

GLUECLOSE SPIKE GLOSSARY OF TERMS



By Larry D. Killion, P.E., J.D.

Contents

INTRODUCTION.....	3
ANTIOXIDANTS (Auntie Oxidant).....	5
ATOMS AND THEIR ELECTRON STRUCTURE	5
CARBOHYDRATES.....	11
DIABETES	17
DOPAMINE	18
ELECTROMAGNETIC RADIATION.....	19
ENZYME.....	19
FAT	22
FIBER	32
FREE RADICALS	32
FREQUENCY	35
GLUCOSE SPIKE.....	35
GLYCEMIC INDEX.....	36
GLYCEMIC LOAD.....	37
GLYCEMIC VARIABILITY	38
INFLAMMATION	38
INORGANIC.....	39
INSULIN	39
LIPID	40
METABOLIC OR METABOLISM	41
MITOCHONDRIA	42
MOLECULES	48
ORGANIC	48
PERIODIC TABLE	49
PHOTONS	49
PHOTOSYNTHESIS.....	51
RADIATION	55
STARCHES.....	57
WAVELENGTH.....	57

INTRODUCTION

The reader of this Glossary of Terms reference (and accompanying 6 videos) will not be shocked as it is free of charge. (OK...a dumb pun...I'll have more).

The Glossary complements a 6-part video about human health and metabolism of human food intake of carbohydrates, proteins and fat and the associated digestive effect on managing Glucose Spikes.

- **Video Part 1:** A short discussion about molecules, atoms and electrons, the building blocks of life. Reactive 'valence' electrons and their movement in an atoms outer energy shell, is what causes life's chemical reactions to take place. Each electron in an atom has a unique 'social security number' defined by 4 'quantum numbers', no two being alike in the same atom. The quantum ID number confirms that electrons in an atom do not step on each other's toes and cannot be in the same place at the same time.
- **Video Part 2:** A short discussion about photosynthesis and how with sunshine, plants produce carbohydrates, such as glucose, the essential energy fuel of life.
- **Video Part 3:** A short discussion on human body metabolism, using the preferred glucose molecule from carbohydrates as its energy fuel of choice to power all of our body functions: first the 24/7 essential life sustaining basal metabolic rate (heart, breathing, temperature, brain function) then digestion then our daily elective activities (working and playing).
- **Video Part 4:** Short discussion about our cells and the mighty mitochondria, the powerhouse and engines of life that converts glucose fuel to useful energy (to power our muscles and all the other life forces). Our bodies discharged and charged batteries (ADP and ATP) cycle in our mitochondria to provide power as needed, where glucose provides the recharging energy.
- **Video Part 5:** Short discussion about enzymes, hormones, inflammation and fats, our body chemistry functions and affects.
- **Video Part 6:** A short discussion on affects of Free Radicals and 'Auntie Oxidants'; connection of insulin with diabetes; manage our glucose spikes – for a healthier life - by managing our glycemic index, glycemic load and glycemic variability – the how and in what order we eat our food, all things in moderation. Manage like your life depends on it.

Glucose Spike is a measure of the peak of how much glucose (our bodies energy fuel) is in our blood stream (blood sugar) at any one time as a consequence of eating and digesting food. The Spike ideally should be managed and limited to a mild bump and not sharp peaks and swings that can cause damage to our bodies health and erratic and chaotic hormone release. All that explained in the videos (the how and why).

The writing of the Glossary and associated videos were inspired by the insightful book on the topic entitled "*Glucose Revolution (The life-changing power of balancing your blood sugar)*", by Jessie Inchauspe'. A user-friendly discussion on the topic of Glucose Spike.

A deeper understanding of the glucose spike topic beyond the *Glucose Revolution* book's messages was desired, hence research, study and preparation of this Glossary and videos.

As disclosure, the author is not a trained medical or nutritional professional, though a curious self-inflicted student of the topic. As a chemical engineer (with math credentials) there is a base understanding of the chemistry and the fundamentals of chemical reactions (whether in a chemical plant or in our bodies). These non-medical credentials were used to prepare the Glossary and videos from the vantage point of an interested student in managing and improving human health.

Knowledge is a great thing as it allows us to make better informed decisions based on credible insight and understanding – the why not just the how. A little bit of sunshine is a great disinfectant!

ANTIOXIDANTS (Auntie Oxidant)

- Antioxidants, such as Vitamins C and E, Beta-Carotene (carrots), selenium (seafood and nuts) and polyphenols (tea, berries, dark chocolates), are chemical compounds that have an available electron in their atomic and molecular structure that they are willing to share or give to Free Radicals. The electron sharing neutralizes the adverse health effects caused by Free Radicals. The antioxidant is not damaged by the giving up of the electron. Antioxidants are one of our body's most important health protecting bodyguards (one of our cleaning brooms). See Free Radicals for complementary discussion.



Auntie Oxidant
To the rescue.

ATOMS AND THEIR ELECTRON STRUCTURE

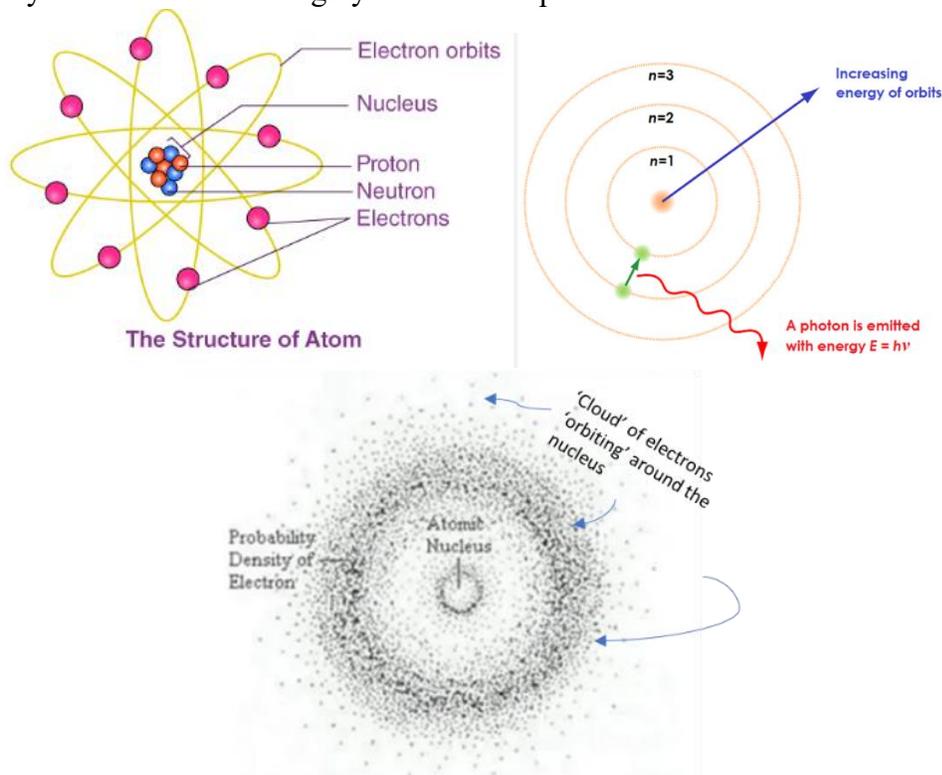
- **Atoms** (or elements) and its electrons - the basic building blocks of molecules that make up matter, the smallest units of an element that retains its chemical properties. (Examples: Carbon, Hydrogen, Oxygen atoms. Single atoms are not to be confused with molecules, for example, hydrogen gas, H₂, two hydrogen atoms bonded together, is a molecule). Atoms are made up of protons (that have a positive charge), electrons (that have a negative charge) and neutrons (that have no or neutral charge). Neutrons and protons are made up of smaller components studied in particle physics named 'quarks'; electrons are a fundamental particle and are not made up of any smaller components. Protons and neutrons are bound together (by nuclear forces) in the center or nucleus of the atom and the electrons orbit around the nucleus in a cloud like state in orbitals of different shapes (whose properties mimic that of both a discrete particle like a grain of sand and a wave, like an ocean or sound wave that has oscillating wavey up and down characteristic motion). Each atom (element) has a unique number of protons and 'ground state' electrons. Although atoms normally also have unique number of neutrons, they can have more or less their normal number of neutrons (known as 'isotopes'). The addition or deduction of neutrons generally only affects an atom's mass or weight (it gets heavier or lighter) hence the *kinetic isotope effect*, which affects how quickly a reaction can take place (fatter isomer atoms with extra neutrons do not move or react very fast). Electrons in an atom especially its outer electron shell valence electrons, determine its chemical properties and how reactive an atom is (a fundamental basis of chemistry – the reactivity of an electron).

Electrons are confined to certain discrete energy orbital states or distances from the nucleus and can move from a lower energy orbit to a higher energy orbit if a discrete or fixed amount of energy (called the quanta of energy) is added to cause the electron to move (instantaneously jump) from its lower energy orbit to a higher energy orbit if the new residence orbit is not already occupied by its maximum number of allowed electrons (just like an elevator there are capacity limits). The transition of an electron from one orbit to another is not continuous, like temperature gradually and continuously increasing on a thermometer, but discrete, jumps instantaneously from one orbit to another in fixed increments, like switching a light switch

GLUECLOSE SPIKE GLOSSARY OF TERMS (2025)

which is either on or off and nothing in between. When an energized electron jumps (falls) from a higher energy orbit to a lower energy orbit, it releases a photon which has a fixed quanta amount of energy (and that energy can be used in a chemical reaction).

The reactivity and movement of the electron in the atom is part of the fundamental and mysterious world causing photosynthesis to take place in plants to create carbohydrates and where carbohydrates when eaten are consumed to make energy and give human's (and other living organisms) life forces. Although carbohydrates are considered to fuel human body energy, it really all starts with the mighty electron and photon.



The set of numbers (comparable to a unique one of a kind social security number) used by physicists and chemists to describe the position and energy of the electron in an atom are called quantum numbers. There are four quantum numbers: 1. principal, 2. azimuthal, 3. magnetic and 4. Spin, quantum numbers.

Number	Symbol	Possible Values
Principal Quantum Number	n	1, 2, 3, 4, ...
Angular Momentum Quantum Number	ℓ	0, 1, 2, 3, ..., $(n - 1)$
Magnetic Quantum Number	m_ℓ	$-\ell, \dots, -1, 0, 1, \dots, \ell$
Spin Quantum Number	m_s	$+1/2, -1/2$

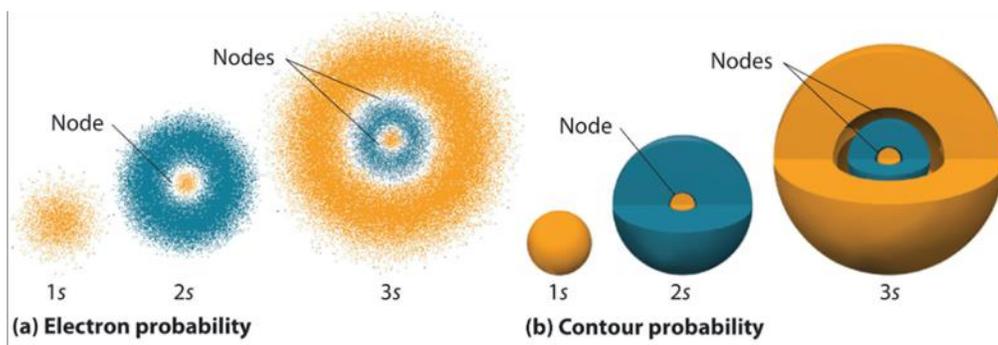
Principal Quantum Number

- The principal quantum numbers are denoted by the symbol 'n'. They designate the principal electron energy shell of the atom typically designated as an integer 1 (closest energy shell or principal quantum number to the nucleus of an atom and lowest energy or 'ground state') through n, or a capital letter starting with K..L, M, N, O, etc. Since the most probable distance between the nucleus and the electrons is described by it, a larger value of the principal quantum number implies a greater distance between the electron and the nucleus (which, in turn, implies a greater atomic size).
- When a given electron is exposed to extra quanta of energy (its 'excited state') above its 'ground state', it can be observed that the electron instantaneously jumps from one principal shell to a higher shell, causing an increase in the value of n for that jumped electron. Similarly, when electrons lose energy, they instantaneously jump back into lower shells and the value of n for that electron decreases.
- The increase in the value of n for an excited electron is called 'absorption', emphasizing the photons or energy being absorbed by the electron. Similarly, the decrease in the value of n for an electron is called 'emission', where the electrons emit their extra energy.

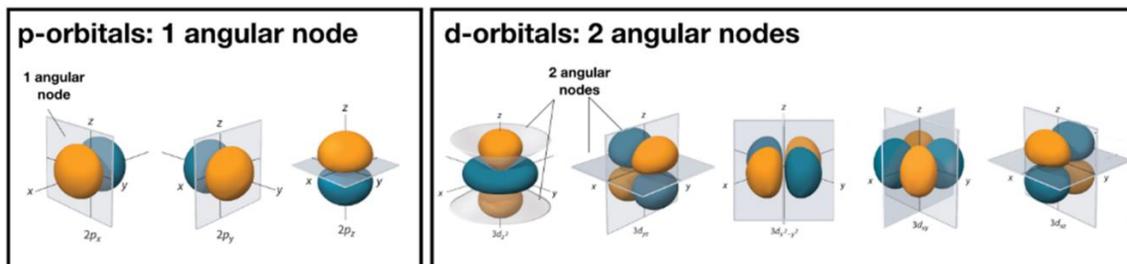
Azimuthal Quantum Number (Orbital Angular Momentum)

- The azimuthal (or orbital angular momentum) quantum number describes the shape of a given orbital. The angular momentum terminology was chosen as the most descriptive term describing the space through which an electron 'orbits' around the nucleus of an atom. An orbital is the likely space boundary through which an electron moves. Each orbital can contain either one or a maximum of two electrons - with opposite spin (since although every electron is identical in character, the same electron cannot occupy the same space. As a minimum, two electrons in a common orbital must have opposite spins, spin +1/2 or -1/2, and hence are distinguishable and the two opposite spin electrons can be in the same orbital or same bounded space orbiting around the atom's nucleus. The azimuthal quantum number is denoted by the symbol ' ℓ ' and its value is equal to the total number of angular nodes in the orbital. Angular nodes are planar or conical surfaces within an atom where the probability of finding an electron is zero, and the number of angular nodes is equal to the azimuthal quantum number, or ℓ .

Node: Location at which the probability of finding an electron is zero (0), 'not there'.



The orbital shape represents the region in space where the electron is most likely to be found. The different lobes of an orbital are separated by regions in space where the probability of finding an electron is *zero*. These are nodes, and there are two types: **angular nodes (planar nodes)** and **radial nodes (spherical nodes)**.

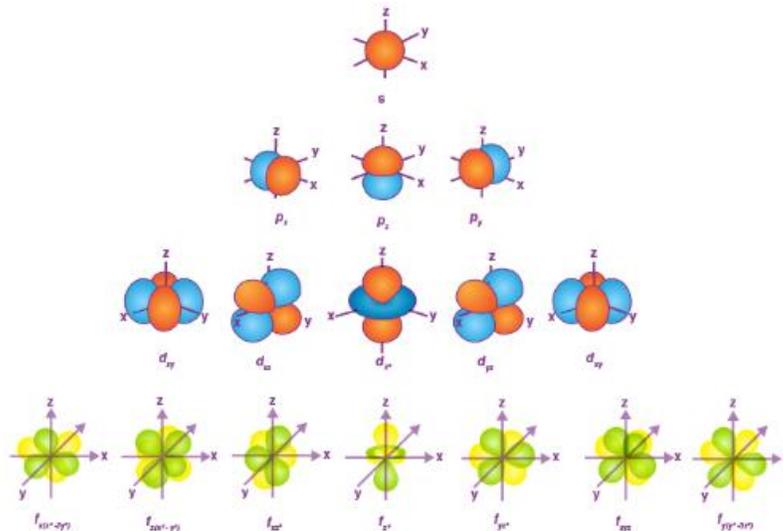


The angular nodes in p-orbitals and d-orbitals are shown. Every p orbital has one angular node, and every d orbital has two angular nodes. The number of angular nodes in any orbital is equal to the value of the quantum number, l .

- A value of the azimuthal quantum number can indicate either an s, p, d, or f subshell which vary in shape. This value depends on (and is capped by) the value of the principal quantum number, i.e. the value of the azimuthal quantum number ranges between 0 and $(n-1)$. These subshells (s,p,d,f) exist within a given shell (n). While these subshells each have their own discrete energy level, the structure of atoms is such that the subshells can overlap with subshells from a different shell because of the differences in energy levels. Since electrons always prefer to reside in a lower energy level, it is possible for an electron to reside in a subshell located in a higher energy shell in preference to its own unfilled subshell since the other subshell energy is lower.
- For example, if $n = 3$, the azimuthal quantum number can take on the following values – 0,1, and 2. When $l = 0$, the resulting subshell is an ‘s’ subshell. Similarly, when $l = 1$ and $l = 2$, the resulting subshells are ‘p’ and ‘d’ subshells (respectively), and for $l = 3$ the resulting subshell is f. Therefore, when $n=3$, the three possible subshells are 3s, 3p, and 3d and when $n=4$, the four possible subshells are 4s, 4p, 4d and 4f.
- In another example where the value of n is 5, the possible values of l are 0, 1, 2, 3, and 4. If $l = 3$, then there is a total of three angular nodes in the atom.

