**Why we need to eat food**

First, some fundamental science – matter is everything that occupies space (has volume) and has mass (weight). All stable matter (ignoring things that have a life time of less than 1 second) are made of various combinations of atoms. An atom is the smallest part of a chemical element; there are 90 naturally-occurring elements + some that we made in ‘atom smashers’.

Some nutrients are single atoms – as an example – Zinc ions (Zn+2 atoms). However, even these are not as simple as they appear. With the exception of metallic substances, such as aluminum foil, gold as in a gold ring or a gold nugget, silver, as in a silver coin, metal ions are always ‘stuck’ to something. The nature of what the metal atom is bonded to (stuck to) can be very important. For example, there is a significant difference between iron in meat and iron in beans. ‘Complexation’ of the metal is important in regards to how well the human body can access that metal. More on this later.

Energy is the ability ‘to do work’ – basically, energy is motion (‘kinetic energy’) and the ‘capability for motion’ (potential energy). Energy is very important in nutrition – everyone is familiar with ‘Calories’, which is a measure of energy. Technically, a ‘dietary Calorie’ (upper case C in Calorie) is 1000 calories (lower case c in calories) = 1 kilocalorie (kilo = 1000 of). Adult humans are assumed to eat about 2000 Calories per day on average, although, as we will see, the actual energy requirement is influenced by body weight, sex, body fat percentage, age and activity level. This gets complicated quickly.

All living things require energy. The biochemical reactions that occur in a living organism require energy.

Thermodynamics (thermo = heat, dynamics = motion) is the study of energy. There are two very important, fundamental ‘laws’ of thermodynamics. The First Law is concervation of energy – energy cannot be created or destroyed in non-nuclear processes. (An aside: nuclear processes, such as nuclear energy, convert matter into energy; the amount of energy produced is determined by the amount of matter that is destroyed as described by the famous equation E = mc2, where E = the amount of energy produced and m is the amount of matter destroyed).

The Second Law of Thermodynamics is that no energy transformation can be 100% efficient – some of the original ‘useable energy’ will ALWAYS be ‘lost’ as unwanted heat, sound or light. Your electronic devices (cell phone, laptop computer, tablet computer, etc. cannot use all of the energy that comes in from the wall plug with perfect efficiency as some of this energy becomes unwanted heat while charging the battery, discharging the battery and using the device. If batteries did not produce unwanted (waste) heat, they would last forever.

A consequence of the Second Law is that there is a loss of energy in every ‘step’ in a system.

**Biological Energy**

Virtually all biological energy comes from sunlight.

Producers: biological organisms that convert sunlight into ‘chemical energy’ in the form of sugars (carbohydrates), fats (triglycerides) and proteins. Producers produce chlorophyl which gives them the ability to capture the energy in sunlight and use this energy to convert carbon dioxide and water to sugar. Producers are the ‘first level’ in a ‘food chain’

6 CO2 + 6 H2O + sunlight 🡪 C6H12O6 + 3 O2

Humans are incapable of photosynthesis. We do not produce chlorophyl. If we did produce chlorophyl 1) our skin would be green and 2) we still would not be able to produce the 2000 Calories per day that each of us needs.

Primary consumers are animals and other organisms that feed off of producers; herbivores. Primary consumers are a ‘second level’ in the food chain. Note that as per the Second Law, some of the energy in the plant is ‘lost’ when the plant is eaten by the primary consumer.

Secondary consumers are animals and other organisms that eat primary consumers. Basically, carnivores. Note that once again, there is an energy loss between the primary and secondary consumers.

Humans (and bears) are the rare examples of omnivores. Vegans – humans who do not eat animal produces (no meat, fish, dairy, eggs or honey) are primary consumers. Likely there are very few humans who are do not eat SOME plant material. While the ‘cave man’ diet is trendy, in reality, it is very difficult to consume only animal produces for more than a few weeks.

In terms of energy efficiency, we should be vegans. In terms of what 1000’s of years of evolution has produced, we are natural omnivores. Similar to bears, we will eat both berries, fish and whatever else we can get our hands on.

So, we eat because we need the (chemical/potential/food) energy in the food. This energy powers our physical movements, keeps us at a consistent body temperature, as we are ‘warm blooded’ organisms, and provides the energy needed to fuel the chemical reactions that are required to maintain our physical bodies. As an aside, our brains are one of the highest energy consuming organisms in our bodies.

