NUTRIENTS 101

PROTEIN

Proteins are molecules made up of chains of amino acid building blocks and are fundamental to the structure and function of all plant and animal cells. Proteins are composed of differing amounts of AAs, as few as a couple and as many as 30,000. Like the other macronutrients fat and carbohydrates, they are built from carbon, hydrogen, and oxygen atoms, but they also contain essential nitrogen atoms. All foods, be they from animal or plant sources, contain protein, including all the essential (ones we can't make and must consume) and non-essential amino acids. Animal sources in general do contain higher amounts of protein but many plant foods contain a lot of protein as well. Plant foods that are rich in protein include beans, and nuts. Grains and vegetables contain smaller amounts of protein but in fact, broccoli contains more protein per calorie than a steak.

AMINO ACIDS. Roughly 500 amino acids have been identified in nature, but just 20 amino acids make up the proteins found in and used by the human body. The 20 common types of amino acids are: alanine, arginine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tryptophan, tyrosine, and valine. 9 of these AAs are essential, meaning that our bodies can't make them, and we need to consume them. These consist of histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. The branched-chain amino acids (BCAAs), leucine, isoleucine, and valine, are potent stimulators of muscle growth and are found in highest amounts in animal proteins (meat and dairy) and in some plant proteins, such as beans. Proteins differ in their amino acid composition. The sequence of amino acids in a protein is coded by genes, which provide the blueprint for making proteins. Obtaining a balanced mixture of amino acids in the diet requires eating a variety of different protein-rich foods. Although not very efficiently, our bodies can store amino acids for a short period of time, primarily in the intestinal wall. This store of AAs can then be called upon when needed to make whatever compound the body needs at that time. This is why we don't always have to have all the amino acids in every meal. Our bodies can scrounge up leftovers.

PEPTIDES. These are shorter chains of AAs than proteins, containing between 2-50 or so amino acids, as opposed to as many as 30,000 in full protein AA chains. During digestion, the proteins we eat are broken down into small peptides (2-3 amino acids) and individual amino acids for uptake across the gut. We also make peptides in our bodies from amino acids, including many important hormones.

CARBOHYDRATES.

Carbohydrates are sugars, starches, and fibers and are found in foods such as honey, fruits, vegetables, grains, beans, pulses, and milk. They also occur in low levels in liver and muscle meat in the form of glycogen, the storage form of sugars. Carbohydrates are made up of carbon, hydrogen, and oxygen atoms in a 1:2:1 ratio. Most carbs in nature are made from the air and sunlight by plants and algae using atmospheric carbon dioxide (CO_2) and water (H_2O) in the process of photosynthesis. During this process, they release oxygen (O_2) into the atmosphere.

SUGARS. Sugars are small carbohydrate molecules (saccharides). They are the building blocks of larger carb molecules, such as starch and fiber. The basic building blocks are the single "mono" saccharides, which include glucose, fructose (fruit sugar), and galactose (in milk). Glucose is the primary product of photosynthesis by plants and algae. It is the main fuel for life for all organisms and is the blood sugar that circulates around our bodies. One molecule of glucose joined to one molecule of fructose forms sucrose (a disaccharide), which is table sugar. Sucrose circulates in the sap of plants, notably sugar cane and beets. High-fructose corn syrup is a sucrose substitute used in processed foods and beverages. It is a mixture of fructose and glucose, industrially produced by breaking down corn starch. One molecule of glucose joined to one molecule of galactose forms lactose, milk sugar, the carb without which none of us would be here today.

STARCH. Starch is a storage form of complex carbohydrates (polysaccharides), produced by plants by joining together long chains of smaller sugar units, mainly glucose. Starch is stored in tubers, stems, and seeds to provide the plant with energy for later germination and growth. Starchy foods include breads, pasta, potatoes, and sweet potatoes. Resistant starches are those that are difficult to digest without the assistance of microbes in the gut, which ferment them to produce short-chain fatty acids.

Resistant starches are found in foods such as green bananas, beans, and lentils and are formed when starchy foods such as potatoes, pasta, and rice are cooked and allowed to cool. They are very important for gut health.

FIBER. Fiber is another complex carbohydrate produced by plants in which the simple sugar units are joined together. But unlike starch, the units are hard to break apart during digestion. Fiber is an essential part of a healthy diet and mostly comes from vegetables, fruits, grains, pulses, beans, nuts, and seeds. Soluble fiber is the gloopy stuff found in fruits, vegetables, oats, barley, and legumes. It slows the rate of gut emptying, which helps you feel fuller, longer. It also lowers bad cholesterol and supports blood glucose control. Insoluble fiber is the rough stuff that adds physical bulk and absorbs water, creating a feeling of fullness and softening feces in the bowel. It is found in whole-grain breads and cereals, nuts, seeds, wheat bran, and the skin and pulp of fruit and vegetables. The most abundant carbohydrate fiber on the planet is cellulose. Cellulose is built by plants from glucose units and forms the rigid walls that surround plant cells. Animal cells are squishy bags with flexible membranes, their pliability facilitated by cholesterol which is a major cell wall constituent. But plants require more structural support to remain upright and withstand the elements, so their cells are all housed in cellulose shells, and their main structural parts (stems, trunks) are reinforced with fiber and wood. Cellulose is among the hardest carbohydrates for animals to break down and is indigestible to humans. It adds physical bulk to the diet, however, and helps dilute calories. It is also useful for making paper and textiles.