Magnetic Quantum Number

- The total number of orbitals (three-dimensional space in which electrons move) in a subshell and the orientation of these orbitals are determined by the magnetic quantum number. It is denoted by the symbol ‘ m_l ’. This number yields the projection of the angular momentum corresponding to the orbital along a given axis.
- The value of the magnetic quantum number is dependent on the value of the azimuthal (or orbital angular momentum) quantum number. For a given value of l , the value of m_l ranges between the interval -1, 0, +1. Therefore, it indirectly depends on the value of n .
- For example, if $n = 4$ and $l = 3$ in an atom, the possible values of the magnetic quantum number are -3, -2, -1, 0, +1, +2, and +3 (6 shapes)



Shapes of Orbitals (as per the corresponding Quantum Numbers)

- The total number of orbitals in a given subshell is a function of the ' ℓ ' value of that orbital. It is given by the formula $(2\ell + 1)$. For example, the '3d' subshell ($n=3, \ell=2$) contains 5 orbitals ($2*2 + 1$). Each orbital can accommodate 2 electrons. Therefore, the 3d subshell can hold a total of 10 electrons (5 orbitals, 2 electrons per orbital, each with opposite spins).

Azimuthal Quantum Number Value	Corresponding Number of Orbitals ($2\ell + 1$)	Possible Values of m_ℓ
0 ('s' subshell)	$2*0 + 1 = 1$	0
1 ('p' subshell)	$2*1 + 1 = 3$	-1, 0, and 1
2 ('d' subshell)	$2*2 + 1 = 5$	-2, -1, 0, 1, and 2
3 ('f' subshell)	$2*3 + 1 = 7$	-3, -2, -1, 0, 1, 2, and 3

Electron Spin Quantum Number

- The electron spin quantum number is independent of the values of n (the principal energy shell).
- The electron spin quantum number is independent of the values of $n, \ell,$ and m_ℓ . The value of this number gives insight into the direction in which the electron is spinning and is denoted by the symbol m_s .
- The possible values of the electron spin quantum number are $+\frac{1}{2}$ and $-\frac{1}{2}$.

- The positive value of m_s implies an upward spin on the electron which is also called ‘spin up’ and is denoted by the symbol \uparrow . If m_s has a negative value, the electron in question is said to have a downward spin, or a ‘spin down’, which is given by the symbol \downarrow .
- The up and down ‘spin’ notation is not the same as a spinning top, but a differentiator used to distinguish between two electrons, since they cannot have the same quantum numbers in the same orbital.
- The value of the electron spin quantum number determines whether the atom in question has the ability to produce a magnetic field (since by electromagnetic principles, a moving charge, such as a negatively charged electron, produces a magnetic and electric field). The value of m_s can be generalized to $\pm\frac{1}{2}$.

Summary...

- It is impossible for two electrons (although identical) of the same atom to have exactly the same quantum state or exactly the same values of the set of quantum numbers (no common ‘social security’ number).

Name and Symbol	Meaning and Possible Values
Principal quantum number, n	Electron shell, $n \geq 1$
Azimuthal quantum number, l	Subshells ($s=0, p=1, \text{etc.}$), $(n-1) \geq l \geq 0$
Magnetic quantum number, m_l	Total number and orientation of orbitals, $l \geq m_l \geq -l$
Electron spin quantum number, m_s	The direction of electron spin, $m_s = \pm\frac{1}{2}$

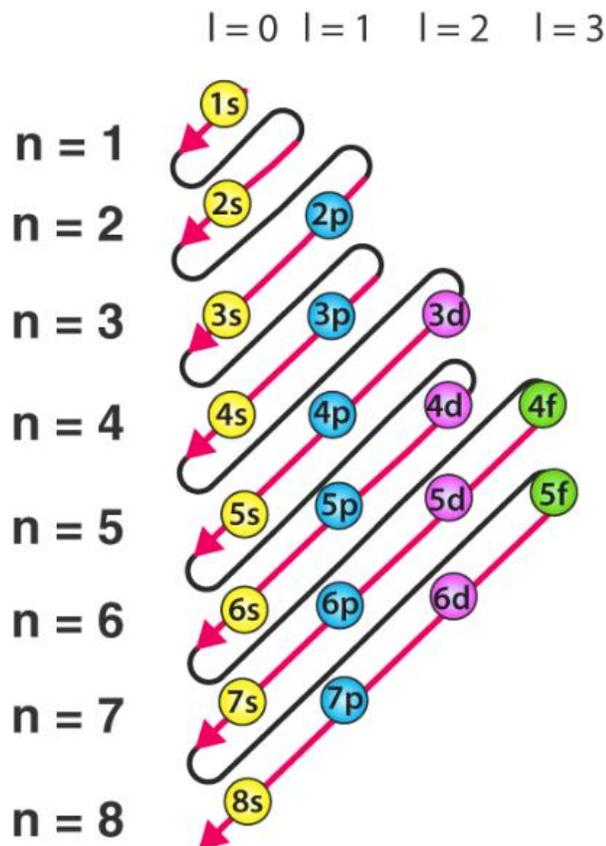
Aufbau Principle

- The energy order of subshells is described by the **Aufbau Principle** which is a fundamental rule in atomic theory that explains in what order electrons fill atomic orbitals and related subshells (though there are a few exceptions required to accommodate some atoms whose electron configuration is such the Aufbau principle cannot be fully applied, sort of like avoiding dancing electrons from stepping on each other’s toes). ‘Aufbau’ is German for ‘building up,’ and that’s exactly what this principle describes—how electrons build up in an atom from the lowest energy level to the highest.
- Electrons occupy **orbitals** in order of **increasing energy**. That means:
 - Lower-energy orbitals fill **first**.
 - Electrons in the ground state only move to higher-energy orbitals **after** the lower ones are full.
- The general sequence of subshell order follows this pattern (based on ground state energy levels):

$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s$

GLUECLOSE SPIKE GLOSSARY OF TERMS (2025)

- This order isn't strictly numerical—it's based on energy, which is for example why **4s fills before 3d**, (because 4s subshell located in the 4th or N energy shell energy, is lower than 3d subshell energy located in the 3rd or M energy shell).
- A common way to remember the order is the **diagonal rule**, where you write orbitals in columns and draw arrows diagonally to show the filling sequence. Order in which subshells are filled by ground state electrons based on lowest energy potential. (Example, 2s is filled before 2p; 4s is filled before 3d; 4d is filled before 5p)
-



- Some elements (like chromium and copper) break the rule slightly due to **electron stability** in half-filled or fully filled subshells. These exceptions are explained by quantum mechanics and electron repulsion.
- The Aufbau Principle helps us:
 - Predict **electron configurations**
 - Understand **chemical behavior**
 - Explain **periodic trends** like atomic size and ionization energy

CARBOHYDRATES

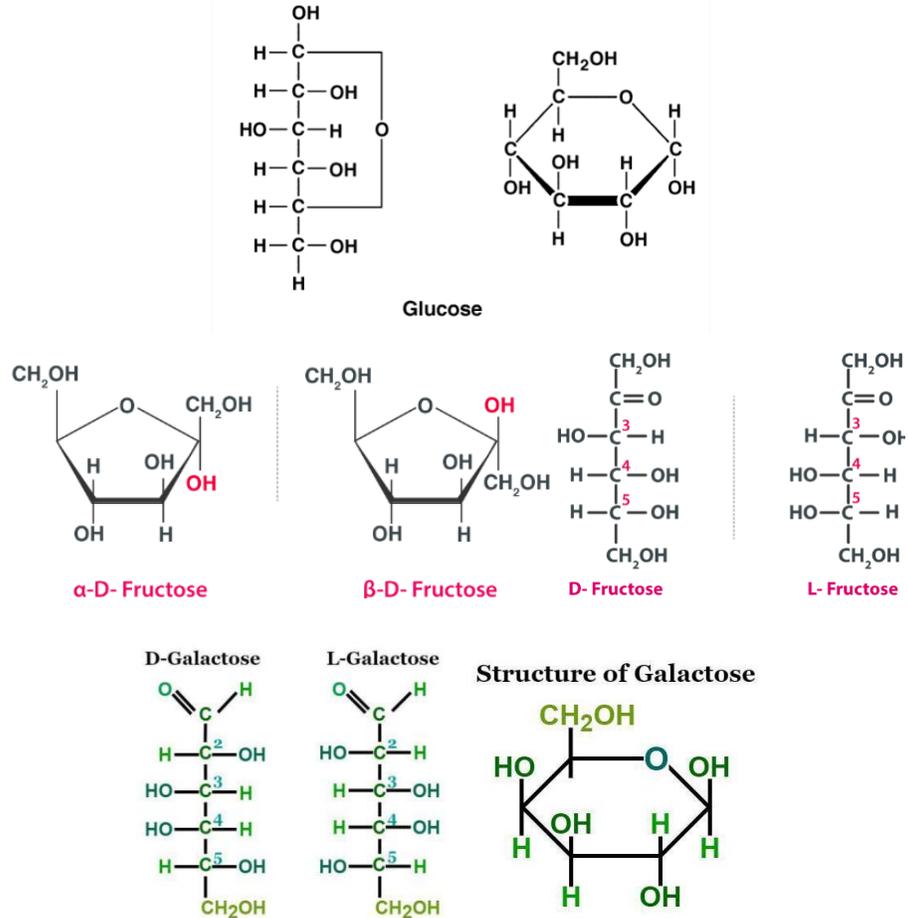
- **Carbohydrates** (or 'carbs') – organic molecules of sugar, starches and fiber – (probably the most abundant and widespread organic substances in nature and essential constituents of all living things serving as energy sources – sugars and starches the fuel of life sort of like bio-gasoline powering the biological engine – and nondigestible fiber the essential structural or

building block components in living organisms), but not fats (not a carbohydrate but an ester) composed primarily of Carbon, Hydrogen and Oxygen atoms. Carbohydrate means “*watered carbon*” since the general chemical molecular formula $C_x(H_2O)_y$ (a combination of Carbon atoms and Water like molecules) represents many different kinds of carbohydrates. Carbohydrates are generally created by the chemical reaction of Carbon Dioxide with Water, $xCO_2 + yH_2O \rightarrow C_x(H_2O)_y$. The ‘x’ represents the number of Carbon atoms in the carbohydrate molecule and y the number of representative water (H_2O) molecules. Carbohydrates are typically formed by green plants using Carbon Dioxide (CO_2) from the atmosphere and Water (H_2O) from the plants root system during the process of photosynthesis taking place in the green leafy part of the plants. Carbohydrates are classified into four major groups:

- a) **Monosaccharides or simple carbs** (‘mono’ meaning single molecular structure, or ‘simple’ sugars found in grapes, fruits, honey, also referred to as monomers); contain 3 to 9 carbon chained atoms with 5 to 6 the most common; Monosaccharides are also known as *polyhydroxy aldehydes or ketones*; that is, they are molecules containing in their molecular structure more than one chemical *hydroxyl group* (- OH, single bonded Oxygen and Hydrogen atoms), and a chemical *carbonyl group* (C=O, double bonded Carbon atom bonded to an Oxygen atom) located either at the terminal (end of the molecular structure) carbon atom (ex. *aldose*, C-C-C=O) or located at the second carbon atom (ex. *ketose*, $\begin{array}{c} \text{C-C-C} \\ \quad \quad \quad \text{O} \end{array}$). Hydroxyl and Carbonyl groups are also referred to as *radicals*. (In chemistry, a radical, also known as a free radical, is an atom, molecule, or ion (an ion is an atom or molecule that has an electrical charge due to an imbalance of protons and electrons; atoms that lose electrons become cations (positively charged), while atoms that gain electrons become anions (negatively charged); this charge is indicated by a superscript next to the element's symbol (e.g., Na^+ for a positively charged sodium ion which means the loss of a negatively charged electron)) that has at least one unpaired ‘valence’ electron. Valence electrons are the electrons located in the outermost shell or cloud orbital of the atomic structure of an atom. These outer energy shell valence electrons are the ones that participate in chemical reactions and chemical bonding with other atoms. The number of valence electrons in an atom determines its chemical properties and how aggressively it will interact with other atoms. With some exceptions, these unpaired outer orbit valence electrons (odd number of electrons) make radicals highly chemically reactive. Significant simple monosaccharide sugars are glucose (aka dextrose, from grape or corn sugar); fructose (fruit sugar) and galactose (milk sugar). All three simple sugars have the same molecular formula, $C_6H_{12}O_6$ or $C_6(H_2O)_6$, and can either be a straight chain or ring molecular structure. Although these simple sugars have the same molecular formula, the location and arrangement of all its elements (its atoms, hydroxyl or carbonyl group) in the sugar molecule structure vary (the same molecular formula but different arranged structure is called *isomers*), and isomers are what makes simple sugars have different characteristics

(example, fructose tastes much sweeter than glucose) as well as causing how a human body processes and uses such sugars (somewhat like a right and left handed person – still a person with two hands but different dominate hand).

Example monosaccharide molecular structures (both straight and ring chained):



Sugar and Humans: Sugars such as single molecule glucose and fructose (monosaccharides) and sucrose (a disaccharide composed of two monosaccharides, glucose and fructose), have a desirable sweet taste to human's, our sweet tooth. The sweet taste in humans is an adaptive ancestral survival trait because it signals the presence of high-calorie, energy-rich foods, which were crucial for early humans to survive in an environment where calories (food in general) were scarce (a calorie deficit). This innate preference helped our ancestors find and consume necessary nutrients, while also stimulating the brain's "dopamine" pathway, promoting enjoyment and reinforcing the consumption of sugar-rich foods for energy and survival. However, this evolutionary advantage has become a challenge in the modern world, where processed foods provide an overabundance of sugar which stimulates the good feeling hormone dopamine, leading to negative health consequences.

Consuming excessive amounts of sugar can have several detrimental effects on health. Increased Risk of Chronic Diseases includes:

- **Type 2 diabetes:** High sugar intake can lead to insulin resistance, increasing the risk of type 2 diabetes;
- **Heart disease:** Sugar consumption can raise blood pressure, cholesterol levels, and inflammation, contributing to heart disease;
- **Obesity:** Sugary drinks and processed foods high in sugar can provide excessive calories, leading to weight gain and obesity;
- **Cancer:** Some studies suggest a link between high sugar intake and an increased risk of certain types of cancer, such as colon and liver cancer;
- **Tooth decay:** Sugar feeds bacteria in the mouth, leading to tooth decay and cavities;
- **Liver damage:** Excessive sugar consumption can damage the liver and lead to fatty liver disease; excess glucose first converted to glycogen (linked glucose molecules) and when the liver and muscles are full of glycogen, triglyceride fatty acids are produced and stored in fat cells or the liver;
- **Increased blood sugar levels:** Consuming large amounts of sugar can cause blood sugar glucose spikes, which can lead to fatigue, headaches, and mood swings;
- **Metabolic syndrome:** A cluster of conditions, including high blood pressure, high cholesterol, and excess abdominal fat, can be associated with high sugar intake;
- **Increased risk of kidney disease:** High sugar intake can put stress on the kidneys and increase the risk of kidney disease.

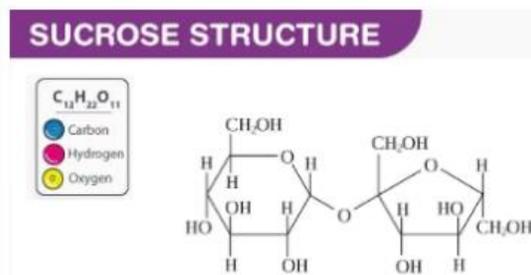
Sugar and Non-Human Animals. The sugar-sweet taste of fruits attracts animals, which then eat the fruits and disperse the seeds through their feces. This is a mutually beneficial arrangement called seed dispersal by frugivory. Most mammals have an innate preference for sweet tastes because they signal the presence of high-energy, caloric sugars like glucose and fructose. This helps them identify and consume energy-rich foods needed for survival. For plants, this sweet tooth digestive seed dispersed strategy, known as endozoochory, is a crucial part of their life cycle.

By consuming sweet fruits and defecating (pooping) undigested seeds elsewhere, animals transport the seeds away from the parent plant (a free transportation ‘trick’ by plants to disperse their offspring). This reduces competition for resources, helps colonize new habitats, and increases the plant's chances of survival and propagation. The journey of the sweet fruit and seeds through an animal's digestive tract, with its churning action and acidic juices, can break down or weaken the seed's protective outer coating. This process, called scarification, primes the seed for germination. Seeds are deposited in a ready-made pile of nutrient-rich dung

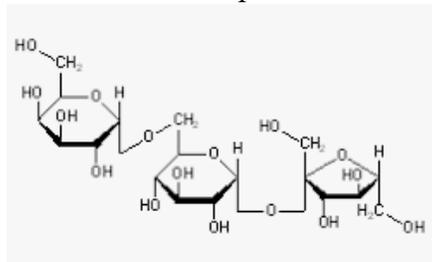
(poop), which acts as a natural fertilizer. The feces provide essential nutrients like nitrogen and phosphorus, giving the new seedling a healthy start. Some plants have evolved specific fruit characteristics to attract particular animal species. The yew tree, for example, produces bright red, sweet-tasting fruits that appeal to badgers, which can handle its poisonous seeds. This ensures dispersal by a suitable animal without harm.

- b) **Disaccharides a complex carb** are two monosaccharide molecules linked together by a ‘glycosidic bond’. The three major disaccharides are sucrose, lactose and maltose. Sucrose is formed in green plants by photosynthesis which links glucose monosaccharide with fructose monosaccharide into disaccharide sucrose ($C_{12}H_{22}O_{11}$ or $C_{12}(H_2O)_{11}$; lactose is milk sugar; maltose is produced from the breakdown of starch (a polysaccharide carbohydrate) in digestion and consists of two molecules of glucose connected by an alpha linkage.

