper function of the human body in response to varying physiological conditions. This chapter will review the energy-yielding nutrients.

Energy-Yielding Nutrients
Energy-yielding nutrients are those nutrients that provide the body tissues with usable energy to form ATP. All of the energy-yielding nutrients contain the chemical element carbon. The carbon atoms are bound together into varying carbon chain skeletons. Carbon chains become linked with atoms of other elements to form lipids, carbohydrates, and proteins. When consumed, the process of digestion breaks food down to its most basic energy form. In the small intestine, the nutrients are absorbed into the blood and transported to tissues to perform their respective jobs throughout the body.

Once the energy is in the bloodstream, chemoreceptors identify the nutrients and determine a specific course of action for the energy. The body has the ability to manipulate the energy to meet any particular demand or to store the energy for later use. The metabolic organs determine the outcome of the energy consumed in the diet via hormonal regulation. The liver is the primary metabolic organ that can manipulate the energy form based on the acute internal needs of the body. If needed, the liver can convert proteins into carbohydrates, or proteins and carbohydrates into fat by arranging the carbon chains and elements to reflect the desired energy substrate. The rearrangement of carbons by the body is an important function, as it supports the ability of the body to reformulate nutrients that are needed but may not be present in necessary quantities. This process allows for energy needs to be met during work and energy to be stored when not currently needed by the body.

Carbohydrates
Although all nutrients are necessary for the body to function properly, carbohydrates are the most important nutrient related to physical activity. They represent the primary fuel source for intense work and are necessary for the formation of ATP used by the central nervous system, making the nutrient an indispensable part of a healthy diet. Carbohydrates fall into three general categories: monosaccharides, disaccharides, and polysaccharides. Monosaccharides are the most basic form of carbohydrate. They represent a single sugar moiety. Different monosaccharides vary from each other based on their carbon-to-hydrogen-to-oxygen linkage sequences.

These differences in sequence determine a carbohydrate’s biochemical characteristics. For example, glucose and galactose are monosaccharides with the same number of carbon, hydrogen, and oxygen atoms, but they are arranged differently, thus making them behave and taste slightly different from each other. Disaccharides, as their name implies, are formed by the joining of two separate sugar molecules (monosaccharides). Lactose is a disaccharide formed by the combination of a glucose molecule with galactose. Both mono- and disaccharides are referred to as simple sugars because they require little manipulation by the cell for use as energy. Finally, polysaccharides are chains of monosaccharides linked together in sequences from as few as three sugars, to as many as several thousand. As the chains of monosaccharides sugars increase in length and diversity, the complexity of the nutrient increases. Polysaccharides are more commonly referred to as complex carbohydrates and have chain linkages of tens to thousands of monosaccharide residues.
~Key Terms~

**Monosaccharides** - The simplest form of carbohydrates, comprised of one saccharide molecule.

**Disaccharides** - A simple form of carbohydrate, comprised of two monosaccharides.

**Polysaccharides** - A form of carbohydrate, consisting of a number of monosaccharides.

**Complex Carbohydrates** - Sugar molecules that are strung together in long, complex chains.

**Glycogen** - The main storage carbohydrate found primarily in the liver and muscles.

residues. These complex chains are classified as either plant or animal polysaccharides depending on their dietary source.

Glycogen and starch are two common forms of polysaccharides in our diets. **Glycogen** is the storage form of carbohydrates in animal tissue, while **starch** is the term used for the storage form of carbohydrates in plants. Starch is the larger component in seeds, corn, potatoes, beans and the various grains that make up common foods like spaghetti, bread, and cereals. Plant starch remains the most important source of carbohydrates for most Americans, accounting for more than 50% of the total carbohydrates consumed. This number has decreased by 30% since the turn of the century, when starches comprised about 80% of carbohydrate sources. This significant decline has been met by an equally significant increase in simple sugar consumption.

**Fiber**

Fiber is a non-starch polysaccharide, and in the form of cellulose, is the most abundant organic molecule found on earth. It is a tough material that resists enzymatic breakdown, making it indigestible by humans, except for a small portion that is fermented by intestinal bacteria. Fiber is commonly categorized as either **soluble** or **insoluble**. The bacterial breakdown of fiber generally contributes less than 2 kcal per gram, making it an excellent addition to calorie-controlled diets. Its consumption is linked with lower occurrences of several “Western” diseases including obesity, diabetes, hypertension, intestinal disorders, some cancers, and heart disease (1; 19; 55; 61). Due to the fact that most Americans consume far less (12-15g) than the recommended 20-35 grams, the Western diet predisposes consumers to an elevated disease risk (65).

