The Whole Life Chemistry imbibed in The Human Body

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Every time we swallow a bite of sandwich or slurp a smoothie our body works hard to process the nutrients we have eaten. Long after the dishes are cleared and the food is digested, the nutrients we have taken in become the building blocks and fuel needed by our body. Our body gets the energy it needs from food through a process called metabolism.

What Is Metabolism?

Metabolism is a collection of chemical reactions that takes place in the body's cells. Metabolism converts the fuel in the food we eat into the energy needed to power everything we do, from moving to thinking to growing.

Specific proteins in the body control the chemical reactions of metabolism, and each chemical reaction is coordinated with other body functions. In fact, thousands of metabolic reactions happen at the same time — all regulated by the body — to keep our cells healthy and working.

Metabolism is a constant process that begins when we're conceived and ends when we die. It is a vital process for all life forms — not just humans. If metabolism stops, living things die.

The process of metabolism in humans begins from plants as follows:

- First, a green plant takes in energy from sunlight. The plant uses this energy and a molecule called chlorophyll (which gives plants their green colour) to build sugars from water and carbon dioxide by the process called photosynthesis.
- When people and animals eat the plants (or, if they're carnivores, they eat animals that have eaten the plants), they take in this energy (in the form of sugar), along with other vital cell-building chemicals. Then, the body breaks the sugar down so that the energy released can be distributed to, and used as fuel by, the body's cells.
- After food is eaten, molecules in the digestive system called enzymes break proteins down into amino acids, fats into fatty acids, and carbohydrates into simple sugars (e.g., glucose). Like sugar, amino acids and fatty acids can be used as energy sources by the body when needed.
- These compounds are absorbed into the blood, which carries them to the cells. In the cells, other enzymes act to speed up or regulate the chemical reactions involved with "metabolizing" the compounds. The energy from these compounds can be released for use by the body or stored in body tissues, especially the liver, muscles, and body fat.

Metabolism - A Balancing Act

The process of metabolism is really a balancing act involving two kinds of activities that go on at the same time — the building up of body tissues and energy stores and the breaking down of body tissues and energy stores to generate more fuel for body functions:

Anabolismor constructive metabolism is all about building and storing. It supports the growth of new cells, the maintenance of body tissues, and the storage of energy for use in the future. During anabolism, small molecules are changed into larger, more complex molecules of carbohydrate, protein, and fat.

Anabolic reactions use up energy. They are endergonic. In an anabolic reaction small molecules join to make larger ones. For example, the following condensation reactions that occur in cells are anabolic:

Amino acids join together to make dipeptides:

e.g. $NH_2CHRCOOH + NH_2CHRCOOH \rightarrow NH_2CHRCONHCHRCOOH + H_2O$

and the process continues as large protein molecules are built up.

Small sugar molecules join together to make dissacharides:

e.g. $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$

and the process continues as large polysaccharide molecules are built up.

Glycerol reacts with fatty acids to make lipids:

e.g. $CH_2OHCH(OH)CH_2OH + C_{17}H_{35}COOH \rightarrow CH_2OHCH(OH)CH_2OOCC_{17}H_{35}$

and the process continues as the trigyleride is produced via similar reactions with the other two hydroxyl groups of the glycerol molecule.

During photosynthesis carbon dioxide and water are used to produce glucose and oxygen:

e.g. $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Catabolism or destructive metabolism is the process that produces the energy required for all activity in the cells. In this process, cells break down large molecules (mostly carbohydrates and fats) to release energy. This energy release provides fuel for anabolism, heats the body, and enables the muscles to contract and the body to move. As complex chemical units are broken down into more simple substances, the waste products released in the process of catabolism are removed from the body through the skin, kidneys, lungs, and intestines.

Catabolic reactions give out energy. They are exergonic. In a catabolic reaction large molecules are broken down into smaller ones. For example, the reverse of the condensation reactions described above, i.e. hydrolysis reactions, are catabolic.

A simple example of a catabolic reaction that occurs in cells is the decomposition of hydrogen peroxide into water and oxygen:

$2H_2O_2 \rightarrow 2H_2O + O_2$

The conversion of glucose during respiration to produce carbon dioxide and water is another common example:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

How chemical reactions occur

Chemical reactions that occur during metabolism are affected by temperature. Many animals maintain a constant temperature which results in relatively stable rates of metabolic reactions. Cold-blooded animals are particularly influenced by the temperature of their environment - they are livelier when warm. In the cold their metabolism slows dramatically, and this is why some cold-blooded animals hibernate. Surgery is sometimes carried at low temperatures to slow the patient's metabolic rate, for example, during operations on the heart or brain.