Example sucrose disaccharide structure (glucose + fructose):



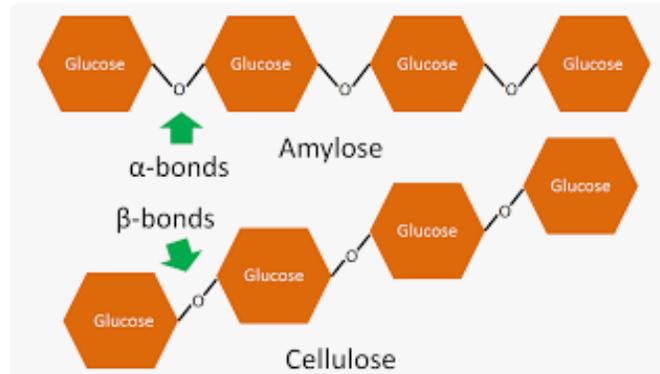
- c) **Oligosaccharides a complex carb** are any carbohydrate with 3 to 6 monosaccharides linked together. Example is *raffinose* ($C_{18}H_{32}O_{16}$ or $C_{18}(H_2O)_{16}$) a trisaccharide (‘tri-’ meaning three monosaccharides linked together) found in plants. Raffinose consists of three monosaccharides: melibiose – a disaccharide composed of two monosaccharides (galactose and glucose) plus the monosaccharide fructose. Raffinose example molecular structure:



- d) **Polysaccharides a complex carb**, the most naturally occurring carbohydrates (often being many glucose molecules linked together), have a molecular structure that is either branched or linear. For example, (1) **linear** cellulose fiber like polysaccharide carbohydrate forms rigid structures in plants (hence why rope like woven fiber stripped from a plant makes a strong basket or why hemp rope is so strong); in contrast to (2) **branched** polysaccharide carbohydrate forms, like Gum Arabic, are soluble in water and form pastes and don’t provide building structure

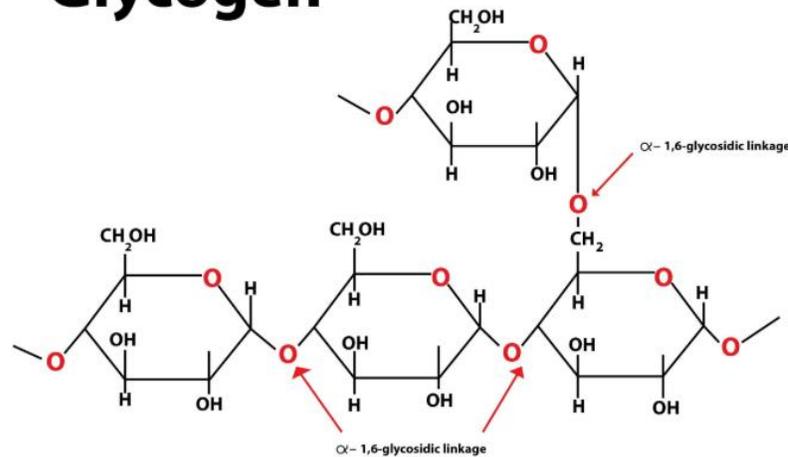
GLUECLOSE SPIKE GLOSSARY OF TERMS (2025)

strength like fiber. Example molecular structures of (a) amylose, a starch, and (b) cellulose, a fiber, polysaccharide carbohydrates composed of chained glucose molecules:

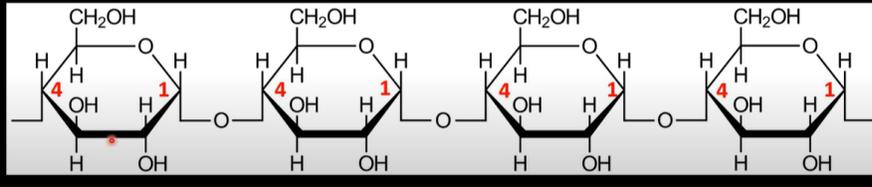


Polysaccharides composed of many molecules of one sugar (example all glucose molecules) or one sugar derivative are called *homopolysaccharides* (*homoglycans* – homo being ‘same’). Example homoglycans composed of only glucose molecules, include cellulose, glycogen and starch – the energy storage carbohydrates of animals and plants. Example glycogen and starch molecular structures:

Glycogen



**Starch is used as carbohydrate storage in plants.
It is a polymer composed of α -glucose with
 α -1,4 glycosidic links between glucose molecules.**



Heteropolysaccharides (hetero being ‘different’), in contrast, are composed of two or more different types of monosaccharide molecules, such as (1) hyaluronic acid, which contains both glucuronic acid and N-acetyl-glucosamine (a component of connective tissue); (2) heparin – an anticoagulant; or (3) glycoproteins – found in proteins; (4) glycolipids – found in nervous systems.

Fiber is a nondigestible complex polysaccharide carbohydrate that can be either soluble or insoluble in water. Examples include cellulose, hemicellulose, pectin and lignin.

What do carbohydrates or ‘carbs’ do in the human body? Carbs are the human body’s main source of fuel. They give the energy needed to function. Here’s how the process works:

- When you eat carbs, your digestive system begins to break them down into simple monosaccharides (glucose).
- Your bloodstream absorbs the carbs (now called glucose or blood sugar).
- Your body releases insulin, which directs the glucose to your cells where the mitochondria transforms the sugar into energy.
- If you have extra glucose, your body will store glycogen (chained together glucose) in your muscles or liver. Once you max out glucose storage in those places, your body converts extra glucose to fat (visceral or subcutaneous or muscle fibers).

The amount of carbs you consume affects your blood sugar (glucose content in blood). Taking in a lot of carbs can raise blood sugar levels. High blood sugar (hyperglycemia) can put you at risk for diabetes. Some people who don’t consume enough carbs have low blood sugar (hypoglycemia). There is a goldilocks ‘perfect’ zone where there is just the right order and just the right amount of carb intake, which optimizes human body metabolism – efficiently converting carbs to energy (minimize ‘glucose spike’) resulting in a healthy and good quality life style. A good diet takes into account Glycemic Index, Load and Variability management and a moderated glucose spike in your blood.

DIABETES

- **Diabetes** is a chronic condition that affects how the human body turns food into energy—specifically how it handles **glucose**, a type of sugar that's your body's main fuel source. When you eat, your body breaks down food into glucose. A hormone called **insulin**, made by the

GLUECLOUSE SPIKE GLOSSARY OF TERMS (2025)

pancreas, helps move glucose from your blood into your cells. In diabetes, either: Your body **doesn't make enough insulin**, or it **doesn't use insulin properly**. As a result, glucose builds up in your bloodstream, leading to **high blood sugar levels** and your body is starved for energy (not converting glucose to energy). Hence, insulin injections are required to supply the necessary amount of insulin to cause glucose to enter our cells and mitochondria and converted to energy.

Types of diabetes include:

- Type 1: Autoimmune condition where the body attacks insulin-producing cells. Usually diagnosed in children or young adults. Born without an insulin factory in the liver.
- Type 2: Most common type. The body becomes resistant to insulin or doesn't produce enough. Often linked to lifestyle and genetics.
- Gestational: Develops during pregnancy and usually goes away after birth but increases risk of Type 2 later.
- Prediabetes: Blood sugar is elevated but not high enough for a diabetes diagnosis. Can be reversed with lifestyle changes.

Common diabetic symptoms include frequent urination, excessive thirst, fatigue, blurred vision, slow-healing wounds and unexplained weight loss. If left unmanaged, diabetes can lead to serious complications like heart disease, kidney damage, nerve issues, amputations and vision problems. But with proper care – medication, diet, exercise – it is manageable.

DOPAMINE

- **Dopamine** is a type of monoamine neurotransmitter. It's made in your brain and acts as a chemical messenger, communicating messages between nerve cells in your brain and the rest of your body. Dopamine also acts as a hormone. Dopamine, epinephrine and norepinephrine are the main catecholamines (a label based on having part of the same molecular structure). These hormones are made by your adrenal gland, a small hat-shaped gland located on top of each of your kidneys. Dopamine is also a neurohormone released by the hypothalamus in your brain. As a hormone, dopamine is released into your bloodstream. It plays a small role in the "fight-or-flight" syndrome. The fight-or-flight response refers to your body's response to a perceived or real stressful situation, such as needing to escape danger. Dopamine is known as the "feel-good" hormone. It gives you a sense of pleasure. It also gives you the motivation to do something when you're feeling pleasure.

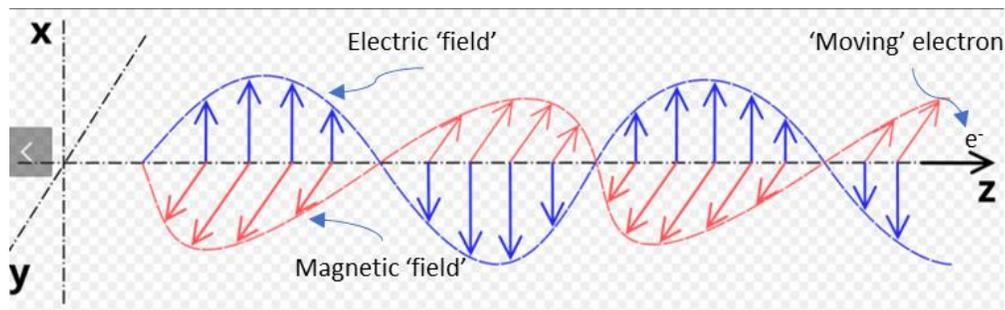
Dopamine is part of your reward system. This system is designed, from an evolutionary standpoint, to reward you when you're doing the things you need to do to survive — eat, drink, compete to survive and reproduce. As humans, our brains are hard-wired to seek out behaviors that release dopamine in our reward system. When you're doing something pleasurable, your brain releases a large amount of dopamine. You feel good and you seek more of that feeling. This is why junk food and sugar are so addictive, a remnant of ancestral survival instincts when tasty sweet fruit are eaten in a calorie deficit environment that triggers the feel-good hormone dopamine release in the brain. They trigger the release of a large amount of dopamine into your

brain, which gives you the feeling that you're on top of the world and you want to repeat that experience.

Over time, high sugar intake can lead to increased tolerance, stronger cravings, and potential dependence, similar to drug addiction, as the brain requires more sugar to achieve the same dopamine effect.

ELECTROMAGNETIC RADIATION

- **Electromagnetic (EM) radiation (see Photon):** is energy that travels at the speed of light in a vacuum at different frequencies and wavelengths in waves through space and matter, comprising oscillating electric and magnetic fields. Electromagnetic radiation energy encompasses a wide spectrum of forms, including radio waves, microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays. Sources of EM radiation range from (1) natural phenomena like the sun to (2) human-made devices such as radio transmitters and X-ray machines. The energy wave must be moving in order to generate electric and magnetic fields. Example of electric and magnetic fields, perpendicular to each other, when there is either a moving electric charge or a moving magnet in a coiled wire – the movement generates the respective fields.

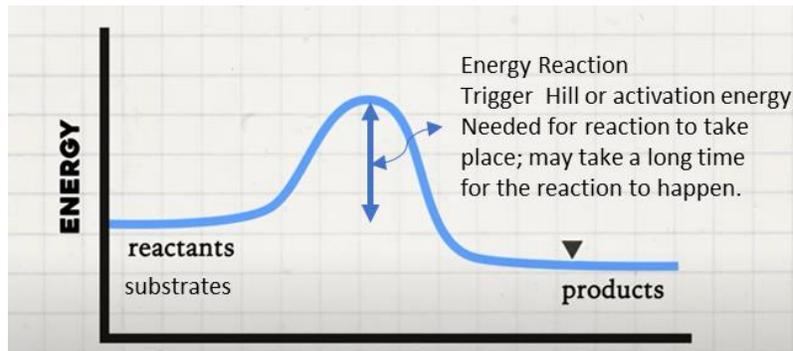


ENZYME

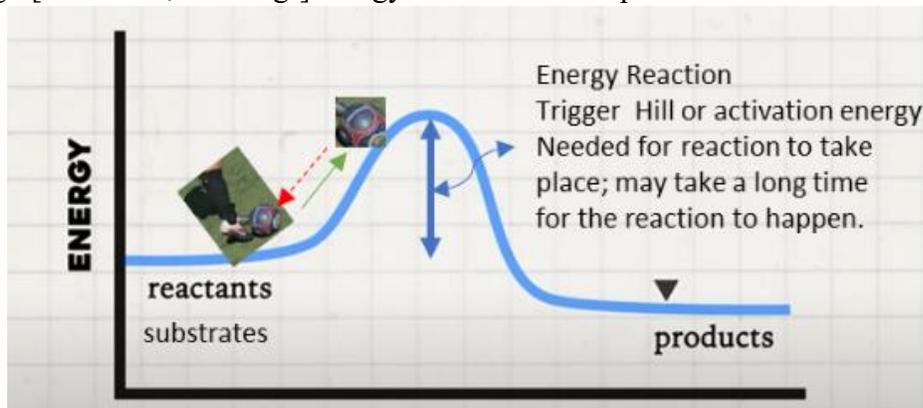
- **Enzyme** is a chemical compound (such as a protein) acts as a biological catalyst (or stimulate), accelerating chemical reactions without the enzyme itself being consumed in the process. The molecules in a chemical reaction on which enzymes act are called *substrates*, which are converted into *products*. Nearly all metabolic processes within a cell depend on enzyme catalysis to occur at biologically (fast) relevant rates. Metabolic pathways or sequence of chemical reactions are typically composed of a series of enzyme-catalyzed steps. Enzymes increase the chemical reaction rate by lowering the reaction's *activation energy*, often by factors of millions. A striking enzyme example is orotidine 5'-phosphate decarboxylase, which accelerates a reaction that would otherwise take millions of years, to occur in milliseconds. Like all catalysts, enzymes do not affect the overall equilibrium of a reaction and are regenerated or reused at the end of each chemical reaction cycle (First. Reactants or substrate molecules connect with enzymes, Second. The reactants are 'broken' up by the enzyme to permit new products to be quickly made from the reactants, Third. The enzyme is set free and available to be reused again in the reaction cycle). What distinguishes enzymes from catalysts

is their high specificity, determined by their unique three-dimensional structure, and their sensitivity to factors such as temperature and pH (where pH – which ranges from a low of 1, most acidic, to 14, least acidic) is the measure of how acid something is such as sulfuric acid in a battery has a very low pH close to ‘1’ pH (minimum), water is neutral at ‘7’ pH and sodium hydroxide used to clean out sewers has a pH close to ‘14’ (maximum)).

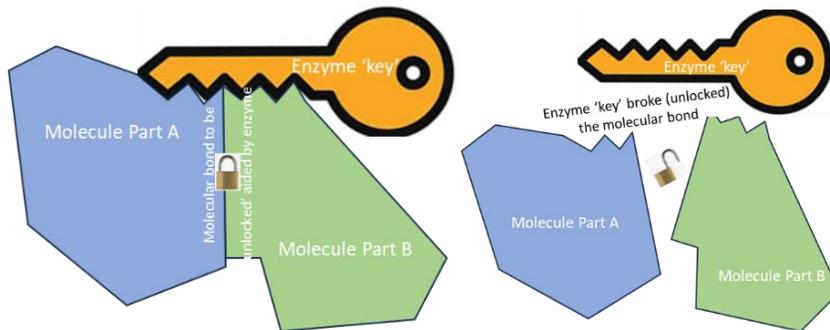
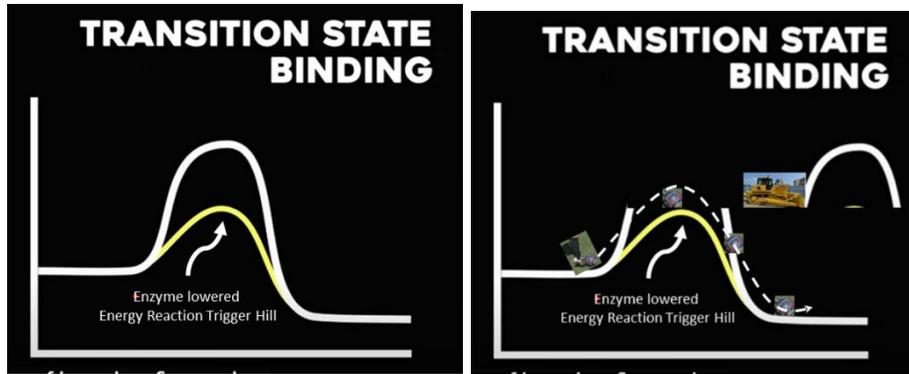
Chemical reactions are illustrated in the graph below in which the Y axis represents the energy budget needed for a reaction to take place and the X axis the time dependent state of the reaction (initial reactants or substrates, intermediate reactants, end products). Enough energy must be available for a reaction to take place...its *activation energy* or energy reaction trigger hill.