In less industrialized nations, the fiber content of the average diet is between 40-100g per day (17). Not surprisingly, the rate of related diseases is dramatically lower in those countries than in America. Fiber enhances gastrointestinal function and reduces irritation to the intestine wall, mobilizes harmful chemicals and compounds inhibiting their activity, shortens the time for intestinal transport to excretion, decreases the length of time carcinogenic materials stay in the intestines, and slows down the absorption rate of carbohydrates, acting positively on blood glucose dynamics. Additionally, the foods associated with a high fiber diet often support health by being lower in calories and more nutrient-rich (6; 7). For this reason, fiber should be consumed through food sources rather than as a supplement (66). Sample foods high in fiber are whole grain products, fruits, and leafy green vegetables.

Due to the fact that carbohydrates serve as the primary fuel source for physical activity, it makes sense that they represent the largest portion of energy from the diet. The recommended dietary intake for carbohydrates is 55%-60% of the total diet, with the majority being derived from polysaccharide (complex) sources. However, the average American consumes only about 40-50% of their total diet from carbohydrate sources with 50% of those calories being derived from mono- and disaccharides (simple sugars). It has been

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**Foods High in Fiber**

<table>
<thead>
<tr>
<th>Oat Bran</th>
<th>Whole Wheat Flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Germ</td>
<td>Rice Bran</td>
</tr>
<tr>
<td>Oatmeal</td>
<td>Almonds</td>
</tr>
<tr>
<td>Pumpkin Seeds</td>
<td>Peanuts</td>
</tr>
<tr>
<td>Pinto Beans</td>
<td>Lime Beans</td>
</tr>
<tr>
<td>Avocado</td>
<td>Pear</td>
</tr>
<tr>
<td>Figs</td>
<td>Strawberries</td>
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<tr>
<td>Corn on the Cob</td>
<td>Bran Muffin</td>
</tr>
<tr>
<td>Spaghetti, Whole Wheat</td>
<td>Grapefruit</td>
</tr>
<tr>
<td>Apple</td>
<td>Chestnuts</td>
</tr>
<tr>
<td>Broccoli, Raw</td>
<td>Green Beans</td>
</tr>
<tr>
<td>All Bran Cereal</td>
<td></td>
</tr>
</tbody>
</table>

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**Hidden Calories**

One 12 oz. can of soda per day

39 grams of sugar per can x 365 days in a year = 14,235 grams of sugar

14,235 grams sugar = 32 lbs of sugar
estimated that at least 25% of the American diet is simple sugar, a trend that significantly contributes to the increased risk for obesity, diabetes, and heart disease. Most people consume more than 100 lbs. of sugar annually, mainly in the form of sucrose and high fructose corn syrup (23).

**Sugars**

Sugars fall into the categories of monosaccharides and disaccharides. **Glucose, fructose** and **galactose** are all monosaccharides. They are similar in chemical formula but differ by specific carbon, hydrogen, and oxygen linkage. Glucose is the main monosaccharide used by the body. It can be split for ATP, stored for later use as glycogen, or converted into lipid form following its absorption into the cells. Fructose is nature’s fruit sugar. It is the sweetest of the sugars per gram. When ingested, it is converted into glucose by the liver. Galactose is an animal monosaccharide found in dairy products.

The disaccharides include **lactose**, **maltose**, **sucrose**, and **trehalose**. Sucrose is the most commonly consumed sugar form, representing up to 25% of some American diets (24). It is commonly consumed in baked products or in the form of table sugar. Lactose is formed from glucose and galactose. It is often referred to as dairy sugar. Many people around the world are lactose intolerant, lacking sufficient enzymes to break the disaccharide down in the body. When two glucose molecules are combined, they form maltose, which is present in cereals, germinating seeds, and beer.

**Glycemic Response**

When sugars enter the blood, they raise the blood glucose levels. The specific response is based on the amount and type of sugar consumed. The elevation in blood glucose concentrations is quantified using a measurement system called **glycemic indexing**. The glycemic index describes the effect carbohydrate sources have on circulating blood glucose levels by rate and concentration. The rate at which the food increases blood glucose is called the **glycemic response**. The amount of glucose in the blood is referred to as the **glycemic load**.

In low fiber diets, manufacturer processed starches and simple sugars are digested quickly and enter the blood stream at a rapid rate. This causes the release and often over-release of insulin, which heightens hyperinsulinemia (a state of high insulin release by the pancreas) (4; 9; 12; 18). Consistently eating high glycemic foods may lead to reduced insulin sensitivity (3; 6; 7; 9). This reduced insulin sensitivity causes the pancreas to release higher amounts of insulin in response to the blood sugar; this response in conjunction with obesity is linked to the development of Type II diabetes.

As mentioned earlier, a concern with high amounts of insulin is that abnormally high levels facilitate the conversion of sugar into triglycerides in the liver, which are then stored as fat in adipose tissue. Diets high in sugar are directly linked to an increased risk for obesity. Contrary to this, foods high in dietary fiber and protein slow the absorption rate of the sugars and minimize surges of blood glucose. A reduction in blood sugar causes a decrease in the concentration of insulin secreted into the blood. Additionally, when fat is combined with simple carbohydrates, the glycemic effect is reduced, compared to the effects of the independent sugar source (29; 59). Regular exercise also exerts a notable positive influence on the body’s sensitivity to insulin making regular physical activity a key component in the prevention and management of diabetes.