Several of the hormones of the endocrine system are involved in controlling the rate and direction of metabolism. Thyroxin, a hormone produced and released by the thyroid gland, plays a key role in determining how fast or slow the chemical reactions of metabolism proceed in a person's body.

Another gland, the pancreas secretes hormones that help determine whether the body's main metabolic activity at a particular time will be anabolic or catabolic. For example, after eating a meal, usually more anabolic activity occurs because eating increases the level of glucose — the body's most important fuel — in the blood. The pancreas senses this increased level of glucose and releases the hormone insulin which signals cells to increase their anabolic activities.

Chemical substances in the biological system:

Although amount of metallic elements is significantly smaller (representing only some 2 % of the total body mass), the life functions are much more dependent on them than the values indicate. This is due to a number of inorganic elements playing a key role in numerous biochemical processes. We can find them in molecules:

1) Metalloenzymes and enzyme cofactors (40 % of the known enzymes, especially oxidoreductases (Fe, Cu, Mn, Mo, Ni, V) and hydrolases (e.g. peptidases, phosphatases: Zn, Mg, Ca, Fe))

2) Nonenzymatic metalloproteins (e.g. haemoglobin: Fe)

3) Biominerals (bones, teeth: Ca, Si ...)

4) Vitamins and coenzymes (e.g. vitamin B_{12}: Co)

5) Nucleic acids (e.g. DNA n-$(M^+)_n$12: Co); M = Na, K)

6) Hormones (e.g. thyroid hormones – thyroxin, triiodothyronine: I)

7) Antibiotics (e.g. ionophores: valinomycin/K)

8) Chlorophyll (like a low-molecular-weight natural products: Mg)

Sodium, potassium, magnesium and calcium are important compounds of living systems (sodium being the principal extracellular and potassium the major intracellular monovalent cations). Alkaline and alkaline earth metal cations also participate in the stabilization of cell membrane, enzyme, polynucleotide (DNA, RNA) conformations via electrostatic interactions and little bit osmotic effects. Nucleic acids are polyanions and as such require counterions to neutralize partially or completely the negative charged phosphate groups, so that electrostatic repulsions do not overwhelm other stabilizing effects. This charge neutralization requirement is generally accomplished by cations; it is therefore possible to use Na^+, K^+, Mg^{2+} cations for their neutralization.

Calcium (Ca)

Calcium is a key component in the structure of biomineralized tissues of mammals, and Ca^{2+}ions also serve as a key intracellular messenger, supporting a wide range of biological processes. Examples include bone formation, muscle contraction, blood coagulation, exclusion of neurotransmitters and hormones, or being a co-factor in stabilizing proteins. Some extracellular enzymes bind one or more Ca^{2+} ions and those thus become an inseparable part of their structure. In very few of them, the Ca^{2+} ion is bound on or close to an active location, which is related to the maintenance of its catalytic activity (phospholipase A2, α-amylase, nuclease).

Magnesium (Mg)

Magnesium is a fundamental component of the human body with a healthy adult consuming on an average 500 mg daily. Considering the fact that Mg can be found in the chlorophyll molecule, leafy vegetables constitute an ideal source. The human body contains about 25 g Mg^{2+} ions, of which 65 % is stored in the bones and the remaining 35 % is widely used as a cohesive factor in the conformation of nucleic acids (RNA) or as an enzyme activator. Magnesium is also helping in stabilizing ribosome. Quite all enzymes cooperating with phosphate cofactors (e.g. ATP) require the presence of Mg^{2+} for their proper function. A deficit of Mg^{2+} ions in the organism may cause cramps.

Sodium

In the earth's crust and hydrosphere we can find sodium or Natrium (chemical symbol Na) almost everywhere. Sodium chloride (stone salt – NaCl) as well as sodium nitrate (Chilean saltpeter – $NaNO_3$) are part of soil and water. Seawater contains ~3 % NaCl. The content of Sodium in the human body is around 70-100 g and about 50 % ofit is extracellular, about 40 % in the bones and about 10 % in the intracellular fluids. Sodium is here present in a completely dissociated form as a sodium ion – Na^+. The concentration of Sodium in extracellular liquids is around 140 $mmol.l^{-1}$, in intracellular liquids around 3-10 $mmol.l^{-1}$ and in erythrocytes ~15 $mmol.l^{-1}$.