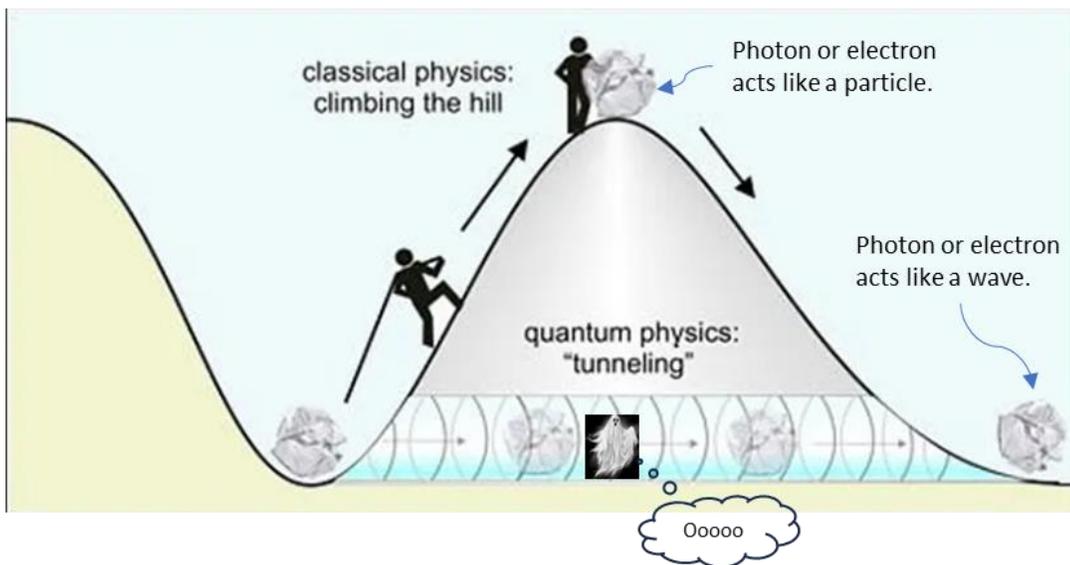
Enzymes act like a magic key that fits nicely (called ‘*transition state binding*’) into the target ‘substrate’ reactants that ‘unlocks’ and causes the energy reaction trigger hill or activation energy to be reduced (called the *transition state*), thereby causing the reaction to not only happen at a lower energy – less activation energy - but quicker. This is sort of like trying to kick a soccer ball up and over a hill and each time you kick, the ball rolls back to you because not enough [activation, ‘kicking’] energy was used to catapult the ball over the hill.



Bring in an enzyme (in this illustration a bulldozer, cut down the height of the energy activation hill, and walla, you now can now easily and quickly kick the ball over the hill). After the unlocking, the chemical reaction quickly takes place and end products produced, the enzyme ‘key’ released from the lock, and the enzyme key reused again to repeat the process.



Research indicates that in some biological functions, enzyme *quantum tunneling (superposition)* might also improve reaction efficiency. Quantum tunneling is the bizarre quantum mechanics world circumstance where a sub-atomic particle (massless photon, electron, etc.) can because of their dual particle and wave properties, either bounce off an apparent solid object (if a particle) or magically travel through the solid wall and appear on the other side (probabilistic quantum tunneling – like a ghost traveling through a wall) because of the ‘particle’s’ wave property (sorta like sound waves traveling through a wall).



Photosynthesis relies on several key enzymes, the most crucial being Rubisco (ribulose-1,5-bisphosphate carboxylase/oxygenase). [Rubisco evolved billions of years ago in an ancestral archaeal organism and was later adopted by cyanobacteria and plants for photosynthesis. It's a key enzyme that fixes carbon dioxide (CO₂) into organic molecules, a process essential for life on Earth. Cyanobacteria (blue-green algae) and some non-photosynthetic bacteria also contain Rubisco.]

Different forms of Rubisco exist across diverse photosynthetic and some non-photosynthetic organisms, with the most common form (Form I) found in plants, algae, and some bacteria. Rubisco is essential for fixing carbon dioxide into sugars, a process that underpins almost all life on Earth. Other important enzymes involved in photosynthesis include those in photosystem II, which facilitates the splitting of water, and enzymes involved in the Calvin cycle, where carbon dioxide is converted into sugars.

FAT

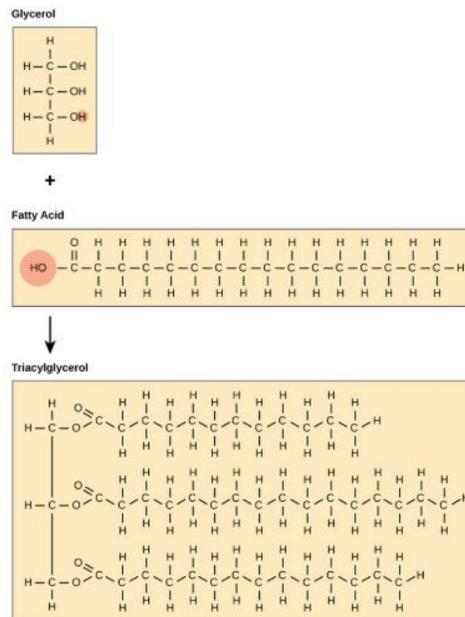
- **Macronutrients** are the food components humans need larger amounts of, such as
 - Carbohydrates (or carbs – are the body's primary fuel; they provide energy for muscles and the central nervous system during movement and exercise),
 - Protein (provides structure to the tissue, includes cell membranes, organs, muscle, hair, skin, nails, bones, tendons, ligaments and blood plasma. Proteins are also involved in metabolic, hormonal and enzyme systems and help maintain the acid-base balance in human bodies).
 - Fat – which is not a carbohydrate (is vital for the body as an energy reserve, for insulation and the protection of human organs, and for the absorption and transport of fat-soluble vitamins – essential 'fertilizer' for good health. The main thing that sets fats apart from carbohydrates and proteins is calorie density. Fats have the highest concentration of calories of any macronutrient. All fats, regardless of type, contain 9 calories per gram. That's more than double the 4 calories per gram found in carbohydrates or proteins).

These macronutrient components of food are what the body needs for energy and to maintain its structure and systems. Macro means 'big.'

Micronutrients, meanwhile, are the vitamins and minerals human's need in very small amounts. All foods are made up of some percentage of both macro and micronutrients. The prefix 'micro' means small, which is appropriate because human's need these nutrients in much smaller quantities than macros and micros are also smaller in size on the molecular level than the macro carbohydrates and fats.

Fats belong to a type of lipid called triglycerides (see lipids). Your body needs lipids, including fats, to do certain jobs. The walls of many of your cells are lipid-based. And lipids help store or carry things throughout your body more easily. Some key examples of that are the fat-soluble vitamins, A, D, E and K. Your body needs fat to use them properly.

A lipid fat molecule consists of two main components: glycerol and fatty acids. Glycerol is an alcohol with three carbon and five hydrogen atoms, and three hydroxyl (OH) groups. Glycerol can be made in the human body through a complex multi-step process using glucose as the base ingredient. Fatty acids have a long chain of hydrocarbons with a carboxyl group attached and may have 4-36 carbons; however, most of them have 12-18. In a fat molecule, the fatty acids are attached to each of the three carbons of the glycerol molecule with an ester bond through the oxygen atom. During the ester bond formation, three molecules are released. Since fats consist of three fatty acids and a glycerol, they are also called triacylglycerols or triglycerides.



Fat in your food helps activate your body's feeling of satiety. That's the feeling of satisfaction or fullness that tells you you're no longer hungry and it's time to stop eating.

The main hormones that make you feel hungry are ghrelin and the feeling of fullness is primarily regulated by leptin. Ghrelin, nicknamed the "hunger hormone," is released by the stomach and signals the brain to increase appetite, while leptin, produced by fat cells, signals fullness to the brain (hypothalamus). The hypothalamus, a part of your brain, is the central control center for appetite and receives signals from these hormones. When ghrelin levels are high and leptin levels are low, you feel hungry and are motivated to eat. As you eat and your energy stores are replenished, leptin levels increase and ghrelin levels decrease, signaling that you are full and should stop eating.

Leptin hormone also promotes excess glucose to be converted into glycogen an energy store house (long connected chain molecules of glucose) to be stored in the liver or muscles (and if still extra glucose, store as fat). The promotion of glycogen process is actually a negative promotion by the hormone suppressing the effect of insulin and suppressing the breakdown enzyme glycogen phosphorylase from breaking down glycogen.

In contrast, ghrelin hormone causes stored glycogen to be broken down into glucose in part by inhibiting insulin from converting glucose to glycogen, the glucose entering the blood stream and used as fuel in the mitochondria.

High blood glucose levels after eating trigger the release of insulin, which also acts on the hypothalamus to signal fullness.

The fats in your food don't automatically turn into body fat (adipose tissue). Your body only stores fat if you take in more calories from protein, carbs or fats than your body needs to burn for energy.

Fat is a complex and vital organ in the human body, known as adipose tissue. It is essential for survival and plays roles beyond simple energy storage, including hormone production, temperature regulation, and protecting internal organs.

The body preferentially uses the simple glucose monosaccharide carbohydrate sugar molecule for its immediate energy needs. Excess glucose not used first is then converted to glycogen and stored in the liver and muscles for later use. Once the liver and muscles glycogen stores are full and there is still unused glucose, it can be stored as subcutaneous or visceral fat or muscle fat.

Thus...glucose, glycogen and glucagon are all related to how your body uses its main source of energy from carbohydrates, but they all have different functions.

Glucose. You get glucose from carbohydrates in the food you eat. Blood glucose (blood sugar) is the main simple monosaccharide sugar found in your blood. This sugar is an important source of energy and provides nutrients for your body's organs, muscles and nervous system. Glucose is very important because it's the primary source of energy for your brain.

Glycogen. When your body doesn't need excess glucose right away, it preferentially stores it as glycogen in the liver and muscles. Glycogen is made of many connected glucose molecules (homopolysaccharide). Although your liver stores a greater ratio of glycogen than your skeletal muscle, since your total muscle mass is greater than that of your liver, about three-quarters of your body's total glycogen is in your muscles.

During intense and prolonged exercise, the glycogen in your active muscle cells can substantially reduce. The amount of glycogen in your liver cells varies throughout each day depending on certain factors, including: The number of carbohydrates you consume; The length of time between your meals; The intensity and duration of recent physical activity; After 12 hours to 24 hours of fasting, liver glycogen is almost totally used up.

The glycogen stores in your liver also partially help with muscle activity and exercise. At the start of exercise, your liver begins breaking down glycogen to maintain blood glucose levels as your

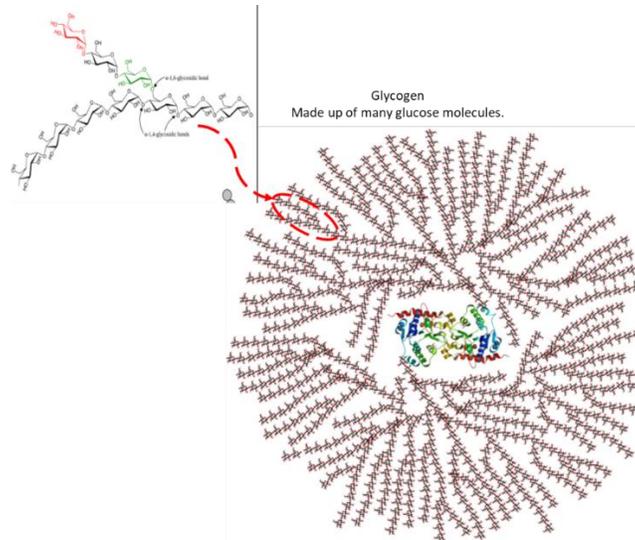
working muscles use it for energy. However, your muscles primarily use their own glycogen stores to function. Muscle glycogen serves mainly as a source of metabolic fuel for your muscles. Your muscles need lots of energy to function in order for you to move. If your muscles relied on glucose from your bloodstream for this energy, your body would quickly run out of glucose. Because of this, your body stores three-quarters of your total glycogen in all of your skeletal muscles so they have a consistent supply of energy, especially during exercise, without dramatically affecting the levels of your blood glucose.

Glucagon. Glucagon is a hormone your pancreas makes that triggers glycogen to convert back into glucose and to enter your bloodstream so your body can use it for energy. Glucagon and insulin are the primary natural hormones that regulate your body's blood glucose levels.

Your body mainly uses the store of glycogen in your liver to help regulate your blood glucose (sugar) levels. Your body normally carefully regulates your blood glucose primarily with the hormones glucagon and insulin. When your blood glucose levels fall too low (hypoglycemia), your pancreas releases more glucagon. Glucagon, in part, triggers glycogen in your liver to convert back to glucose so it can enter your bloodstream. This process is called glycogenolysis. When glucose is in your bloodstream, cells throughout your body can use it for energy.

A glycogen molecule (aka animal starch) is a highly branched polysaccharide carbohydrate (a complex carbohydrate) made of many glucose molecule units, serving as the primary short-term energy storage for animals and fungi. It's characterized by a central core with branching strands connected by alpha-1,4 and alpha-1,6 glycosidic bonds. This branched structure increases solubility and allows for rapid storage and release of glucose to maintain blood sugar levels.

Glycogen consists of thousands of glucose molecules polymerized (attached) together. The molecule is highly branched, with glucose units linked by alpha-1,4 glycosidic bonds in the linear strands and alpha-1,6 glycosidic bonds at the branching points. The central core of the glycogen molecule includes a protein primer called glycogenin.



Glycogen acts as the main storage form of glucose in animals and fungi, providing an immediate energy source. By storing and releasing glucose as needed, glycogen helps maintain stable blood sugar levels, which is crucial for the brain and other cells.

Glycogenesis: The process of synthesizing glycogen from glucose.

Glycogenolysis: The process of breaking down glycogen back into glucose for use by the body.

Hormones like insulin and glucagon regulate the synthesis and breakdown of glycogen to control blood glucose levels.

Glycogen does not directly turn into fat; the body converts excess glucose (which is stored as glycogen) into fat once glycogen liver and muscle stores are full and energy needs are met. When you consume more carbohydrates than your body needs for immediate energy or to fill its limited glycogen stores, the leftover glucose is then processed through various metabolic steps into fatty acids, which are then stored as fat in adipose tissue.

When you eat carbohydrates, they break down into glucose. Glucose is used for energy, or it's stored as glycogen in the liver and muscles. There is a limited capacity for glycogen storage in the body. Once the glycogen stores (liver and muscles) are full and your body's energy needs are met (a balanced glucose intake), any additional glucose is converted into fat.

This conversion of excess carbohydrates (glucose) into fatty acids (a process also called *de novo lipogenesis*) occurs through a multi-step metabolic pathway. These fatty acids are then transported to fat cells (adipocytes) and combined with glycerol to form triglycerides, which are stored as body fat (a subcutaneous or visceral fat).

It's the excess glucose from carbohydrate intake that eventually becomes fat, not the stored glycogen itself. The body prioritizes using glycogen for energy, but when it's already full, it has to find a way to store the extra glucose.

Fat creation in the human body, a process known as adipogenesis, occurs when excess calories consumed from the diet are converted into fat, or triglycerides, and stored in specialized fat cells called adipocytes. This process can involve either the enlargement of existing fat cells (hypertrophy) or the creation of new fat cells from precursor cells (hyperplasia). The body can also store fat in the liver, but the accumulation in adipose tissue is its primary energy reserve function.

Glycogen can raise blood sugar levels, but only when it is broken down in the liver through a process called glycogenolysis. When your blood sugar falls too low, hormones like glucagon signal the liver to convert stored glycogen back into glucose, which is then released into the bloodstream, increasing blood sugar levels to normal. Muscle glycogen, however, is primarily used by the muscles for energy and does not directly release glucose into the blood.

Glycogen itself does not raise blood sugar. It is a storage form of sugar. The breakdown of liver glycogen (glycogenolysis) raises blood sugar levels: by releasing glucose into the bloodstream. This process is triggered by hormones like glucagon when blood glucose is low.

The pancreas monitors the amount of glucose in the blood and is the primary organ responsible for controlling blood sugar by producing the hormones insulin and glucagon.

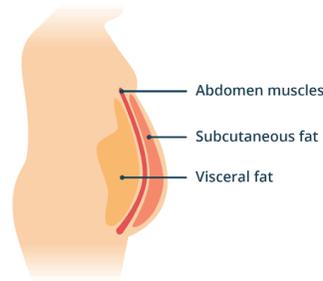
- Insulin lowers blood sugar by moving glucose from the bloodstream into cells (muscle, fat, liver) by helping cells absorb glucose for energy and storing excess glucose in the liver and muscles as glycogen.
- When blood sugar is low, glucagon is released, which signals the liver to convert stored glycogen back into glucose, increasing blood sugar levels. Glycogen in muscles is converted to glucose and used for energy when signaled by insulin.

Types of body fat based on cell type:

- White fat: The most abundant type of fat in the body, its primary role is to store energy in large, white fat cells. White fat also acts as an endocrine organ, secreting hormones that regulate metabolism and appetite. Too much white fat is linked to health problems.
- Brown fat: Composed of iron-rich cells that give it a brown color, this fat burns energy to generate heat, a process called thermogenesis. Infants have a higher concentration of brown fat to stay warm, and adults retain a small amount, typically in the neck and shoulders.
- Beige fat: Also known as "brite" fat, these cells function similarly to brown fat and can burn calories to produce heat. White fat can be converted into beige fat through exercise or cold exposure.

Types of body fat based on location:

- Subcutaneous fat: This "soft" fat is located just under the skin and accounts for most of the body's total fat. A healthy amount offers benefits like insulation and cushioning, but excessive levels can lead to health concerns.
- Visceral fat: This "deep" fat is stored within the abdominal cavity, surrounding the major organs like the liver and intestines. Though it protects internal organs, excess visceral fat is particularly dangerous and is strongly linked to chronic diseases.
- Muscle fat: Fat within muscle tissue that can interfere with the muscle.
- Essential fat: This is the minimum amount of fat required for physiological function. It is found in the brain, nerves, bone marrow, and membranes that protect the organs. Essential fat is crucial for hormone regulation, vitamin absorption, and fertility.

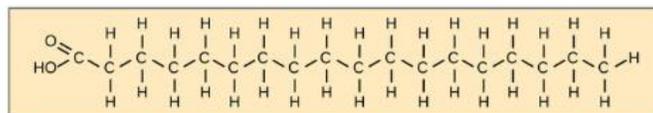


Saturated and Unsaturated fats:

Fatty acids may be saturated or unsaturated. In a fatty acid chain, if there are only single bonds between neighboring carbons in the hydrocarbon chain, the fatty acid is said to be saturated. Saturated fatty acids are saturated with hydrogen since single bonds increase the number of hydrogens on each carbon. Stearic acid and palmitic acid, which are commonly found in meat, are examples of saturated fats.