The following glycemic index table identifies foods according to their specific insulin responses. The glycemic value in the table is determined after ingesting 50 grams of a carbohydrate source and comparing the resulting blood sugar levels over a two-hour period to a standard for carbohydrates, usually white bread or glucose, which has an assigned value of 100. The corresponding value expresses the relationship or percentage of total area under the curve set by the reference standard. If white bread represents 100% of the curve, then a food encompassing 45% of the total area would be assigned a glycemic index value of 45. International values for glycemic index do exist, but slight discrepancies arise when comparing specific trials due to variations in the foods used.

---**Quick Insight**---

Monosaccharides can be broken down to form derivatives which can be used by the body. Sugar acids, sugar alcohols, and amino sugars are formed when monosaccharides are metabolized. Amino sugars and sugar acids are present in connective tissue and assist in supporting the tissue’s metabolic needs. Sugar alcohols have become a popular additive to supplements and foods to provide flavor with a decreased energy value. Glycerol and sorbitol, among others, are used in energy bars and foods that attempt to provide reduced sugar content and glycemic effect in the diet (2). They are often not counted under the total carbohydrates measured on the labels of food or they are advertised on the label as “non-impact carbs” for carbohydrate-conscious consumers. They generally provide 1-3 calories and have much less of an effect on blood glucose dynamics (52).
Certain sugars, such as sucrose and high fructose corn syrup, can wreak havoc on blood glucose stability. These saccharides are collectively identified as dietary troublemakers. Naturally occurring fructose is touted as dietary, or a more desirable sugar, because of its sweetness and reduced glycemic index (see below), particularly when consumed from non-juiced, whole fruit sources. But unlike naturally occurring fructose, the commercially formulated high-fructose corn syrup is quickly absorbed and causes a rapid rise in the body’s blood glucose concentration. Research trials identified increased serum cholesterol and low-density lipoprotein (LDL) concentrations in the blood when 20% of the dietary calories came from this monosaccharide.

It is estimated that the largest part of the American population routinely exceeds 20% of total dietary calories from sucrose and high fructose corn syrup. The high consumption of sugars disrupts normal metabolic pathways due to the response of insulin in attempts to prevent hyperglycemia. The hormones that control the level of circulating blood sugar are regulated by beta- and alpha-cells in the pancreas. Elevated blood glucose causes the pancreas to release insulin in proportion to the rate and quantity of sugar absorption. Insulin facilitates an uptake of the circulating blood sugar into skeletal muscle and the liver, where it is stored as glycogen.

When high amounts of simple sugars are consumed on a regular basis, the body works hard to remove the glucose from the blood. Once glycogen stores are filled, the body may metabolize the sugar as fuel or convert it in the liver into triglycerides. Triglycerides are then stored as fat in adipose cells. Insulin is lipogenic, meaning it increases fat storage. Consistently elevating blood glucose and the consequent release of insulin causes an increased susceptibility to fat gain. This phenomenon is considered a major contributor to weight gain in America.
such as the brain. Eating patterns that cause the body to work in constantly fluctuating blood glucose level conditions cause higher concentration release of pancreatic hormones. These conditions manifest themselves in poor utilization of energy nutrients and cause changes in the cellular use of glucose. For the ideal blood glucose situation to occur, we need to take in smaller quantities of food at roughly 90-120 minute intervals, reflecting a grazing style of eating. This suggests the average meal size should be lower in calories to maintain optimal blood glucose levels (20; 62; 67). Grazing animals such as deer follow this eating pattern and maintain low levels of body fat and do not develop type II diabetes, in part because their foods are high in fiber and low in calories, but it is also because regular intake normalizes blood glucose (30). Although 7-9 meals may be unrealistic, many nutritionists recommend eating small meals more frequently throughout the day to mirror the grazing pattern of eating to avoid large spikes in blood glucose levels.

A second benefit to increasing the consumption frequency of carbohydrates and consuming calories in smaller portions is to thwart hunger. When chemical receptors in the tissues identify reduced levels of blood glucose, the hypothalamus stimulates the physiologically controlled hunger mechanism to communicate the need for food. When this occurs, the required calorie intake to meet the current need is often low, equal to maybe a couple hundred calories. If food is consumed at this time, the hunger mechanism is relieved and blood glucose levels are appropriately re-established. If hunger is deferred, it soon turns into appetite. Appetite is the psychological perception of caloric need. The brain’s psychological discernment of need exceeds the physiological requirements for food and predisposes an individual to over consume calories. Anyone who has ordered and consumed appetizers before the main course at a restaurant probably realized they were not as hungry as they originally thought when the main dish arrived. Avoiding appetite-related eating patterns is important for preventing overeating habits (8).