**Our mutualistic guest, the ‘gut biome’**

Gut biome describes the colony of microorganisms (bacteria, viruses and fungi) that live in our large intestine. We now know that these microorganisms are involved in digestion, our immune system, our weight and our mental health. Some essential vitamins are chemically produced by our gut biome. When we eat, we feed both our body and our gut biome. We are learning why it is important to feed the gut biome and what we should feed it to keep it ‘healthy’. As with our body, the gut biome obtains its energy from the food we eat.

**Why we eat: atoms and molecules**

As previously mentioned, all (stable) matter, including our physical bodies, are made of atoms. Almost all of the atoms in our bodies came from the foods and liquids that we consumed, plus a very small amount of oxygen atoms from the air we breathe and possibly a very, very small amount from our birth. Our bodies are organized by cells; cells are constantly being created and destroyed. As an example, our skin cells have a finite lifetime (10 days? 14 days?) after which they will leave our bodies and be replaced by new cells which must come from new atoms and molecules.

So, we eat for the energy for our bodies, the energy for our gut microbiome and for the atoms and molecules required to replace those that are lost.

**What we eat: the macronutrients**

**Carbohydrates** (‘carbon hydrates’ C + H2O) are molecules that have the GENERAL formula CnH2nOn ; one of the most important carbohydrates is glucose, C6H12O6; glucose (‘grape sugar’) is formed by many producers from sunlight + CO2 + H2O via photosynthesis. Glucose is a hugely important carbohydrate for humans as the human brain is fueled almost exclusively by glucose.

Glucose and other carbohydrates also have structural roles. For example, sugar molecules on cell surfaces is one way in which the body can determine the identify of cells.

Current dietary advice is to obtain 45 – 65% of daily Calories from carbohydrates.

Disaccharides (‘two sugars’) are ‘dimers’ of sugar molecules. This means that disaccharides consist of two ‘monosaccharides’) that have chemically bonded together. Sucrose, also known as ‘table sugar’ and ‘sugar’ – the white crystalline solid that people use for cooking and for sweetening coffee and tea – is a disaccharide in which a fructose molecule has bonded to a glucose molecule. When we ingest sucrose, our bodies break the fructose-glucose bond, turning sucrose into fructose + glucose.

Lactose (‘milk sugar’) is another disaccharide; this one consists of a galactose (another monosaccharide) that is bonded to a glucose. If you are lactose tolerant, your body still produces the protein (‘enzyme’) that converts lactose to glucose + galactose (note: the galactose effectively gets turned to glucose). If you are lactose intolerant, your body no longer can convert lactose to glucose + galactose; the lactose stays in tack during digestion and the gut biome uses it for food. This often produces digestional discomfort.

Fructose is a monosaccharide (= ‘one sugar’) that is associated with fruit (fructose = ‘fruit sugar’). Fructose is used by the liver while the rest of the body generally uses glucose.

Starches and cellulose are glucose ‘polymers’ (poly = many, mer = parts). In glucose and cellulose molecules, there are 100’s to 1000’s of glucose molecules that have bonded together. These glucose molecules are connected differently in starch than in cellulose. This rather subtle difference explains why our bodies can convert some starches to glucose but cannot break cellulose into glucose. We can digest the starch in wheat seeds (= wheat flour), but we can’t digest the cellulose in the wheat straw.

**What to know:** carbohydrates are important to our diets; these should be about 50% of our dietary calories. As we will see, starches are ‘more healthy’ than are simple sugars and ‘resistant starches’ – those that we can’t digest, but our gut biome can digest – feed the gut biome (which is a ‘good thing’).

When we eat carbohydrates, our bodies use some of the carbs (fructose, glucose and glucose-containing disaccharides) for immediate energy, stores some of the glucose in cells as ‘glycogen’ (a glucose polymer that is similar to starch) and converts some of it to fat.

**Proteins** are ‘polymers’ that are made from various combinations of the 20 amino acid molecules. Think of these as long ‘chains’ that are made from various combinations of 20 different ‘chain links’.

Proteins are hugely important to our health. Our muscles are made of protein. Enzymes – the biochemical ‘catalysts’ that are involved in virtually all of our biochemical reactions – are proteins. Some of the immune molecules (antibodies) are proteins.