Saturated fatty acid

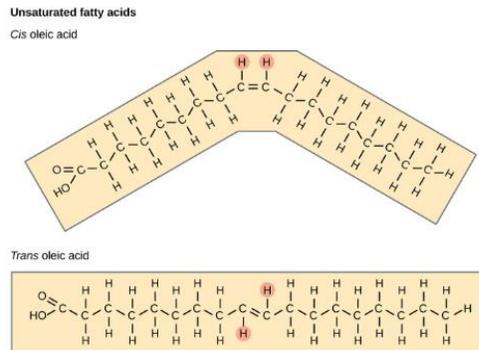
Stearic acid



When the hydrocarbon chain contains a double bond, the fatty acid is said to be unsaturated. Oleic acid is an example of an unsaturated fatty acid. Most unsaturated fats are liquid at room temperature and are called oils. If there is only one double bond in the molecule, then it is known as a monounsaturated fat; e.g. olive oil. If there is more than one double bond, then it is known as a polyunsaturated fat; e.g. canola oil. Unsaturated fats help to lower blood cholesterol levels whereas saturated fats contribute to plaque formation in the arteries.

Unsaturated fats or oils are usually of plant origin and contain cis unsaturated fatty acids. Cis and trans indicate the configuration of the molecule around the double bond. If hydrogens are present in the same plane, it is referred to as a cis fat; if the hydrogen atoms are on two different planes, it is referred to as a trans-fat. The cis double bond causes a bend or a "kink"

that prevents the fatty acids from packing tightly, keeping them liquid at room temperature.

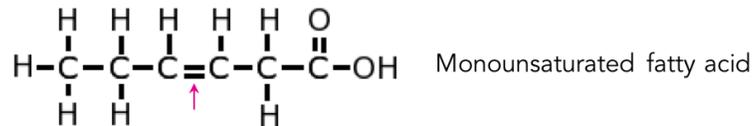


Cis - an oil and Trans a solid (at room temperature)

Fats are more than just two categories: saturated and unsaturated, more complicated than that. There are four types of dietary fats:

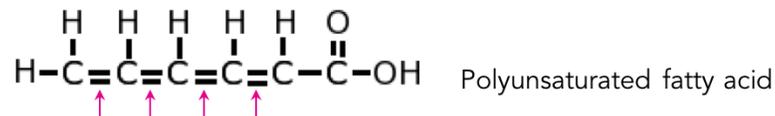
- Monounsaturated fats

- Also known as monounsaturated fatty acids (MUFAs), mainly come from avocados and avocado oil, nuts and nut oils, olives and olive oil. There is only one double bond between two carbon atoms in the fat molecule.



- Polyunsaturated fats

- These are also known as polyunsaturated fatty acids (PUFAs). There are two or more double bonds between carbon atoms.

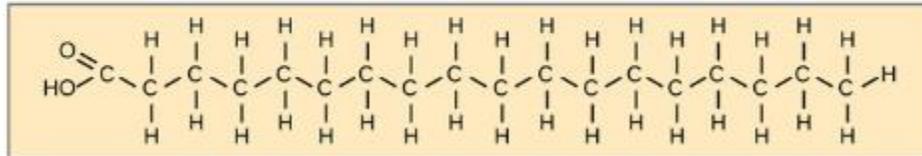


- Some of these are essential, meaning the human body can't work properly without them. A human body also can't make them, so a human needs to include them in their eating habits.
- The essential polyunsaturated fatty acids are **Omega-3** and **Omega-6**.
- There are two main types of omega-3 fatty acids, each coming primarily from different sources:
 - **Long-chain.** From fatty fish, especially herring, mackerel, salmon, sardines and trout, and mussels, a type of shellfish. They're also found in breast milk.
 - **Short chain.** These mainly come from plant and vegetable sources. Examples include leafy green vegetables, canola oil, flaxseed and flaxseed oil, soybeans, and walnuts and walnut oil.
- There are many sources of omega-6 fatty acids. They include:

- Corn and corn oil, Eggs, Legumes like soybeans and soybean oil, Sesame seeds and sesame seed oil, Sunflower seeds and sunflower seed oil, Softer types of margarine, Wheat germ
- Saturated fats
 - Saturated fats are solid at room temperature. In small amounts, they're not harmful. There are no double bonds between carbon atoms in the molecular structure.

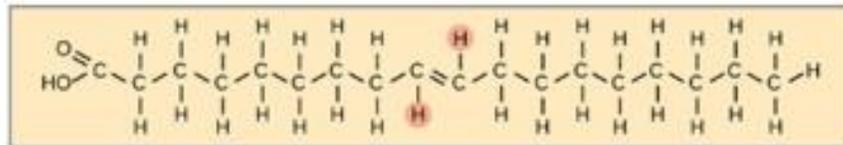
Saturated fatty acid

Stearic acid



- But saturated fats in excess can be bad for you. That's because they may increase your risk of developing cardiovascular disease or heart disease. Experts suspect it has something to do with how they raise your LDL cholesterol. That's one of the biggest reasons that experts strongly recommend limiting the amount of saturated fat you eat and how often you eat it.
- The main sources of saturated fats include: Animal fats like tallow and lard, Cocoa butter and chocolate, Coconut milk and coconut oil, Dairy, especially butter, cream, whole milk and certain cheeses, Palm oil, Red meats
- Trans fats
 - Trans fats are a lot like saturated fats. The only real difference is a quirk of their chemical structure. Hydrogen atoms at the double bond are on opposite sides of each other.

Trans oleic acid



- Both are still solid at room temperature, and both raise your LDL cholesterol. But trans fats also lower your HDL cholesterol (also known as “good” cholesterol).
- Trans fats can come from:
 - Natural sources and processes. There are trace amounts of them in red meats and dairy fat. Tiny amounts also form when oils reach high temperatures.
 - Artificial sources. Trans fats can be manufactured by processing liquid vegetable oils in certain ways.
 - But in many places around the world, including the United States, it's illegal to make or add artificial trans fats to food products. That's because of the long-term health risks from eating trans fats. And there's evidence that links trans fats to increased risks of cancer and other health issues.

Functions of body fat

- Energy storage: Excess calories from food are stored in fat cells (adipocytes) as triglycerides for future use. A gram of fat contains more than double the energy of a gram of carbohydrates or protein.
- Insulation and protection: The layer of subcutaneous fat insulates the body to help maintain a stable internal temperature. Visceral fat cushions vital organs to protect them from physical shock.
- Hormone production: Adipose tissue is a major endocrine organ that secretes more than 50 hormones, including leptin (which regulates appetite) and adiponectin (involved in insulin sensitivity).
- Metabolic regulation: Fat tissue communicates with other organs to regulate overall metabolism and energy balance. This process involves responding to and secreting hormones like insulin and estrogen.
- Brain function: Fats and lipids are a major component of the brain and nerve cells, playing important roles in nerve impulse transmission, memory storage, and tissue structure.
- Vitamin absorption: Dietary fats are necessary for the absorption and use of fat-soluble vitamins (A, D, E, and K).

How the body stores and uses fat for energy

- Storage: When you consume more calories than you burn, your body stores the excess energy as triglycerides in fat cells. These cells can expand significantly to accommodate this storage.
- Mobilization: When your body needs energy, such as during fasting or exercise, it signals the fat cells to release fatty acids into the bloodstream.
- Utilization: Your muscles, lungs, and heart take up these fatty acids, which are then broken down inside the cells' mitochondria to produce adenosine triphosphate (ATP), the body's main energy currency.
- Efficiency: Fat is the preferred fuel source for low-intensity, long-duration activities because the body has a much larger reserve of fat than glycogen (stored carbohydrates). Carbohydrates are used for faster, more intense activities when energy is needed quickly.

Health implications of body fat, Both too much and too little body fat can be detrimental to health.

Too much body fat (obesity), excess body fat, particularly visceral fat, can lead to serious health problems.

- Metabolic syndrome: Increased risk for high blood pressure, high blood sugar, and unhealthy cholesterol levels.
- Heart disease and stroke: High blood pressure and high cholesterol can increase the risk of cardiovascular disease.

- Type 2 diabetes: Excess fat can lead to insulin resistance, causing blood sugar levels to rise.
- Certain cancers: Obesity is linked to higher risk for cancers of the breast, colon, pancreas, and others.
- Inflammation: Enlarged fat cells can release inflammatory markers that contribute to metabolic disorders.

Too little body fat, an insufficient amount of essential fat can also lead to health problems.

- Hormonal imbalance: In females, very low body fat can disrupt estrogen levels, causing irregular periods and impacting reproductive health.
- Impaired immune system: Low fat stores can compromise the immune system, making the body more susceptible to infections.
- Nutrient deficiencies: The body may struggle to absorb fat-soluble vitamins if there is not enough dietary fat.

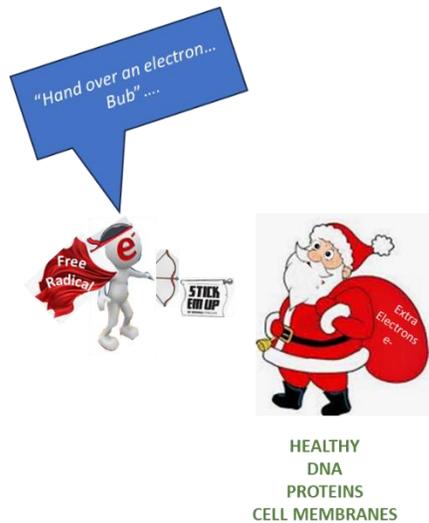
FIBER

- **Fiber** is a complex healthy polysaccharide carbohydrate with two types — water soluble and insoluble. A human's body cannot break down fiber well. Soluble fiber can dissolve in water whereas insoluble fiber can't. Corn is an example of insoluble fiber. Soluble and insoluble fiber pass through the intestines, stimulating and aiding digestion (colon's little broom). Fiber also regulates blood sugar, lowers cholesterol and keeps you feeling full longer. Plant-based foods — like fruits, vegetables and whole-grain products — contain fiber. Animal products, including dairy products and meats, have no fiber.

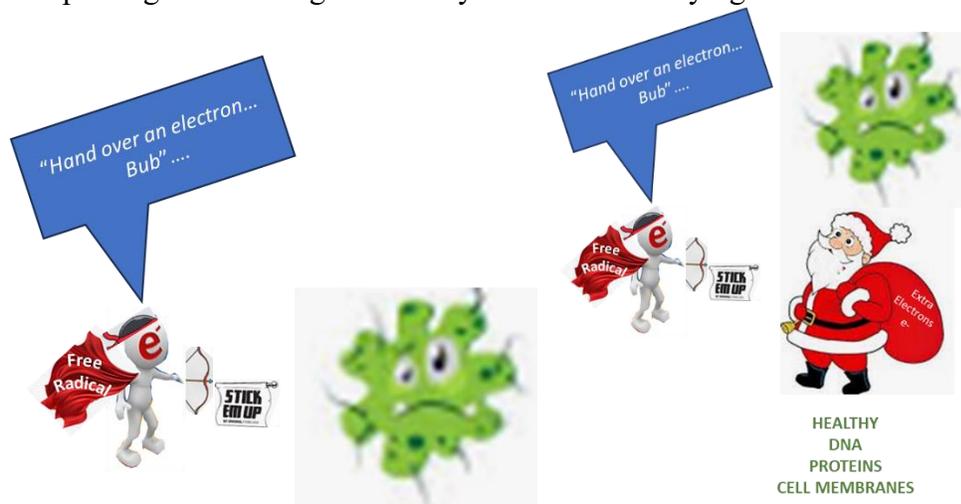


FREE RADICALS

- Free Radicals are chemical compounds that originate as a by-product in mitochondria energy production, formed during exercise, exposure to atmospheric toxins – smoking – x-rays – alcohol – processed foods, and inflammation. During these reaction activities, outer energy shell atom valence reactive electrons move about. Free Radicals are reaction molecule products that are unstable because they have an unpaired outer atomic shell valence electron that wants to be paired up with another electron (since electron's are happiest when they are paired up). Free Radicals want to 'steal' an electron from other molecules, such as healthy DNA, proteins and cell membranes. Such theft results in the damage or destruction of healthy cells and hence damage to our body's health.



- Part of the inconsistency in life is that when humans are injured or have an infection, white blood cells as part of inflammation come to the rescue to attack bacteria or virus. Part of the attack mechanism is that white blood cells produce Free Radicals which attacks bacteria and virus – stealing one of their electrons and destroying the invader. The problem is that Free Radicals don't discriminate against bad bacteria cells and healthy cells and can attack either. If an inflammation event is short term acute, the white blood cell Free Radicals tend to do their job on mainly the bad cells. But if inflammation becomes long term chronic, the Free Radicals hang around longer and can end up doing more damage to healthy cells than destroying bad ones.



- Let's take a deeper dive into Free Radical formation with an example... Consider the reaction of methane – 1 carbon and 4 hydrogen atoms (CH_4 , natural gas) with Chlorine gas – 2 chlorine atoms bound together (Cl_2)...
 Atom electron energy shell structure is:
 Carbon (6): $1s^2, 2s^2, 2p^2$
 Hydrogen (1): $1s^1$
 Chlorine (17): $1s^2, 2s^2, 2p^6, 3s^2, 3p^5$

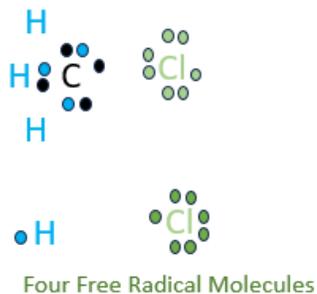
(where: [atom] (# electrons in atom): [energy shell number or letter] [subshell orbital, s,p,d,f] [number electrons in subshell], thus, $2s^2$ means, location of electron is in energy shell 2 (or L), subshell s, with two electrons.

The molecular reactant formulas with electron bonding are shown below:

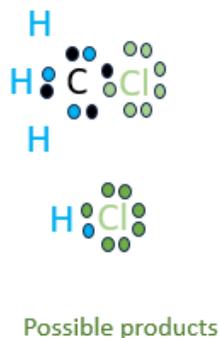


Methane plus Chlorine plus energy equals

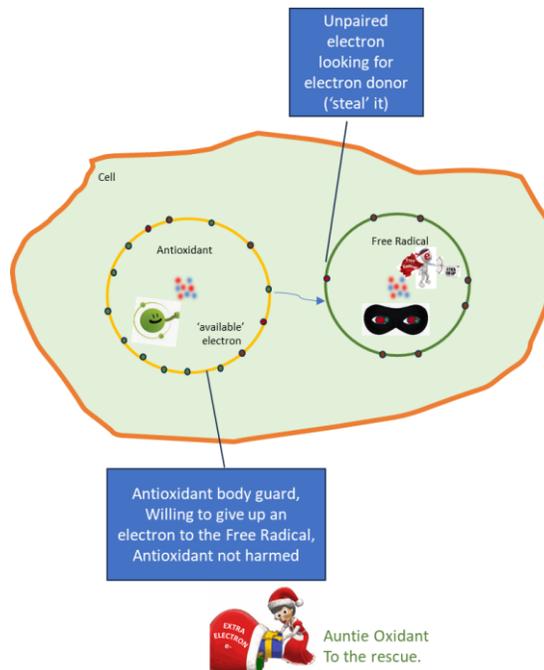
Adding 'Initiation' energy breaks hydrogen and chlorine bonds resulting in four Free Radical molecules (all looking to pair up, steal, an unpaired valence electron).



Free radicals can react (pair up their unpaired electrons) to form new products.



Free radicals are formed in our bodies wanting to steal electrons from healthy cells but antioxidant molecules have an electron to share which reduces the destruction of free radicals.

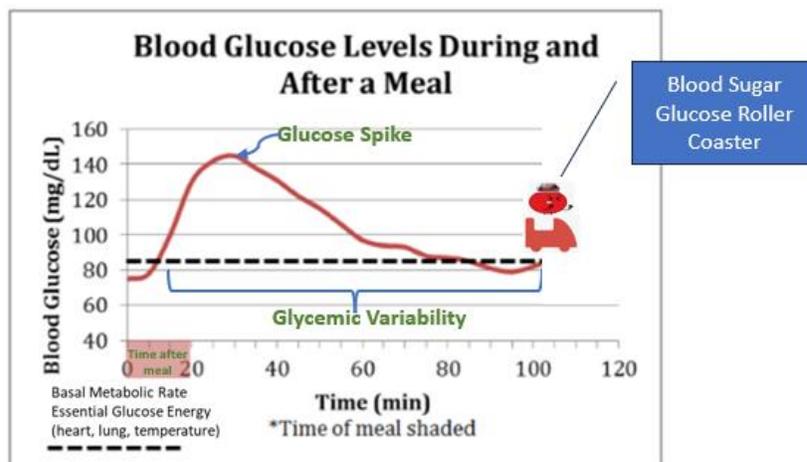


FREQUENCY

- **Frequency** – cycles per second, cps measured in hertz where 1 hertz is 1 cycle per second - (see photosynthesis for diagrams) - how rapidly electromagnetic radiation waves move or 'oscillate' up and down. The lower the frequency of radiation, the lower its energy.

GLUCOSE SPIKE

- **Glucose Spike** is a sharp, rapid increase in your blood sugar (glucose) levels—usually occurring within 1–2 hours after eating, especially meals high in simple carbohydrates or sugar.