When carbohydrate selections are made intelligently, they can effectively aid in the reduction of body weight and improve health. Carbohydrates account for most of the thermic effect of food, which can represent up to 10% of daily caloric expenditure. As previously stated, complex carbohydrates are nutrient dense and provide dietary fiber, which reduces the risk of digestive disorders, and can be low in calories when

~Key Terms~

**Starch**- A complex carbohydrate found in seeds, fruits, and stems of plants and more notably, in corn, rice, potatoes, and wheat.

**Fiber**- Indigestible plant matter, consisting primarily of polysaccharides that when consumed increase water absorption and intestinal peristalsis.

**Soluble Fiber Sources**- Oats/oat bran, dried beans, nuts, barley, and vegetables such as carrots.

**Insoluble Fiber Sources**- Dark green/leafy vegetables, fruit skins, corn bran, and seeds.

**Glucose**- A simple sugar (monosaccharide) used as the primary fuel source by most cells in the body to generate energy.

**Fructose**- A sweet sugar (monosaccharide) found primarily in fruits.

**Galactose**- A simple sugar (monosaccharide) found in dairy products.

**Lactose**- A disaccharide in dairy products that hydrolyzes to yield glucose and galactose.

**Maltose**- A white sugar formed during the digestion of starch.
consumed from appropriate sources. Likewise, phytochemicals and other compounds found in whole grains can reduce the risk of certain diseases, such as cancer and cardiovascular disease (31; 48). Compliance with the suggested guidelines for carbohydrate consumption seems to be one of the problems with the American diet. Due to the fact that the majority of calories in the average diet come from processed carbohydrates and sugars, the added health benefits from the foods are minimal, and the thermic effect of most diets is low. Authors of diet books have recognized this pattern and recommend reducing carbohydrates to decrease the effects of sugar and processed carbohydrates for weight control. Carbohydrate selection can play a major role in weight management and disease risk when intelligently applied.

The current trend toward cutting carbohydrates should refer to reducing simple sugar and processed carbohydrate consumption, not cutting complex carbohydrates from the diet. The problem lies in the dissemination of information to the general public. In many cases, the popularized low-carbohydrate diets cause weight loss for all the wrong reasons. Cutting carbohydrates reduces the stored glycogen in the body and is often not appropriately replaced. Due to the fact that glucose bonds with water molecules when forming glycogen in the cell, reducing glycogen stores within the body also reduces the body’s water content. The body will significantly diminish its carbohydrate stores in about 96 hours under an extended fast, which can account for significant metabolic water loss (21; 54). This mechanism accounts for most of the initial weight loss in low carbohydrate diets. Whereas calorie control and exercise have been touted as the only way to effectively lose weight and keep it off, most low carbohydrate dieters gain the weight back soon after finishing the diet. In fact, attempting to lose weight by diet alone usually is only successful for approximately 2-5% of the population (13; 33). Most dieters gain the weight back within 6-9 months. Additionally, low carbohydrate diets are contrary to the metabolic functions of the body for activity. When glycogen stores are low, so is work capacity. In general, low carbohydrate diets should not be recommended for physically active people. It should be noted that controlling sugar and processed carbohydrates is not the same as a low carbohydrate diet.

**Carbohydrate Depletion**

Carbohydrate availability affects more than energy output alone; it also affects metabolic biochemistry. When carbohydrate consumption is reduced by poor eating habits, high protein diets, reduced energy intake, starvation, or fasting, the body reacts to compensate for the deficit. Reduced glycogen reserves and low plasma glucose concentration trigger glucose synthesis through a process called gluconeogenesis in the liver and, to a lesser extent, in the kidneys. Amino acids and triglyceride molecules are rearranged to form sugar to fuel the body’s need. The gluconeogenic conversion breaks down both lean mass and fat mass to augment carbohydrate availability. Normally the body has a natural protein-sparing mechanism, maintained by an adequate consumption of carbohydrates and fat. Preferably, the body does not want to use protein for fuel. Even if adequate protein is consumed to meet functional requirements, protein-sparing may not occur because it is regulated by neural and hormonal assessment of carbohydrate stability. Without protein-sparing, amino acids are liberated from lean mass, primarily skeletal muscle, and reformulated into carbohydrates in the liver for energy. Prolonged effects of lean mass catabolism can lower the body’s total metabolic rate. This problem is exacerbated by the fact that the body relies on carbohydrates as the primer for fat metabolism. As mentioned earlier, with the by-products of carbohydrate breakdown being reduced,
there is an increased fat mobilization and decreased capacity for fat oxidation. Under this state of insufficient carbohydrate metabolism, more fat is mobilized than can be oxidized. This produces an incomplete breakdown of the fat and the build up of acetone byproducts referred to earlier as ketone bodies. For this reason, low carbohydrate diets are also referred to as ketogenic diets. Only consumption of adequate amounts of carbohydrates will prevent this phenomenon from occurring.