Recommendations are for proteins to be 10 to 35% of our daily 2000 or so Calories. Adult humans need at least 0.8 g of protein per kg of body weight per day. To state this differently, a 154 pound person (= 70 kg) needs at least 70 x 0.8 = 56 grams (= 0.123 pounds = 2 ounces) of protein, on average per day.

WARNING! 2 ounces of proteins is NOT the same as 2 ounces of meat! Various cooked meats have various amounts of proteins; the rest of the weight is mostly water and various fats.

Dietary proteins are described as ‘complete’ or ‘noncomplete’. Meats are complete proteins which means that they contain sufficient amounts of all of the ‘essential’ amino acids. An ‘essential’ nutrient is one that our bodies cannot make and must obtain from our diet. Vegetarians/vegans must be strategic in regards to ensuring that they consume foods that, OVERALL provide them with sufficient amounts of each of the essential amino acids. This isn’t as simple as eating a cooked chicken breast.

**Fats and oils** are ‘triglyceride esters’ of glycerol/glycerin (these two words describe the same molecule) and ‘fatty acids’. Fatty acids are ‘unbranched carboxylic acids’.



Molecular structure of a ‘fat molecule’ (a triglyceride). Each ‘bend’ is a carbon atom. Each carbon atom has four bonds. Most of the hydrogen atoms are not shown; their presence is implied by the ‘four bonds to each carbon atom rule’. The glycerol/glycerin part of the molecule is depicted in black. In blue is a ‘saturated’ fatty acid (saturated = no carbon- carbon double bonds). In green is a ‘monounsaturated’ fatty acid (‘one C=C’) an in red is a ‘polyunsaturated’ fatty acid (‘poly’, in this context, means ‘more than one’; unsaturated means C=C). Image is from Wikipedia.

Note: the difference between ‘fats’ and ‘oils’

Oils – typically are liquids at room temperature, come from plants and have more ‘unsaturation’ (Carbon – Carbon double bonds).

Fats – are solids at room temperature, usually come from animals (palm and coconut oils are exceptions) and have less ‘unsaturation’ (less C=C double bonds).

Recommendations for a healthy adult is for 20 to 35% of calories to come from fats. Unsaturated fats are considered to be healthier than are saturated fats.

There are essential fats – fatty acids that are not made by the human body but are needed for good health.

The ‘omega-6’ fatty acid/fat linoleic acid and the ‘omega-3’ fat/fatty acid ‘alpha linoleic acid’ are essential fats. While in theory eicosapentaenoic acid (‘EPA’) and docaheanenoic acid (‘DHA’) can be made from alpha linoleic acid, the reality is that this conversion happens in such little amount that effectively EPA and DHA are essential fats. It is believed that most people in modernized countries (including the USA) consume too much linoleic acid and not enough of the omega-3 acids.

If you are interested, both the omega-6 and the omega-3- fatty acids are unsaturated; omega = ‘end’; the first double bond in the omega-6 fatty acids are six carbons away from the methyl (CH3) end of the fatty acid chain; those in the omega-3 fatty acids are three carbons away from the CH3 end of the chain.



Structure of linoleic acid. Note that the ‘first’ C=C bond is the sixth carbon from the left hand side Note that this is also a ‘polyunsaturated’ fatty acid. The two C=C’s are separated by one CH2 group, which makes this a ‘conjugated’ polyunsaturated fatty acid. Being a conjugated, polyunsaturated fatty acid with the first C=C on the sixth carbon from the CH3 end makes this an ‘omega-6’ fatty acid. Image is from the internet.

Structure of alpha linolenic acid. Note that this is a conjugated fatty acid and that the first C=C starts on the third carbon from the CH3 end, making this an omega-3 fatty acid. Image is from the internet.

Note that if you count the carbon atoms in linolenic acid and in alpha linolenic acid, you find that both contain 18 carbon atoms; the only structural difference between these two molecules is a carbon – carbon double bond in alpha linolenic acid that is not present in linolenic acid.

Most of the unsaturated fatty acids have ‘cis’ (= ‘same side’) double bonds. While there was a media storm about ‘trans’ (‘opposite side’) fatty acids, which resulted in a ban on ‘trans fats’ in the US, there are naturally produced trans fatty acids.

Fats are used by the human body for energy – we are naturally biologically ‘programed’ to store excess calories, whether they come from excessive carbohydrates, excessive proteins or excessive fats – as body fat. Body fat is a long-term (= between meals) energy storage.