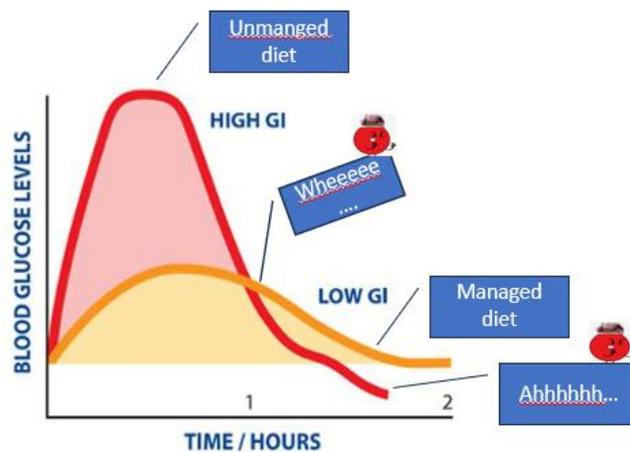


- Eating provides carbohydrate energy fuel supply to provide energy for your body to function. Your pancreas releases insulin triggering your cells to consume the glucose for energy. As you eat and fill up, your fat cells release the hormone leptin signaling fullness to your brain and you stop eating. In contrast, your stomach releases the hormone ghrelin, the “hunger hormone”, signaling the brain to increase appetite and eat. Insulin acts similar as leptin signaling to the brain that you are full.

Causes of glucose spike includes: eating high glycemic foods (white bread, pastries, processed snacks, carbohydrates converted to glucose); large meals (especially if lacking non-digestible fibers which mimic fullness, protein or healthy fats); skipping meals (may lead to overeating); stress or illness (how your body uses insulin to fight infection); and lack of sleep and dehydration.

Glucose spike symptoms includes: fatigue or sluggishness, headache, blurry vision, increased thirst, frequent urination or sudden energy burst followed by a crash (similar symptoms as diabetes).

Glucose spike management includes pair carbs with protein and healthy fats; eat fiber rich food; stay hydrated and monitor your glucose.



Repeated excessive glucose spikes could lead to insulin resistance and increase in type 2 diabetes.

GLYCEMIC INDEX

What is ‘Glycemic Index’ (GI)? A scale of 0 to 100 that ranks how quickly carbohydrate (not including protein or fats) foods raise the glucose or blood sugar level.

- Low (1-55) digest food s-l-o-w-l-y, gradual increase in blood sugar rise (apple)
- Medium (56-69), moderate increase in blood sugar (corn)
- High (70+), quick



GLYCEMIC LOAD

What is ‘Glycemic Load” (GL). A scale of 0 to over 20. How fast carbohydrates increase glucose blood sugar levels and includes typical amount of carbs eaten (takes into account not only magnitude of glucose increase but also amount of food eaten). A better measure of glucose spiking potential.

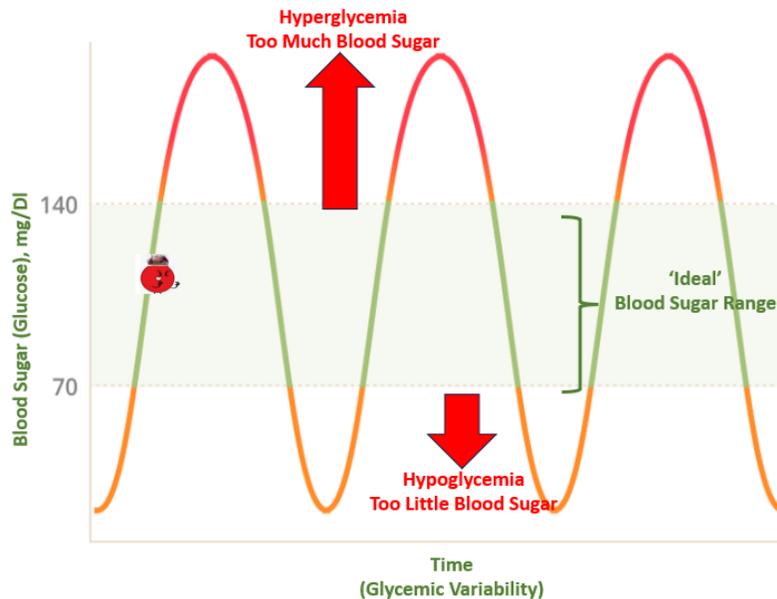
- Low blood sugar increase, 10 or less
- Medium , 11 – 19
- High, 20 or more

Glycemic Load		
Low 10	Medium 19	High 20+
Broccoli	Brown Rice	White Rice
Carrots	Sweet Potato	White Bread
Apple	Oatmeal (plain)	French Fries
Lentils	Pineapple	Watermelon
Peanuts	Whole Wheat Bread	Cornflakes



GLYCEMIC VARIABILITY

Glycemic variability is the variation over time of the glucose blood level concentration (milligrams of glucose per deciliter in blood). The below diagram illustrates such variability with American Diabetic Association of recommendations of safe healthy levels.



INFLAMMATION

- **Inflammation** is your body's natural defense mechanism—a biological alarm system that kicks in when something's wrong, like an injury, infection, or exposure to harmful substances. Inflammation is how your immune system responds to threats. It sends white blood cells and chemicals to the affected area to fight off invaders and start healing. You've seen it (acute inflammation – short term) in action if you've ever had: A swollen ankle after a sprain; Redness and heat around a cut; Fever during an infection

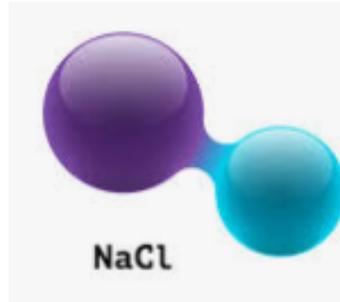
Two faces of inflammation include:

- Acute: Quick response to injury or infection; hours to days; heals tissue, fights infection (with chemicals and fever heat)
- Chronic: Ongoing, low-level inflammation; months to years; can damage healthy tissue and lead to disease. Linked to heart disease, type 2 diabetes, Alzheimer's, cancer and autoimmune disorders like rheumatoid arthritis. Triggered by persistent infections, environmental toxins, poor diet, sedentary lifestyle, stress and smoking/alcohol. Can promote Free Radical development which is detrimental to healthy tissues and cells.

Inflammation is managed by good life style, exercise, good diet (eating anti-inflammatory foods – fish, greens and berries), good sleep hygiene and stress management.

INORGANIC

- **Inorganic** – chemical molecules or compounds that do not have carbon to hydrogen bonds; their molecular structure can be straight chain or ring; they are primarily composed of atoms or elements other than carbon, such as metals and non-metals (Example: ordinary table salt or Sodium Chloride, NaCl, one Sodium atom is bonded to one Chlorine atom). Example:



INSULIN

- **Insulin** is a naturally occurring hormone your pancreas makes that's essential for allowing your body to use sugar (glucose) for energy. If your pancreas doesn't make enough insulin or your body doesn't use insulin properly, it leads to high blood sugar (glucose) levels (hyperglycemia). This results in diabetes. Insulin lowers blood glucose by helping cells absorb it and promotes glycogen (linked stored glucose molecules for later use) and reduces glucose and glycogen formation in liver and muscles. Glycogen is broken converted back to glucose by the hormone glucagon; thus, insulin and glucagon are opposites – they work together to keep blood sugar in balance.

Insulin is released directly into the bloodstream from the pancreas (endocrine function) and then assists moving glucose from your blood into cells all over your body. Glucose comes from both the food and drinks you consume and your body's natural release of stored glucose (glycogen, from the liver and muscles). Glucose is your body's main — and preferred — source of energy. The pancreas also releases enzymes into certain ducts to assist with digestion.

All of your body's cells need energy. Think of insulin as the key that opens the doors of the cells in your body. Once insulin opens your cell doors, glucose can leave your bloodstream and move into your cells and the mitochondria where you use it for energy.

Without enough insulin, glucose can't get into your cells and instead builds up in your blood. This leads to high blood sugar and diabetes. A total lack of insulin for a prolonged time leads to a life-threatening complication called diabetes-related ketoacidosis (DKA).

If you have diabetes, too much (manufactured) insulin can lead to low blood sugar (hypoglycemia). In this case, you may need to consume sugar to raise your blood sugar level.

There are manufactured forms of glucagon available with a prescription for emergency use to treat severe low blood sugar.

LIPID

- **Lipid** are a broad group of organic compounds that include fats, oils, waxes, steroids, and phospholipids. They are characterized by being insoluble in water but soluble in organic solvents, a property central to their biological functions. Lipids are vital for many physiological processes, from storing energy and forming cell membranes to acting as signaling molecules.

The three main types of lipids that are critical for human health are:

- Triglycerides: The most common type of lipid found in the body and in food. They are composed of a glycerol backbone with three fatty acid chains attached.
 - Function: Triglycerides are the body's main form of energy storage. When the body needs energy, it breaks down stored triglycerides into fatty acids.
 - Fats vs. oils: Triglycerides that are solid at room temperature are called fats, while those that are liquid are called oils.
- Phospholipids: Similar to triglycerides, but with a phosphate group replacing one of the fatty acid chains. This gives them both a water-soluble (hydrophilic) head and a fat-soluble (hydrophobic) tail.
 - Function: This unique structure makes phospholipids the primary component of cell membranes, forming a protective lipid bilayer that regulates what enters and exits the cell.
- Sterols: A class of lipids with a distinct multi-ring structure.
 - Cholesterol: The most well-known sterol, found in every animal cell. Your liver produces most of the cholesterol your body needs.
 - Function: It is a precursor for important substances like steroid hormones (estrogen, testosterone), vitamin D, and bile salts that aid in fat digestion.

Lipids perform a variety of essential functions in the body:

- Energy storage: As triglycerides, lipids serve as the body's long-term energy reserve, holding more than double the energy of carbohydrates per gram.
- Cellular structure: Phospholipids and cholesterol are fundamental building blocks of all cell membranes, providing stability and controlling cell permeability.
- Hormone production: Sterol lipids are the precursors for vital hormones that regulate functions such as reproduction and stress response.
- Insulation and protection: A layer of fat under the skin insulates the body against cold, while visceral fat protects delicate internal organs.
- Nervous system health: Lipids are key components of the myelin sheath, a protective layer that surrounds nerve cells and helps transmit nerve impulses.
- Absorption of vitamins: Lipids are necessary for the absorption of fat-soluble vitamins (A, D, E, and K), which are crucial for immune function, bone strength, and vision.

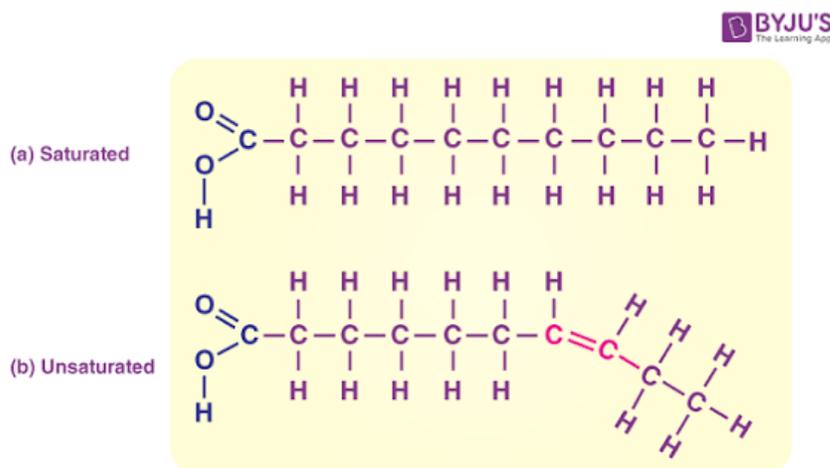
While lipids are essential for health, excessive or imbalanced levels can lead to serious health problems.

- Cardiovascular disease: High levels of LDL ("bad" or "lousy") cholesterol and triglycerides can cause fatty plaque to build up in the arteries, a process known as atherosclerosis. This can narrow the arteries and increase the risk of heart attack or stroke.
- Type 2 diabetes and obesity: Diets high in saturated fats and excess calories can lead to high lipid levels, contributing to weight gain, obesity, and insulin resistance.
- Neurodegenerative diseases: Abnormalities in lipid metabolism are associated with an increased risk for neurodegenerative diseases.

Lipids are found in a variety of foods, with different types offering varying health impacts:

- Healthy unsaturated fats: Found in plant-based oils (olive, canola), avocados, nuts, seeds, and fish. These fats can help lower bad cholesterol.
- Omega-3 fatty acids: A type of polyunsaturated fat found in fatty fish (salmon), flaxseeds, and walnuts. They are associated with heart health benefits.
- Saturated fats: Found in animal products like meat, butter, and cheese, as well as some plant oils like coconut and palm oil. A high intake can raise LDL cholesterol.
- Trans fats: Mostly created artificially, they were once common in fried and packaged foods. They are considered the unhealthiest type of fat due to their strong link with heart disease.

Example molecule of bad saturated fats (no double chemical bonds between carbon atoms) and good (double chemical bond between carbon atoms) unsaturated fat...



METABOLIC OR METABOLISM

- **Metabolic or metabolism** is an adjective meaning having to do with metabolism, which are the chemical reactions in the body that sustain life by converting food into energy, building or repairing tissues, and eliminating waste.

MITOCHONDRIA

- **Mitochondria**

If it wasn't for the glue of glucose, glycogen and glucagon (with the help of some enzymes), us human's would fall apart.

Just like automobiles, the human body needs fuel to operate.

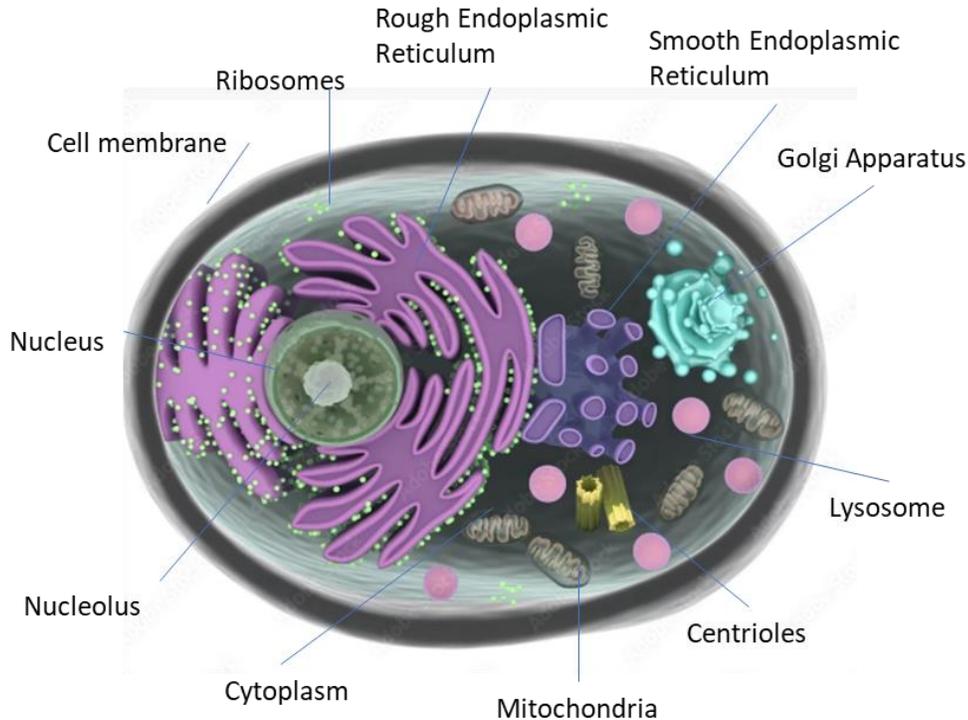
In automobiles, vaporized hydrocarbon gasoline fuel molecules mainly composed of carbon and hydrogen atoms (sometimes mixed with additives to improve the fuel performance) is mixed with oxygen from the air, a spark applied, and the fuel-air mixture explodes (oxidizes – shuffling of electron's) producing hot expanding energy gases (carbon dioxide and water vapor – the same number of carbon, hydrogen and oxygen atoms just rearranged in different molecules, the chemistry of electron shuffling) inside an engine cylinder which pushes on a piston causing a crankshaft to turn and the auto's wheels turning. The chemical energy stored in the hydrocarbon fuel is converted to useful mechanical work energy (thermodynamics – converting one form of energy to another).

When human bodies consume carbohydrates, the digestive system produces glucose. Glucose is the fundamental fuel needed for us human's to operate. Glucose enters the human blood stream and transported to our cells. The mitochondria engine in human cells is the magical kingdom where the glucose (along with proteins and fats) is oxidized (with the aid of its additives in the form of enzymes) and converted from stored chemical energy to useful work energy by an oxidation (shuffling of electron's) process, similar thermodynamic principles that occurred in the automobile operation.

Brain cells need constant glucose supply as even short dips can cause confusion or fainting. Muscles use glucose for quick energy, especially during anaerobic activity. Anaerobic muscle activity is a short-duration, high-intensity burst of exercise where the body's demand for oxygen exceeds supply, forcing it to rely on stored energy (like glucose, stored mainly as glycogen in the liver and muscles but in some cases if glucose and glycogen are in short supply, may convert triglyceride fat (its fatty acids more so than its glycols) to ketone bodies, a substitute energy fuel source for glucose) within the muscles (and liver) for oxygenated fuel rather than inhaled oxygen. Examples include heavy weightlifting, sprinting, and high-intensity interval training (HIIT). This type of activity is crucial for building muscle mass and strength, increasing power, and boosting metabolism. The liver regulates blood glucose by storing it as glycogen and releasing it as needed.

Before discussing the mitochondria energy powerhouse energy production process, it is useful to first describe the function of the human cell in which the mitochondria are located.