Carbohydrate consumption proves to be of further significance due to the fact that the brain and central nervous system require carbohydrates for proper function. Under normal conditions, the brain uses blood glucose almost exclusively for fuel. When the body is deprived of carbohydrates, gluconeogenesis is used to maintain blood glucose concentrations for nerve tissue metabolism and as a fuel for red blood cells. In a low carbohydrate environment, blood glucose can drop to hypoglycemic levels. In extreme situations, this condition can lead to central fatigue and may trigger unconsciousness, and even irreversible brain damage.

**Carbohydrate Need**

Earlier text indicated that carbohydrates are stored in the liver and muscle tissue in the form of glycogen. When consuming a normal diet, the storage capacity for glycogen is between approximately 300 to 400 grams or 1200-1600 kcal of energy, of which about 80% is stored in the skeletal muscles. When exercise is performed, carbohydrates serve to fuel both high- and moderate-intensity exercise anaerobically, and contribute to a substantial amount of energy in higher-intensity aerobic training. Energy derived from the breakdown of absorbed glucose, and glycogen stored in the muscles and liver, powers the protein contractile elements during muscle contractions and additionally required biological work. When exercise is intense or prolonged, glycogen stores are rapidly depleted. For physically active people, carbohydrate intake should mirror the training volume on a daily or weekly basis. Low carbohydrate consumption can lead to premature depletion of glycogen, causing the storage volume to become too low to support activity. The following graph illustrates the varying fuel source contribution to glycogen storage and its role in prolonging steady-state exercise.

After analyzing the relationship between energy metabolism and available carbohydrates, it should be obvious that the consumption of carbohydrates is relative to specific need but has a definite lower limit. The exact quantity consumed depends on the amount and type of physical activity an individual engages in on a regular basis. If a person is sedentary, carbohydrate consumption may be as low as 45% of the total diet because the level of activity they routinely engage in is equally low. For individuals who exercise regularly, carbohydrates should comprise roughly 55-60% of the total diet (27; 38; 43). It is recommended that the majority of carbohydrates come from complex sources
with no more than 10% derived from simple sugar. Total carbohydrate intake recommendation jumps to 70% for individuals who engage in regular intense training (3; 56). The idea behind “carb-loading,” which is the intake of high amounts of carbohydrates prior to a race, is to optimize glycogen reserves, much like topping off the fuel tank of a car before a trip (22; 34; 57). Frequently, however, athletes overeat the amount of carbohydrates required, with the excess amount being stored as fat (58). Additionally, diets that over-emphasize protein often fail to meet the carbohydrate needs of most physically active individuals.

Two ways exist to estimate the grams of carbohydrates necessary for daily intake needs. One method is to calculate the value using a predicted daily need and subjective percentage rate. The other method is to use recommended grams per kilogram of body weight, based on estimations of activity status. Based on the prediction outcomes, the two are similar in predictability when calculated correctly.

This number will vary as relative carbohydrate needs change based on current activity status. If training volume and intensity are increased or decreased, the CHO intake should reflect the shifts in training.

Fats
Fats, also known as dietary lipids, are the other primary source of energy the body uses to fuel biological work. Lipid molecules have the same structural elements as carbohydrate molecules (carbon, oxygen and hydrogen), but differ in the way the atoms are linked. This marked difference determines the way lipids are metabolized and stored in the body. Like carbohydrates, lipids differ in chain length and molecular complexity, which places them in three distinct categories: simple lipids, compound lipids, and derived lipids. The following table identifies the specific characteristics related to each category.

Lipids are necessary for normal function of the body. Most people view fat as a negative constituent of the diet because of the perceived link to obesity. But this is unwarranted, as fat actually serves many important functions in the body.

The aforementioned roles that fat plays in the body identify the importance of adequate consumption in the diet. Problems with fat in the diet occur when more fat
At 9 kcal per gram, the energy in fat is more consumption predicted experienced by many Americans. At 9 kcal per gram, the energy in fat is more than twice that of carbohydrates and protein, a characteristic that can contribute significantly to a positive caloric balance. Additional problems occur because fats are more easily stored as adipose tissue throughout the body than their carbohydrate and protein counterparts. Unlike carbohydrates, where stores are limited and oxidation occurs rapidly, fat storage goes relatively unregulated because the human body has an almost unlimited ability to store lipids. Additionally, biological mechanisms promote fat storage in situations where high amounts of calories are consumed.

Unsaturated and saturated fats differ by the structural bonds and respective carbon element make-up. Saturated fatty acids do not have double bonds between the carbons, which maximizes the hydrogen attachment sites (making them saturated with hydrogen). Monounsaturated fatty acids have a single double bond within the carbon chain, and polyunsaturated fatty acids have multiple double bonds, thereby reducing the number of hydrogen attachments. Additionally, the location of the double bond plays a role in the dynamics of the fatty acid. For instance, when the first double bond is next to the sixth carbon, the fatty acid is an omega-6, and when the first double bond is next to the third carbon it is referred to as an omega-3 fatty acid. The amount of hydrogen and double bond number and site all play a role in how the fatty acid reacts in the body. The following illustration demonstrates the chemical differences between saturated and unsaturated fats. Notice the differences in the bonds and hydrogen concentration.