It was mentioned above that the human brain requires a constant supply of glucose for fuel. When glucose/glycogen levels are low, the human body will start preserving glucose by shifting organisms other than the brain to ‘burn fat’ instead of glucose and will start making glucose (‘gluconeogenesis’) from the amino acids (from proteins; our bodies digest proteins by first breaking them down into their amino acids) and from the glycerol/glycerin portion of fats. Note that while we (humans) convert glucose into fatty acids, this in a ‘one-way street’ in that we are unable to convert fatty acids into glucose.

Body fat is also important for protecting organs and bones from trauma (‘padding’), for making ‘lipid’ steroids such as testosterone and progesterone and for producing cholesterol. Note: cholesterol is a specific molecule. ‘Blood cholesterol’ – also known as LDL (Low Density Lipoprotein – the ‘bad’ (blood) cholesterol) and HDL – High Density Lipoprotein – the ‘good’ (blood) cholesterol) and ‘remnant’ (blood) cholesterol – that which isn’t LDL or HDL – basically remnant is lower density than is LDL) – are ‘complexes’ made from cholesterol and proteins – think of these as little boxes in which cholesterol is in the inside and the protein is the outside (is the ‘box’).

‘Phospholipids’ are molecules that are similar to fats; phospholipids are made from fats. Phospholipids and cholesterol are the primary components of our cell membranes – the ‘hydrophobic’ (‘does not dissolve in water’) layer that surrounds each cell.



Structure of a phospholipid. Note that the difference between a triglyceride and a phospholipid is that one fatty acid in the triglyceride has been replaced by a phosphate + a choline group.

**The ‘micronutrients’**

**Micronutrients** are [essential dietary elements](https://en.wikipedia.org/wiki/Nutrient) required by [organisms](https://en.wikipedia.org/wiki/Organism) in varying quantities throughout life to orchestrate a range of physiological functions to maintain health. (Wikipedia, micronutrient). For humans, micronutrients are minerals – metal ions such as calcium, iron and zinc, and various molecules known as ‘vitamins’ (‘vital amines’; while not all vitamins are ‘amines’ researchers didn’t know this when the term ‘vitamin’ was coined).

Metals must come from diet as metal ions cannot be chemically created. Some vitamins are created by the gut microbiome, essential vitamins, such as vitamin C must come from diet.

Note that it is NOT recommended that most healthy US adults take a vitamin supplement. If you eat a nutritious diet, the food that you eat, along with exposing your skin to sunshine (which produces vitamin D) should provide sufficient amounts of each of the required metals (minerals) and vitamins. Thankfully, diseases produced by chronic vitamin deficiencies – diseases such as scurvy (vitamin C), beriberi (vitamin B1) and pellagra (a niacin and tryptophan deficiency) are rare in today’s society.

Finally, we should note that vitamins are classified as ‘water-soluble’ and ‘non-water-soluble’. Those that are water soluble, such as Vitamin C, cannot be stored by the human body, the body uses what it needs and discards the rest in urine. As a result, we need the water-soluble vitamins on a more or less daily basis. While the ‘bad’ news is that we cannot store unused amounts of these vitamins in our bodies, the ‘good’ news is that these vitamins are nontoxic.

Unused/unneeded ‘fat soluble’ vitamins are stored in our body’s fat deposits. The ‘good’ side of this is that possibly, the body can access these ‘stores’ when needed. The ‘bad’ side is that these vitamins can become toxic when we ingest too much or when too much builds up on our fat deposits.

Nutrition often is a ‘Goldilocks’ situation – some is needed, but too much is toxic. The goal is to stay in the ‘enough, but not too much’ region.

**What to know:** we need each of the macronutrients (carbs, fats and proteins). We need the micronutrients. Despite the nutritional ‘demonization’ of fats that occurred roughly from the 1960’s to about 2010, there are essential fats. This is not an excuse to stuff yourself with chocolate covered lard balls, it is more of a permission to not worry about dietary fat and, as we will see, why it is recommended that you eat ‘fatty fish’ such as salmon at least once per week.

Human nutritional needs can be highly complex. The needs of the young (infant, childhood and adolescent) and those of the old (about 50 years old and older) are different than those who are age ~ 20 to ~ 50 years old.