Reference the diagram below. A human cell is the basic structural and functional unit of the body. There are over 37 trillion cells in one's body. It's like a miniature factory that: converts nutrients into energy, builds proteins and other molecules, communicates with other cells, reproduces itself and maintains internal balance (energy, pH, mass, homeostasis).



The cell membrane provides a protective barrier (like skin) and controls what enters and exits the cell.

The cytoplasm is a gel-like fluid where organelles (these are parts of the cell that act as miniature organs performing different tasks) float and the site or environment of many metabolic reactions (converting nutrients into useful energy or material).

The nucleus is the control center of the cell and contains DNA (the cell's genetic blueprint – the instruction of what it does and its function).

The mitochondria is the powerhouse that produces ATP (energy for the cell and the body) through cell respiration (glucose the fuel, is mixed with oxygen from the blood and an oxidation (exchange of electrons and proton creation) occurs resulting in the creation of energy and release of carbon dioxide into the blood for removal by the lungs. There are typically over 37 quadrillion mitochondria in the body.

Ribosomes are protein factories that build proteins from amino acids.

Smooth endoplasmic reticulum produces lipids (see lipids) and rough endoplasmic reticulum processes proteins with ribosomes.

The Golgi apparatus is like a packaging and shipping center which modifies and sends proteins to destinations.

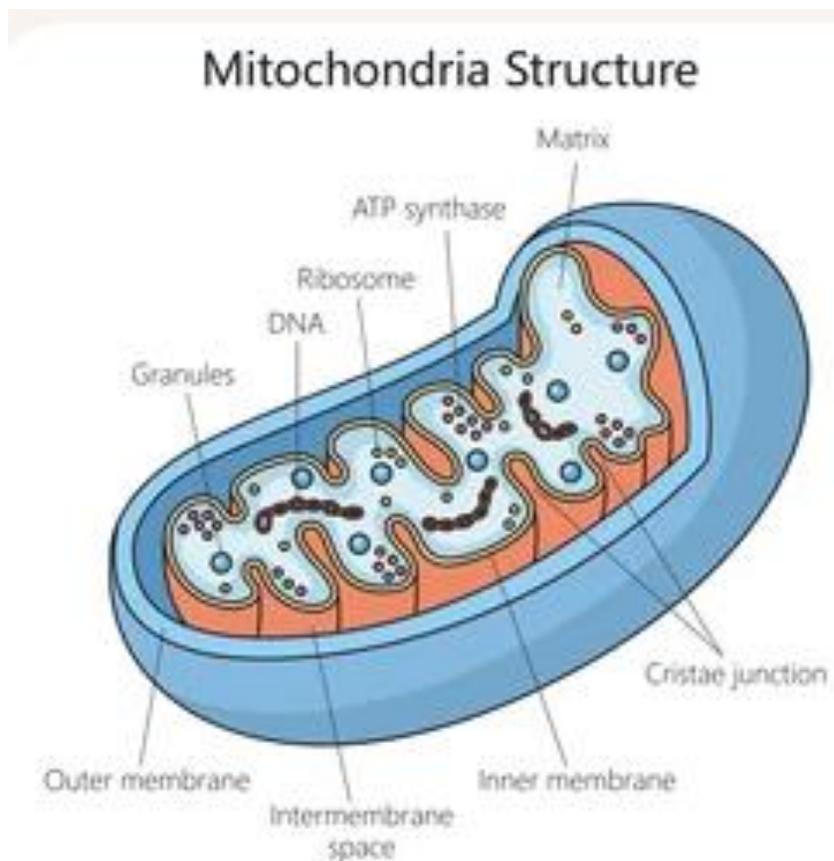
Lysosomes function as a waste disposal site and digest unwanted materials and cellular debris.

Centrioles assist with cell division (mitosis) and reproduction.

Some cells (nerves) live for decades and some cells (skin) are replaced every few weeks. Cells come in all shapes and sizes: muscle cells stretch and contract; nerve cells transmit signals and immune cells hunt invaders.

Mitochondria are tiny structures within plant and animal cells, often called the "powerhouses of the cell," that generate most of the cell's energy by converting sugar and fats into a usable energy form called ATP, through the process of cellular respiration. They are crucial for maintaining life, regulating calcium, controlling cell growth, and initiating programmed cell death (apoptosis). Mitochondria are the primary sites of cellular respiration, a process that uses oxygen to break down nutrients and produce ATP (adenosine triphosphate), the main energy currency for cells. They play a role in monitoring and regulating calcium levels within the cell, which helps balance energy demand and production. Mitochondria are involved in various cell signaling pathways and are essential for cell growth and differentiation. They can initiate the process of programmed cell death, or apoptosis, which helps clear away old or damaged cells from the body.

Refer to the mitochondria diagram below.



The outer membrane is smooth and permeable to small molecules via proteins called porins and acts as a protective barrier and gateway for ions and nutrients (its skin).

The inner membrane is highly folded into cristae (to increase surface area) and impermeable to most ions (charged particles) and it houses the electron transport chain and ATP synthase for energy production.

The Cristae has infoldings of the inner membrane and increases surface area for ATP generating reactions.

The intermediate space is the space between the outer and inner membranes which plays a role in the electron transport chain and proton gradient formation. (When an electron relocates, it leaves behind an imbalance of positively charged proton's which charge sets up a gradient or imbalance of charge in which the mitochondria respiration process takes place).

The matrix is the innermost compartment filled with enzymes, mitochondrial DNA and ribosomes and is the site of the Krebs cycle and fatty acid oxidation and contains genetic material.

The mitochondrial DNA is a circular DNA unique to mitochondria and encodes proteins essential for mitochondria function.

The ribosomes are similar to bacterial ribosomes that synthesize mitochondrial proteins.

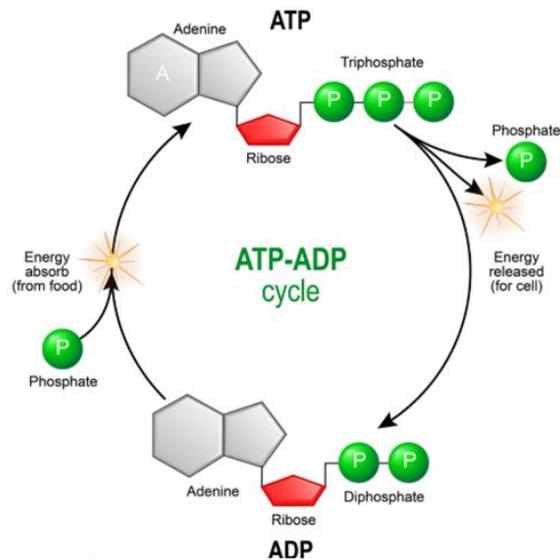
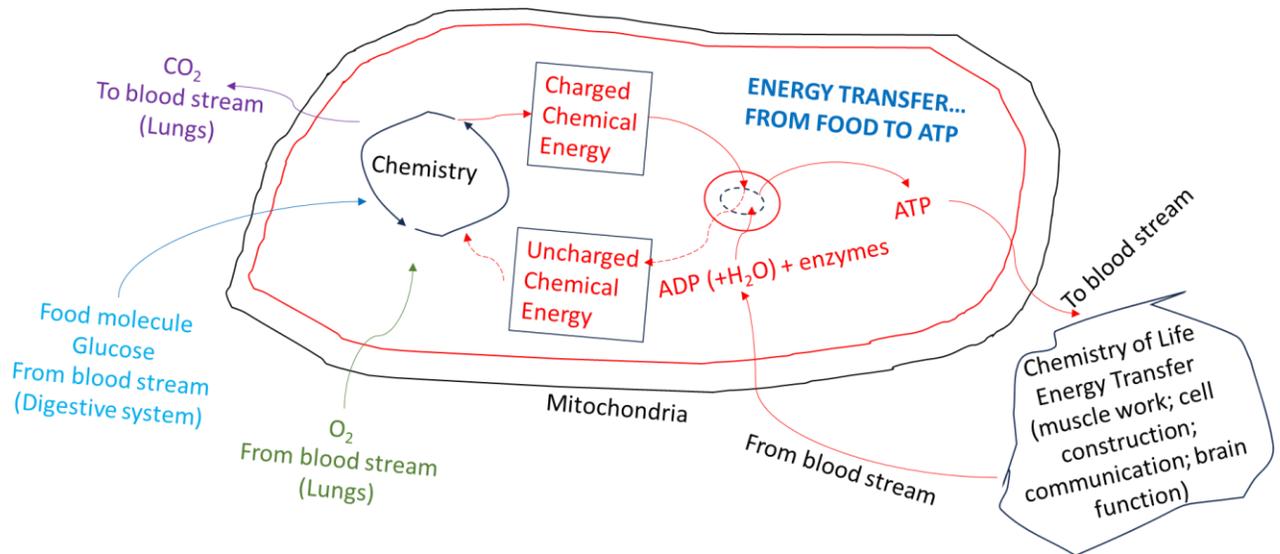
Granules found in mitochondria are primarily Mitochondrial RNA Granules (MRGs), which are fluid, membrane less compartments within the mitochondrial matrix that house newly synthesized RNA and RNA processing/ribosome assembly factors. These MRGs are essential for regulating mitochondrial gene expression and are dynamic, fluid structures that can exchange components, fuse, and are positioned by mitochondrial membrane dynamics. Older research also proposed that granules could store calcium.

ATP synthase is a molecular machine and essential enzyme found in the inner mitochondrial membrane, chloroplasts, and bacterial plasma membranes that produces ATP, the cell's energy currency, from ADP and inorganic phosphate. It works like a rotary motor, using a proton-motive force—an electrochemical gradient—across the membrane to rotate parts of the enzyme, driving the catalytic process that binds ADP and phosphate to form ATP.

A crista junction is a narrow, neck-like opening connecting the folded membranes of the mitochondrial cristae to the inner boundary membrane of the mitochondrion. These junctions form a "diffusion barrier" that regulates the movement of proteins and small molecules, like cytochrome c, creating a distinct micro-compartment within the cristae for cellular respiration and ATP production.

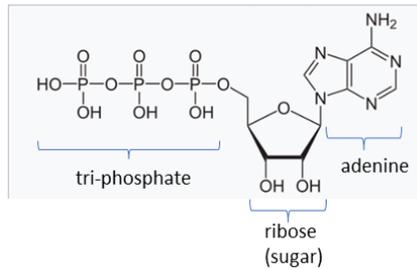
Two critical components in human bodies required to create the energy to keep human bodies going include ATP (Adenosine Triphosphate) and ADP (Adenosine Diphosphate) used to fuel the human body's energy needs. In the mitochondria, oxygen, glucose (plus fats and proteins), water and enzymes react to create ATP which is ultimately converted into ADP with the release of energy. The internal chemistry of the mitochondria (illustrated below) is complicated but is an oxidation reaction (using the oxygen human's breath in and glucose as a fuel source)

allowing magical electron's in the various reacting molecules to shuffle about creating necessary components for life and energy.



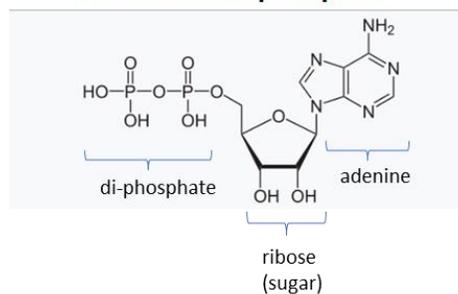
- ATP: The Energy Currency of Life
 - ATP is like the body's rechargeable battery. It powers nearly every cellular activity:
 - Structure: Made of three phosphate groups, ribose (a sugar), and adenine (a nitrogenous base).

Adenosine-5'-triphosphate



- Energy Source: The bond between the second and third phosphate group stores high energy. Breaking this bond releases energy.
 - Functions: Muscle contraction, Nerve impulse transmission, Protein synthesis, Active transport across cell membranes, DNA and RNA production.
 - ATP is a highly unstable molecule. Unless it is quickly used to perform work, ATP spontaneously dissociates into ADP + P_i, and the free energy released during this process is lost as heat.
- ADP: The Spent Fuel That Gets Recharged
 - ADP is what ATP becomes after it gives up one phosphate group and releases energy in the process:
 - Structure: Same ribose and adenine, but only two phosphate groups.

Adenosine diphosphate

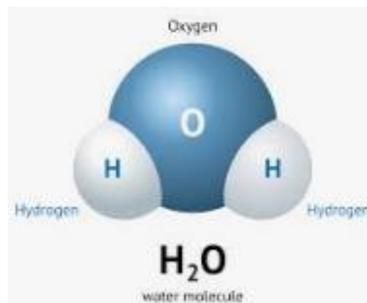


- Role: Signals the cell to regenerate ATP through: Cellular respiration (mainly in mitochondria) and ATP synthase enzyme activity
- The ATP–ADP Cycle: Your Body’s Power Loop
 - This cycle is the heartbeat of cellular energy:
 1. ATP hydrolysis: $\text{ATP} + \text{H}_2\text{O} + \text{enzymes} \rightarrow \text{ADP} + \text{P}_i$ (inorganic phosphate) + free energy
 2. ATP regeneration: $\text{ADP} + \text{P}_i + \text{enzymes} \rightarrow \text{ATP}$ (via energy from food breakdown)
 - This loop ensures a constant supply of energy to the body for everything from blinking to bench pressing.
 - To keep this cycle going, your body:
 - Breaks down glucose, fats, and proteins from food
 - Uses oxygen in cellular respiration to generate ATP

- Stores small amounts of ATP in muscles for quick bursts, but relies on continuous regeneration for sustained activity

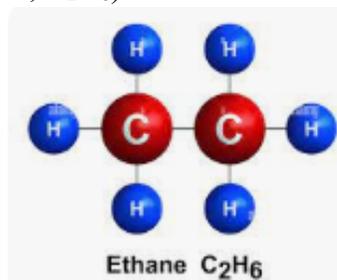
MOLECULES

- **Molecules** - a group of two or more atoms bonded together, representing the smallest fundamental unit of a chemical compound that can take part in a chemical reaction. (Example: A molecule of water, H₂O – which means one Oxygen atom is bonded with two Hydrogen atoms). Example:

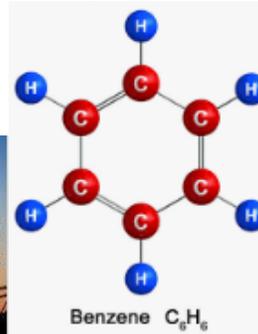


ORGANIC

- **Organic** – chemical molecules or compounds that contain carbon to carbon, or carbon to hydrogen bonding, and often includes Nitrogen, Sulfur or Oxygen atoms in the molecule;
 - a) The carbon-to-carbon bonding structure can be straight chain – one connected after another like railroad cars; Example (Ethane, C₂H₆):



- b) A ring structure such as a Ferris wheel; Example (Benzene, C₆H₆):



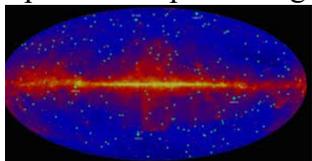
matter their energy content determined by the frequency and wavelength), and possess both wave-like and particle-like properties.



[A little factoid: The general rule is nothing can travel faster than the speed of light (if in a vacuum) – neither matter nor information. Two exceptions:

- (1) The universe is thought to be expanding faster than the speed of light.
- (2) When light travels through a dense medium, say a prism or crystal, such light will have its speed of light determined in the matter it travels through which is slower than its speed in a vacuum. There can be other radiation energy waves when they travel in the same medium, that travel faster than the speed of light in that medium. When that happens the traveling radiation gives off a greenish/blueish glow effect known as Cherenkov radiation, indicative of a ‘sonic boom’ – what happens when a plane flies faster than the speed of sound].

Universe expansion > speed of light;



Cherenkov radiation > speed of light



The energy carried by a photon is directly proportional to its frequency ($E = hf$, E is Energy, h is Planck’s constant, f is frequency) and inversely proportional to its wavelength ($E = hc/\lambda$, c is the speed of light, λ is wavelength). Therefore, shorter wavelengths (like blue or ultraviolet light radiation which causes sunburns) carry more energy per photon than longer wavelengths (like red light such as an infrared heater).

How do photons contribute to photosynthesis?

1. Light absorption by pigments: Photosynthetic organisms contain specialized pigments, primarily chlorophylls, which are responsible for absorbing photons of light.

2. Excitation of electrons: When a photon is absorbed by a chlorophyll molecule, its energy is transferred to an electron within the molecule, elevating it to a higher energy level (an excited state). This makes the electron unstable.
3. Electron transfer and energy conversion: This excited electron is then transferred to a series of molecules in the photosystem, initiating an electron transport chain. This process is akin to the photoelectric effect. The photoelectric effect is a phenomenon where electrons are ejected from a material's surface when light, acting as particles called photons, strikes it with sufficient energy. This is how solar energy power converts light into electricity – light energy or photons from the sun strike a solar panel cell and the cell causes electron's to flow creating solar electricity.
4. Formation of energy carriers: The energy from the electron transport chain is used to create ATP (adenosine triphosphate) and NADPH (nicotinamide adenine dinucleotide phosphate). These molecules act as temporary energy carriers within the plant.
5. Splitting of water and oxygen release: To replace the electron lost by the chlorophyll molecule, water molecules are split (a process called photolysis), releasing oxygen into the atmosphere as a byproduct and replenishing the electron supply. So, hat's off to chlorophyll for continuously creating life sustaining atmospheric oxygen. Factoid: greater than 50% of earth's oxygen is created by seawater phytoplankton, a living organism like plants that utilize photosynthesis.

Where does the energy ultimately go?

The ATP and NADPH molecules, generated during the light-dependent reactions, are then utilized in the Calvin cycle (also known as the light-independent reactions) to fix carbon dioxide and produce sugars like glucose. These sugars serve as the primary source of chemical energy for the plant (and phytoplankton), powering its growth, development, and other metabolic activities. Thus, the energy initially captured from photons is ultimately stored in the chemical bonds of glucose molecules.