In the average American diet, lipids represent approximately 35% of total caloric intake (64). About 34% of the dietary fats consumed come from non-animal sources while the majority, 66%, comes from animal sources. Dietary fat is classified as either unsaturated or saturated fatty acids. Monounsaturated and polyunsaturated fatty acids are commonly found in plant sources of fat. Animal sources of fat often contain higher amounts of saturated fats. It is generally recommended that 30% of a individual’s diet be derived from fat sources, with less than 7-10% from saturated fat (40). On average, approximately 15% of total calories are consumed as saturated fatty acids by Americans everyday (39). This is very relevant, as a relationship exists between fat intake, specifically saturated fat, and coronary heart disease (16). Diets high in saturated fats lead to a pronounced change in the blood lipid profile, particularly in LDL cholesterol, whereas a diet higher in monounsaturated fats has been linked with lower coronary heart disease risk (37; 63).

When fatty acids are consumed in the diet, they enter in varying proportion based on the type and quantity of foods consumed. Fatty acids enter circulation through the intestine and are picked up by lipoproteins called chylomicrons. The lipids are transported to the liver where they are metabolized, attached to very low density lipoproteins (VLDL), and delivered to fat
cells to be stored or utilized as fuel in the form of triglycerides. The VLDL gives up the transported lipids and is turned into a **low density lipoprotein (LDL)**. The density of the lipoprotein refers to the protein to fat ratio. VLDLs are 95% fat. LDL cholesterol circulates in the blood en route back to the liver where it can form bile. LDL is considered to be hazardous cholesterol because it is so small it can collect on the lining of damaged arteries. This affinity for the cells of the arterial wall increases risk of oxidation and the proliferation of smooth muscle cells, thereby adding to plaque in the artery, known as atherosclerosis (see Chapter 12). **High density lipoprotein (HDL)** has a protective role, inhibiting arterial plaque formation, making HDL the more desirable cholesterol in circulation.

Cholesterol is produced in the body, but it is also found in food products. The body produces about 70% of its approximately 1000 mg need per day. The remaining 300 mg comes from dietary sources (35; 71). Cholesterol is needed to perform complex bodily functions, including the formation of plasma membranes and hormones. It also works in digestive functions, forming bile and serves as a precursor for vitamin D. Although an important lipid in the body, it can also be problematic if consumed in abundance in the diet. For this reason the American Heart Association recommends consuming no more than 300 mg per day (35). For individuals at higher risk for heart disease, that recommendation drops to between 150 and 200 mg. Dietary cholesterol is common in animal products that contain higher amounts of fat. One egg yolk, for instance, contains the full daily amount of cholesterol. Likewise, red meat, shell fish, and dietary liver are also high in cholesterol.

**Trans Fatty Acids**

Identifying which fats to consume has become increasingly difficult due to the manipulation of fats in processed food. Saturated fats are solid at room temperature, whereas unsaturated fats are liquid. Scientists working on ways to improve upon the dynamics of fatty acids when manufacturing food products created a specialized fat that takes advantage of the desirable chemical components of both saturated and unsaturated fats. **Trans fatty acids** have become an ever-present component in many manufactured food compounds. The molecular manipulation, called **hydrogenation**, occurs when one hydrogen atom of the cis-mono unsaturated fatty acid is moved from its naturally occurring position to the opposite side of the double bond that separates two carbon atoms. In doing so, food manufacturers create more desirable texture consistencies for foods like margarine, cookies, and ice cream. Consequently, this change in the molecular structure changes the way the lipids act in the body. Trans fatty acids have a profound effect on serum lipoproteins and can have possible adverse health affects by increasing LDL cholesterol and triglycerides, while at the same time reducing HDL cholesterol (45-47). Trans fatty acids do not occur in nature, and their intake may have other unknown detrimental effects. The CDC estimates that trans fatty acids account for at least 30,000 deaths annually from heart disease. In 2006, the American Heart Association recommended that 0% of the diet come from trans fat sources (68).
Cardiovascular disease is the number one killer in the United States. Although other factors contribute to heart disease, such as smoking and physical inactivity, fat tends to claim a large segment of the responsibility. Directly, dietary fat has a strong effect on blood lipid profiles. Additionally, dietary fat contributes to increases in fat mass and risk for obesity, which is linked to both heart and metabolic diseases. A high amount of saturated fat in the diet increases blood cholesterol dramatically, which can lead to coronary artery disease. This is further compounded by an excessive consumption of dietary fat, trans fatty acids, and cholesterol. When high amounts of fat are consumed on a regular basis, body fat is often increased, and the risk for disease is further elevated. For this reason, the recommendation is to consume less than 30% of total calories from fat. Categorizing the fat intake is a useful step that can further serve dietary improvement.