GLYCOGEN. Glycogen is composed of glucose units and is the storage form of carbohydrates used by animals. We only store around 1 kilogram (2.2 pounds) of glycogen in our bodies, mainly in the liver but also in muscles. Once this is used up, we need to liberate energy from stored fat. Marathon runners know this point of transition in fuel use as “hitting the wall.”

<u>LIPIDS (Fats, Oils, and Sterols)</u>.

Lipids are built mostly from carbon and hydrogen atoms and are not soluble in water. Fats are solid at room temperature (butter, lard, coconut fat), whereas oils (vegetable oils, fish oils) are liquid. The main fats and oils in our diet are made up of a glycerol molecule attached to three fatty acid molecules. They are found in many foods, such as dairy, meat, seafood, vegetable oils, nuts, avocados, and olives. Fats and oils are used as an efficient energy reserve by plants and animals. This is because they store twice the energy per gram weight as do carbohydrates, which also means they deliver twice the calories per gram when eaten.

FATTY ACIDS. Fatty acid molecules have a tail of carbon atoms, the length of which is used to classify them into short-chain, medium-chain, long-chain, and very long-chain FAs. Short-chain fatty acids include acetate in vinegar and a range of other sour-tasting compounds produced by bacterial fermentation, which occurs when microbes ferment complex carbohydrates in the bowel and during the production of fermented foods such as sauerkraut and kimchi. When all the carbon atoms in the tail of a fatty acid are joined by single links (bonds), they are called saturated FAs. If there are double bonds between any of the carbon atoms in the tail, the FA is said to be unsaturated. If there is just one double bond in the chain, they are monounsaturated FAs, and polyunsaturated FAs have two or more double bonds. If a double bond in a polyunsaturated FA occurs at the third-to-last carbon molecule in its tail, it is termed an omega-3 fatty acid. If it occurs at the f at the sixth-to-last, it is an omega-6 fatty acid. The optimal ratio of omega-6 to omega-3 fatty acids for good health is between 1:1 and 4:1. But this is rarely achieved in the modern Western diet, and values of 16:1 to as much as 25:1 are typical. Rebalancing this ratio requires eating more omega-3-rich foods. Oily fish (salmon, herring, mackerel) are the most widely available sources of omega-3 FAs. Great plant sources include walnuts, hemp, and flaxseeds.

Fats containing high levels of monounsaturated FAs (e.g., olive oil) are among the healthiest fats. Polyunsaturated FAs are found in high levels in corn, canola, and safflower oils and fish oils. Saturated FAs are most abundant in dairy, lard, and many other animal fats, as well as some vegetable oils such as coconut and palm oils. Saturated animal fats are widely considered to be less healthy than unsaturated fats. Saturated FA molecules tend to clump and stack together at room temperature to form solids (e.g., butter, lard, and coconut fat), whereas unsaturated fat molecules tend to remain apart and form liquids, called oils (e.g., fish and most vegetable oils).

TRANS FATS. Trans fats are solid fats produced by chemically treating unsaturated oils to break double bonds and saturate some of the fat molecules. This helps them to stack, making them solid at room temperature. Trans fats added to processed foods are clearly unhealthy. They were used to make margarine until banned and are still used in highly processed snack, packaged, and fast foods. Trans fats are rare in nature, although small amounts are produced naturally by bacteria in the stomachs of ruminant animals such as cows, sheep, and goats and are found in meat and dairy products from these animals.

The hydrocarbon chains making up liquid, unsaturated fats lie in the same plane of the molecule, which forms a *cis* configuration (in this case, two chains form a "v" shape, with the double bond at the point of the "v"). Following hydrogenation, an unsaturated fat is modified into a different configuration that is characterized by a single twist in the center of the molecule (forcing one side of the "v" to twist down). This twist places the chains of hydrocarbons connected by the double bond in opposite planes, and thus the molecule is described as having a *trans* configuration. The trans-fat molecule is linear, and, with the exception of the twist in the center, this structure resembles the linear form of a saturated fat. Thus, through hydrogenation, the liquid consistency of the unsaturated fat is transformed into a soft-solid form that is generally more pliable than the typical hard-solid consistency of a saturated fat.

INTERESTERIFIED FATS. Like trans fats, these are artificial fats that have been industrially produced by altering the chemical structure of vegetable oils. They are created by swapping or rearranging FAs in fat molecules to alter the melting point, improve shelf life, and change mouthfeel. The health effects of interesterified fats are poorly understood, and there is no requirement for package labels to declare interesterified fat content of processed foods.