In summary, photon energy is the driving force behind photosynthesis, initiating a cascade of events that convert light energy into chemical energy stored within organic molecules like glucose. This process is crucial for the survival of plants (and phytoplankton) and, consequently, for supporting life on Earth.

PHOTOSYNTHESIS

- **Photosynthesis [THE MYSTERY AND MAGIC OF PHOTOSYNTHESIS]** (see Photons), is the synthesis of energy and associated carbohydrate products out of light (15,000 tons of biomass – plant material - is produced on earth every second from photosynthesis); this isn't too hard to believe since if we assume one square inch, about the size of a typical small tree leaf, approximately 1.2×10^{13} photons from the sun hit that one inch area every second (over 12 trillion photons per second!!!) – in contrast to the sun, an ordinary light bulb emits in all directions over a billion trillion (10^{20}) photon quanta (discrete packet of energy) each second; (This is why the amount of sunlight striking earth's surface in 1.2 seconds is the same amount

GLUECLOSE SPIKE GLOSSARY OF TERMS (2025)

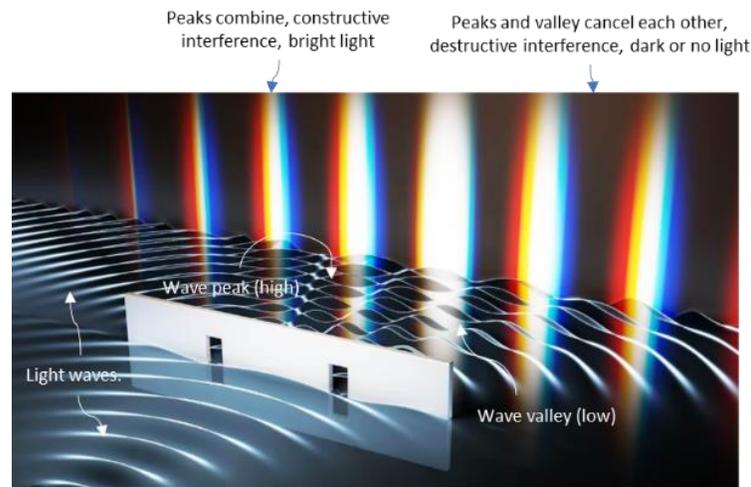
of energy from all non-renewable fuels (once used their gone and not being regenerated) – coal, oil, gas, etc. - that the entire earth uses in one day and why this clean, renewable, free solar energy resource should be a fundamental part of earth’s energy policy. And just think, these photons are just the tiniest fraction of the ones that strike earth, yet the sun is emitting photon’s from its sphere in all directions!;

a) The photosynthesis chemical reaction equation and process are illustrated as:

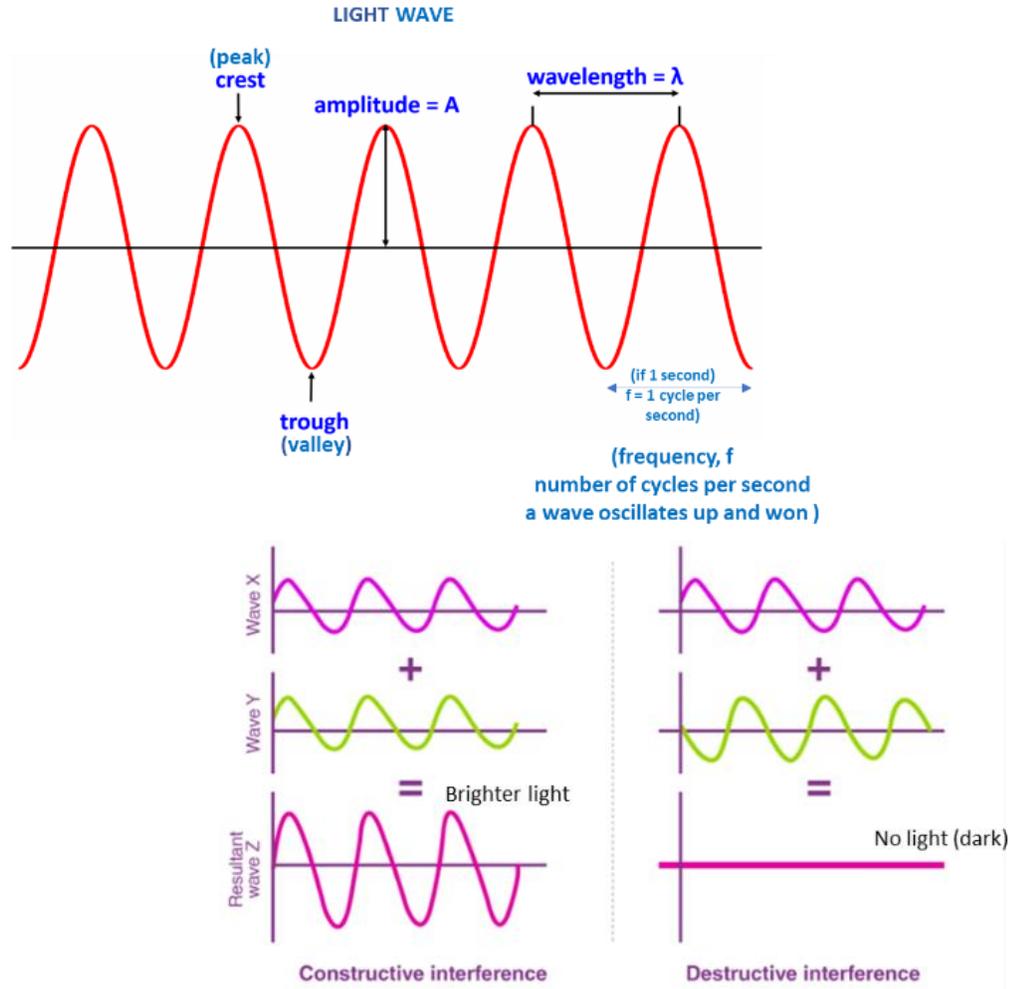
- $[\text{CO}_2 \text{ (carbon dioxide)}_{\text{air}} + \text{H}_2\text{O} \text{ (water)}_{\text{root}} + \text{light (photon)}_{\text{sun}}]_{\text{reactants}} \rightarrow [\text{sugars (C}_6\text{H}_{12}\text{O}_6) + \text{O}_2 \text{ (oxygen)} + \text{useable energy for plant}]_{\text{products}};$
- Sunlight/photon \rightarrow chloroplast \rightarrow thylakoid (photon knocks a loosely bound electron from thylakoid’s magnesium atom – electron goes to *charge separation site* in chlorophyll to create energy products - carbohydrates) \rightarrow chlorophyll;
- It is not easy for an electron to find its way to the *charge separation site* in the chlorophyll yet the process is near 100% efficient (the most efficient engine that scientists and engineers study to determine if they too can replicate an equivalent efficient energy engine – would save a lot of fuel and cost; car gasoline engines are less than 25% efficient – Why difficult?
 - – Now enters quantum mechanics super computer principles which is believed to apply where at the quantum physics level the electron (that has both particle and wavelike properties) is believed to be in a ‘*superposition*’ wave ‘*coherence*’ state before it is measured;
 - – Being a probabilistic bizarre ruled quantum physics world of the electron existing in more than one place at the same time (*superposition state* associated with a wave when an observer is not measuring or trying to measure the process), sort of spooky mystery stuff of the quanta world – *spooky at a distance*;
 - –Once an observer makes measurements, the superposition probabilistic state wave electron collapses to a specific decoherence deterministic particle location, no more probability of occurrence;
 - The photosynthesis quantum physics world has been tested by *two-dimensional Fourier-transform electron spectroscopy* – whew! (say that two times backwards)!
 - – The test looks for *light interference patterns* (recall since light travels in waves, when the amplitudes or same peaks of two light waves overlap, interact and add, they reinforce each other (*constructive interference*) and look brighter. When a wave peak and a wave valley overlap and interact with each other they cancel each other (*destructive interference*) and the interference results in

no light or darkness) – where the interference effect is confirmed by the two-slit experiment (results in quantum beats of the light).

- The diagrams below illustrate the two-slit experiment, light wave pattern and interference.



Two slit light interference experiment.



- – The spectroscopy experiment confirms the free wave magnesium electron was following different paths at the same time (a *superposition state*) hence making the photosynthesis process extremely efficient and quick and arguably governed by quantum mechanics physics principles and not ‘simple’ classic Newtonian physics
- b) Chlorophyll is involved with the system of biological processes by which photopigment – bearing autotrophic organisms, such as most plants, algae and cyanobacteria, convert light energy (sunlight photon energy) into the chemical energy (sugar) necessary to fuel their metabolism.
- c) The term photosynthesis usually refers to *oxygenic* photosynthesis, a process that releases oxygen as a byproduct of water splitting. Photosynthetic organisms store the converted chemical energy (carbohydrates) within the bonds of intracellular organic compounds (complex compounds containing carbon), typically carbohydrates like sugars (mainly glucose, fructose and sucrose), starches, phytyloglycogen and cellulose (fiber). When needing to use this stored energy, an

organism's cells then metabolize the organic compounds through cellular respiration.

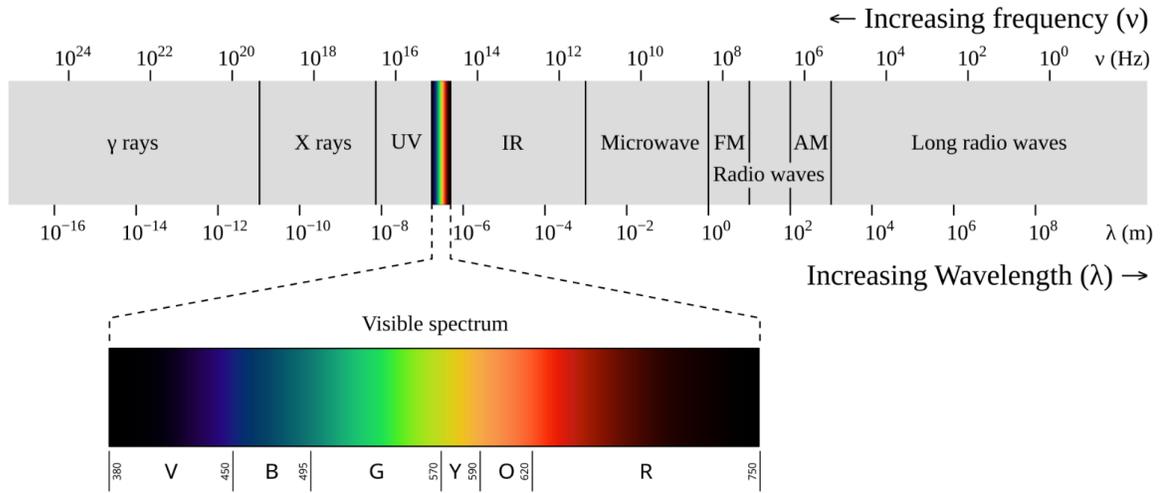
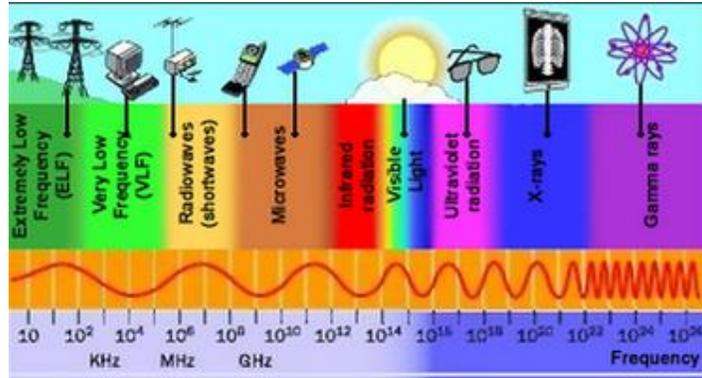
- d) Photosynthesis plays a critical role in producing and maintaining the oxygen content of the Earth's atmosphere, and it supplies most of the biological energy necessary for complex life on Earth. Some organisms also perform *anoxygenic* photosynthesis, which does not produce oxygen.
- e) While the details may differ between species, the photosynthesis process always begins when light (photon) energy is absorbed by the reaction centers, proteins that contain photosynthetic pigments or chromophores.
 - In plants, these pigments are chlorophylls (a porphyrin derivative that absorbs the red and blue spectra of light, thus reflecting green why we human's see plants as green) held inside chloroplasts, abundant in leaf cells.
 - In cyanobacteria, these pigments are embedded in the plasma membrane. In these light-dependent reactions, some energy is used to strip electrons from suitable substances, such as water, producing oxygen gas. The hydrogen freed by the splitting of water is used in the creation of two important molecules that participate in energetic processes: reduced nicotinamide adenine dinucleotide phosphate (NADPH) and adenosine triphosphate (ATP).
- f) In plants, algae, and cyanobacteria, sugars are synthesized by a subsequent sequence of light-independent reactions called the Calvin cycle. In this process, atmospheric carbon dioxide is incorporated into already existing organic compounds, such as ribulose biphosphate (RuBP). Using the ATP and NADPH produced by the light-dependent reactions, the resulting compounds are then reduced and removed to form further carbohydrates, such as glucose.
- g) Thus, photosynthesis occurs in two stages. In the first stage, *light-dependent reactions* or *light reactions* capture the energy of light and use it to make the *hydrogen carrier NADPH* and the *energy-storage molecule ATP*. During the second stage, *light-independent reactions* use these products to capture and reduce carbon dioxide.

RADIATION

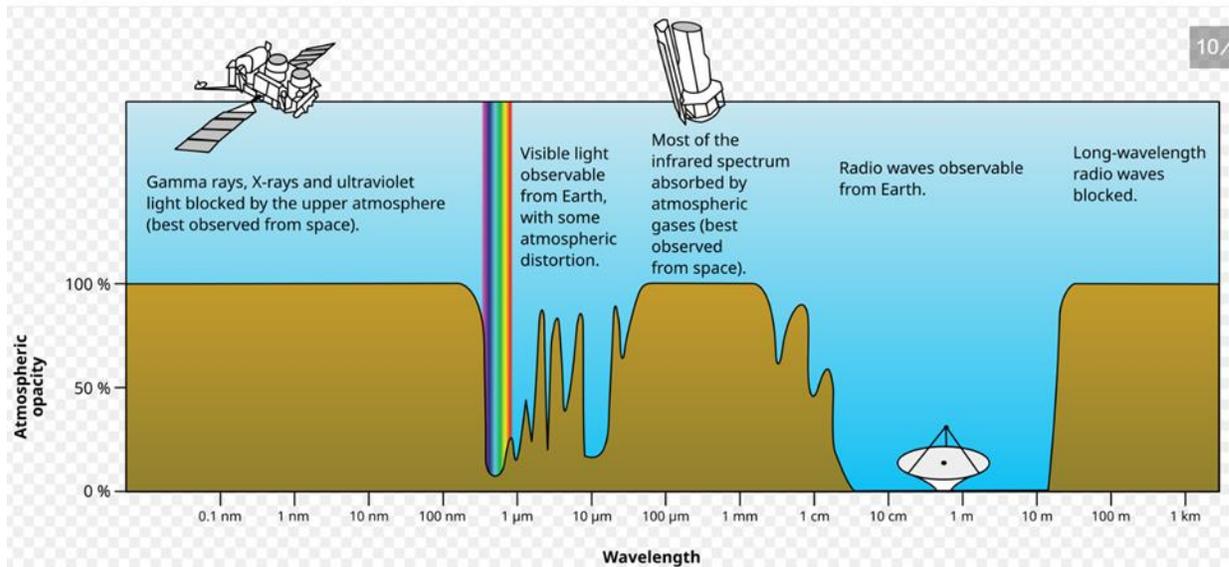
- **Radiation** - Energy in the form of electromagnetic radiation particles and waves (dual properties) moving through space or matter. Familiar radiations are heat, light, radio waves, microwaves, x-rays and ultraviolet (sunburn rays).

Wave radiation energy is a spectrum of wavelengths and frequencies. Human's normally refer to sunshine *light*, which is actually only visible light (radiation) energy (what we human's see with our eyes, a special camera sensitive to only certain wavelengths of light), but human visible electromagnetic light energy is just a small portion of the energy radiation spectrum

that is detected by the human eye. There is much other radiation energy (shorter or longer wavelengths of energy radiation other than visible light) not ‘seen’ by the human eye. Illustration of the electromagnetic spectrum follows:



Earth’s atmosphere naturally absorbs some of the sun’s energy radiation.



STARCHES

- **Starches** are complex polysaccharide carbohydrates that give human bodies vitamins and minerals (micronutrients). It takes human bodies longer to break down complex carbohydrates to glucose to use as an energy resource. As a result, blood sugar levels remain stable, and fullness lasts longer when starches are eaten (thank you Mr. Potatoe Head).

WAVELENGTH

- **Wavelength (see photosynthesis for diagrams)** – Distance covered by one complete cycle of an electromagnetic wave. In other words, the distance from one peak to another peak or from trough to trough in one wave. The longer the wavelength of the radiation, the lower its energy. (Frequency of radiation is its number of up and down wave cycles per second. One full cycle is measured by the wavelength. If a wavelength is long, the number of cycles per second is longer or stretched out and the frequency is longer – takes more time to travel one wavelength. The inverse of frequency is seconds per cycle, which is the *period* of the wave and measures the amount of time for a wave to travel one complete cycle. (short period, ex. 0.01 second per cycle, indicate fast frequencies; short period, ex. 3 second per cycle, slow frequency, long period).