The American Heart Association suggests a ratio of fatty acids of 10:10:10. A healthier split of 30% dietary fat intake may be 15% monounsaturated, 10% polyunsaturated, and 5% or less from saturated sources (11; 53). This recommendation alone would drastically reduce the risk of coronary artery disease in many people.

~Quick Insight~

When excess fat accumulates in the body, the risk for cardiovascular disease dramatically increases. For this reason, manufacturers produce fat-replacers, which serve as tasty substitutes for the higher calorie lipids. These replacers have actually caused more problems in the American diet than they have solved. People seem to confuse fat-free foods with calorie-free foods and consume larger volumes of the food product than they would if real fat was an ingredient. This leads to excessive caloric intake and a positive caloric balance. Although the percentage of fat in the diet has declined from just over 40% in the early eighties to approximately 36% today, the total amount of fat has increased because many diets are higher in calories. Additionally, higher sugar intake is common because sugar is used to improve the taste lost from the removal of the fat, further contributing to the problem. In most cases, moderation of fat and non-fat products will help reduce the chances of overeating calories.
Lipid Characteristics & Examples

**Simple Lipids**
- **Triglycerides**
  - Glycerol + 3 Fatty acids
  - Saturated, Monounsaturated, Polyunsaturated
  - 98% of dietary lipids
  - 90% of fat in the body
  - Play a major role in risk of disease
  - Primary storage form of fat

**Compound Lipids**
- **Phospholipids**
  - Glycolipids
  - Lipoproteins
- **Triglyceride + Phosphorus group + nitrogenous base**
  - Fatty acids + CHO + Nitrogen
  - Protein + Triglycerides or Phospholipids
- **Lecithin**
  - Chylomicron
  - High Density Lipoprotein
  - Low Density Lipoprotein
  - Very Low Density Lipoprotein
- **Approximately 10% of body fat**
  - Modulate fluid movement across the cell membrane
  - Maintain cell structure integrity
  - Play a role in blood clotting
  - Protects nerve fibers
  - Cholesterol transport
  - Transport fat soluble vitamins

**Derived Lipids**
- **Fatty acids**
  - Steroids
  - Hydrocarbons
- **Rings of simple and compound lipids**
- **Cholesterol**
- **Produced in the body 70% Consumed in diet 30%**
  - Builds plasma membranes
  - Vitamin D precursor
  - Aid in formation of adrenal gland and sex hormones
  - Component for bile
  - Forms tissue, organ and body structures during fetal development
Protein

Proteins serve thousands of functions within the human body, representing the primary structural components of non-bone tissues. Proteins are made up of building blocks called amino acids. In the same way many monosaccharides are chained together to form a complex carbohydrate, multiple amino acids are also linked together in a chain to form a protein. Amino acids are substances composed of carbon, hydrogen, and oxygen, much like the other two energy nutrients, but amino acids also have nitrogen added to form an amine group (NH$_2$) and side chains which give each amino acid a unique identity. Proteins are comprised of different amino acid sequences, making up approximately 50,000 different protein-containing compounds in the body. The order and number of the amino acids in a protein give the protein its unique properties. There are not many physiological reactions that occur within the body that do not require the presence of a protein at some point during the process.

As mentioned above, biochemical function and the properties of each protein differ by how the amino acids are structurally arranged. Twenty (20) different amino acids are currently recognized, each differing from the side chains that attach to the amine group and associated carbon skeleton. The side chains dictate the particular characteristics of the molecule and the role they will serve in the body. The body can combine elements to create amino acids and combine the amino acids to form an almost infinite number of proteins. As is clear from the following picture, amino acids are carbon chains with different linkage options, which ultimately determine the type of amino acid and their specific characteristics.

The body can synthesize almost all of the 20 different amino acids from other amino acids. However, there are eight amino acids that the body cannot synthesize. These are labeled essential amino acids and must be consumed through the diet. They are isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Infants and children have additional essential amino acid needs because infants cannot synthesize histidine, and children have been identified to have a reduced capacity to form arginine, lysine, histidine and cysteine (32). The source of the amino acid does not matter, so the proteins can be consumed as animal or plant foods. A protein termed complete is considered to be higher quality because it contains all eight essential amino acids in appropriate quantity and correct ratio to maintain nitrogen balance, whereas an incomplete protein lacks one or more of the essential amino acids.

Animal sources generally receive the highest rating among dietary proteins. For the average American, animal proteins account for up to 70% of the total dietary protein consumed (60). This is an increase of 20% from the early 1900’s. One problem associated with the increased intake of animal proteins is that they are often accompanied by higher amounts of saturated fats and cholesterol. Plant proteins, although often incomplete, can supply all the essential proteins when

~Key Terms~

**Chylomicrons**- One of the microscopic particles of fat occurring in chyle and in the blood, especially after a meal high in fat.

**Very Low Density Lipoproteins (VLDL)**- A lipoprotein containing a very large portion of lipids which carry most of the cholesterol from the liver to the tissues.