CHOLESTEROL. Cholesterol is another type of lipid called a *sterol*. It is essential for building animal cell membranes and for making steroid hormones and vitamin D. Plants contain phytosterols. Cholesterol is only found in animal-based foods. Cholesterol is transported in the blood by being attached to two types of carrier molecules called low-density lipoproteins (LDL) and high-density lipoproteins (HDL). A high ratio of LDL (bad cholesterol) to HDL (good cholesterol) is associated with poor cardiovascular health. Soluble fiber in the diet is associated with reduced LDL, although the precise mechanisms are not fully understood.

DIGESTION.

Once we have eaten complex proteins, fats, and carbs, so-called macronutrients, we need to break them down into their smaller constituent units, amino acids, fatty acids, and monosaccharides respectively, that can be absorbed by the gut and then are able to sustain life. Complex carbohydrates ultimately get broken down into monosaccharides. For starch, this process starts in the mouth, where starch-digesting enzymes in saliva (amylases) get to work, breaking starch down to glucose. Disaccharides such as table sugar (sucrose) and milk sugar (lactose) are split into monosaccharides by enzymes in the small intestine. These monosaccharides are then absorbed into the bloodstream. Sucrose gets broken into glucose and fructose. Much of the fructose we eat is converted into glucose in the intestine, while the rest enters the blood and is processed by the liver. High intakes of fructose from processed foods, primarily sugar-sweetened beverages, but not the fructose from fruits and vegetables, lead to buildup of liver fat. A person who lacks the enzyme for breaking milk sugar (lactose) into glucose and galactose is "lactose intolerant." Originally, we humans lost the ability to digest lactose at the time of weaning, but about 5,000 years ago, populations in different parts of the world evolved the ability to digest lactose and drink milk later in life, allowing full nutritional advantage to be taken of domesticating dairy animals. Still, more than 70% of adults worldwide are lactose-intolerant. Depending on how difficult the carbs in a meal are to digest, they may be completely broken down and absorbed into the bloodstream by the time they get much past the start of the small intestine on their way to the large bowel. More complex carbohydrates and other forms of dietary fiber that are harder to digest make it down to the bowel, where the microbiome breaks them down, liberating energy, short-chain fatty acids, vitamins and gas in the process.

Protein digestion begins in the stomach through the action of stomach acids and the enzyme *pepsin*. Protein digestion continues as the food enters the start of the intestine (the duodenum), where more protein-digesting enzymes enter from the pancreas. Single amino acids and very small peptides (composed of 2-3 amino acids) are absorbed into the cells of the small intestine to be transported into the bloodstream. The pancreas also secretes fat-digesting enzymes into the small intestine, and fats are emulsified by bile, which is produced by the liver and stored in the gallbladder and enters the small intestine. The resultant fatty acids and other lipid components released are absorbed into the cells of the small intestine and then enter the bloodstream.

ESSENTIAL NUTRIENTS.

There are around 100 nutrients that should be in the diet for optimal health and well-being. Some 40 of these are classified by nutritionists as being “essential” for humans, which means that they cannot be made by our bodies but must be consumed in the diet. These include: 9 amino acids (phenylalanine, valine, threonine, tryptophan, methionine, leucine, isoleucine, lysine, and histidine), 2 fatty acids (alpha-linolenic acid and linoleic acid), 13 vitamins [A, C, D, E, K, thiamine (B1, riboflavin (B2), niacin (B3), pantothenic acid (B5), B6, biotin (B7), folate (B9), and B12], and 15 minerals (potassium, chlorine, sodium, calcium, phosphorus, magnesium, iron, zinc, manganese, copper, iodine, chromium, molybdenum, selenium, and cobalt).

PHYTOCHEMICALS.

Phytochemicals are chemicals produced by plants as protection against their natural enemies such as herbivores, insects, harsh environmental climates and diseases. They can be thought of as natural pesticides, sunscreen and even bioweapons. Some are deadly to humans, others taste bitter, and some can be beneficial to health. Phytochemicals have been used as poisons, recreational drugs, and traditional medicines by humans, and other animals, for millennia. Since agriculture began, we have tended to breed them out of our major food crops because in general they make foods taste bitter and harsh. Think bitter raw greens and raw garlic and onions. Some examples of healthy phytochemicals include the *anthocyanins*, which are found in red, blue, and purple fruits and vegetables, *flavonoids*, which are found in onions, berries, parsley, green tea, citrus, bananas, red wine, and dark chocolate, *carotenoids*, found in yellow and orange vegetables, and *salicin*, which is found in willow tree bark and is the basic chemical in aspirin. Some phytochemicals are heavily marketed as food supplements, often because of their antioxidant and anti-inflammatory properties. Evidence that these supplements actually work, however, is limited at best. Far better to get your phytochemicals by eating fruit and vegetables.