**Trans Fatty Acids**- An unsaturated fatty acid produced by the partial hydrogenation of vegetables oils.

**Hydrogenation**- The act of combining with hydrogen

**Essential Fatty Acids**- Any of the polyunsaturated fatty acids which are required in the diet of mammals.

**Linolenic Acid**- An Omega-3 unsaturated fatty acid considered essential to the human diet.

**Linoleic Acid**- An Omega-6 unsaturated fatty acid, considered essential to the human diet.
consumed through a variety of sources and often contain fiber and other beneficial nutrients. This suggests that vegetarians can get adequate protein from the foods they consume, as long as their diets maintain a variety of plant food sources that together provide the eight essential amino acids. Dietary recommendations established by the Food and Nutrition Board of the National Research Council and National Academy of Science reflect the nutritional needs of the total population, not an individual’s specific requirements. The recommendation of 0.8-0.9 grams per kilogram of bodyweight meets the protein requirements for most individuals. Those who are physically active may require increased intake. For most active people, the increased need for protein is already met by the higher caloric intakes associated with extra calories consumed to meet the heightened energy needs. Individuals who engage in high volume resistance programs or participate in endurance training programs often need more protein to meet the tissue re-synthesis requirements associated with recurring microtrauma, or in the case of the endurance athlete, protein lost to energy metabolism.

~Quick Insight~

Most people consume two times the protein they need for the day. If Americans complied with the recommended 10-15% of total calories coming from protein they would likely find their nutritional needs would be met. The American diet relies heavily on protein as a staple to most meals, making the diet rich in nitrogen. For most exercisers, additional protein is not warranted based on their current consumption level and relative intensity of the activities they regularly complete. Many new exercisers want to buy protein supplements to encourage muscle gain. Increasing protein alone will add no new benefits and is likely to contribute to weight gain from a positive caloric balance. Likewise, increasing protein intake requires an equal increase in water consumption to manage excess nitrogen. If protein supplements are deemed necessary to meet training demands, many experts recommend whey protein as a first choice.

A 175 lb. male with 15% body fat, training four days a week and using moderate resistance training would have a recommended protein intake of approximately 110 grams and a total calorie requirement of 2912 kcal per day. His protein needs can easily be met by consuming 15% of his calories from protein.

3000 calorie diet x 10-15% = 300-450 kcal or 75-113 grams

The chart above identifies recommended intake options for different activities and physiological demands.

It should be noted that protein consumption beyond 1.6 grams per kilogram of body weight has been associated with increased risk of elevated saturated fat in the diet due to higher amounts of animal foods consumed and renal and liver distress due to excessive nitrogen in certain individuals.

Individual requirements are based on the frequency, duration, and intensity of exercise. High intensity endurance and resistance training activities increase protein requirements significantly, compared to sedentary and low level physical activity participation. To calculate the estimated protein requirements of an individual use the formula on the next page and the previous protein intake chart.

Protein intakes above 2.0 g/kg of bodyweight often cause increased renal stress due to the high quantities of nitrogen (10; 44). Protein consumption that exceeds requirements for anabolic processes can force the body into additional work to deal with the overflow. Protein is degraded into amino acids during digestion. Deamination occurs in the liver where the amino acid loses its nitrogen group to form urea. When protein is needed in the body, the deaminated amino acids formulate into new amino acids. Excessive protein intakes can cause the deaminated amino acid to formulate carbohydrates or fat, depending on the physiological environment. When protein is over-consumed, the kidneys and liver must process the excess, and therefore, become stressed from additional biochemical reactions. Furthermore, the kidneys require more water to create urine when the solute concentration of urea is high. This can lead to increased fluid loss and dehydration. Excessive protein consumed over an extended period of time can be detrimental to the body.
Essential Amino Acids - Eight of the 20 amino acids that the body cannot synthesize that must be consumed in a diet.

Complete Protein - A food source that contains adequate amounts of the essential amino acids.

Incomplete Protein - A food source that does not contain adequate amounts of the essential amino acids.

Nitrogen balance occurs when the amount of nitrogen in the protein consumed equals the nitrogen excreted by the body. When nitrogen balance is positive, the amount of nitrogen intake exceeds the amount of nitrogen excreted. Positive nitrogen balance occurs when the tissues utilize the largest amount of protein for anabolic processes, such as growth, maintenance and repair. This is commonly seen during the stages of developmental growth, pregnancy, illness and with resistance-trained individuals through protein synthesis. When the nitrogen balance becomes negative, the output of nitrogen exceeds the intake, and protein is utilized as an energy source. Inadequate consumption of carbohydrates and fats can lead to negative nitrogen balance, even in the presence of adequate protein intake. Low carbohydrate diets, inadequate nutrition, or excessive exercise have all been implicated in negative nitrogen balance and consequential loss of lean mass proteins.
CHAPTER SEVEN REFERENCES


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