The regulation of the level of sodium cations is inherently connected to the metabolism of water. The system of renin-angiotensin-aldosterone is contributing to the regulation of natremia and by extension osmotic and volume homeostasis.

The concentration of sodium ion in the organism is strictly monitored and connected with the osmotic pressure of extracellular fluids. If the absorption of sodium from food increases, the reabsorption of water by kidneys and also excretions of sodium will increase. This is applied vice versa – with receiving a bigger amount of hypo-osmotic fluid, kidneys increased reabsorption of sodium and minimizing the absorption of water. Management of free water provides antidiuretic hormone (ADH, vasopressin), which is released by the hypothalamus neurosecretory cells. Natremia is maintained within the physiological range by aldosteronesynthesized by cells of the adrenal cortex. Increased production of aldosterone is mediated by the action of angiotensin, which itself shows a vasoconstrictive effect.

The main function of sodium (with potassium and chlorides) is to maintain a constant osmotic pressure inside / outside of cells and acid-base balance in organism. Sodium with chloride and bicarbonate anions creates base electrolyte, where all cells vital signs take place. Sodium e.g. affects the amount of fluid or maintains the resting membrane potential. Sodium cation is pumped by Na^+/K^+-ATPase (i.e. Sodium-potassium pump) – sodium is pumped out of the cell, and into the cell is conversely blown potassium. Continuous exchange of ions against their concentration gradients is very energetically demanding – energy need is supplied by ATP.

Potassium (K)

Potassium or kalium with a chemical symbol K as sodium could be found in rocks, minerals and in dissolved forms in water.

Potassium is in the organism the main intracellular monovalent cation, unlike its predecessor sodium, 98 % of total amounts in body content are stored intracellular and only 2 % are located extracellular. From the total amounts of the intracellular fluid is 86 % localized in muscle cells, ~6 % in liver and red blood cells. The intracellular fluid contains potassium. Bound potassium ion is part of intracellular phosphates and proteins. The ratio of potassium bound/free depends on the pH of the environment. During catabolic processes it leads to the release of potassium ions and its amounts in the plasma increases. In the processes that lead to anabolism, by contrast, potassium ions are bonded and their content in the blood plasma decreases.

Potassium ions activate some enzymes – e.g. enzymes of glycolysis or respiratory chain. Potassium cations influence the activity of muscles (especially heart), involved in the utilization of carbohydrates, protein synthesis, during the formation of glycogen and maintain the stability of intracellular fluid.

Cobalt (Co)

Cobalt is an essential element and only a little over 1 mg Co is present in an adult human, with the largest amounts being in liver, skeletal muscles, bone, hair, adipose tissue and blood. As essential part of vitamin B_{12}, is important during creation of red blood cells.

Zinc (Zn)

An adult has about 1.5-3.0 g zinc with the largest amounts being in liver and bone with the smallest amounts in muscles. There is evidence that Zn concentrations in blood and several tissues vary considerably in response to many stimuli. Zinc appears to be critical in many functions; especially there are a number of enzymes (about 300) which, at their activity required the presence of zinc (such as alcohol dehydrogenase, carbonic anhydrase, or lactate dehydrogenase). However, it participates in many enzymatic functions – it has antioxidant properties, as part of the transcription factors involved in the synthesis of DNA (important in cell proliferation, tissues regeneration and wound healing) or is applied in the metabolism of carbohydrates. In the fact zinc is forming complexes with insulin molecule.

Molybdenum (Mo)

The trace element molybdenum is essential for nearly all organisms and forms the catalytic centre of a large variety of enzymes (metalloenzymes) such as xanthine oxidases (an important role in the metabolism of purines), aldehyde oxidase and sulphite oxidase.

Xanthine oxidase is an enzyme belongs to the family of oxidoreductases, which with the help of a co-factor FAD and iron-molybdenum complex, catalyzes the following chemical reaction:

Xanthine + H_2O + O_2 → urate + H_2O_2

Molybdenum plays an important role in the metabolism of purines – in the final phase of conversion xanthine to uric acid. Furthermore, molybdenum applied in the release of iron from ferritin in the intestinal mucosa and in mediating the release of iron from ferritin from liver and in erythropoietic tissue or placenta. Molybdenum-flavin enzymes are also involved in the respiratory chain.

Aldehyde oxidase is a complex molybdo-flavoprotein that belongs to a family of structurally related molybdenum-containing enzymes (its cofactor is flavohemoprotein and molybdenum), oxidoreductases and catalyzes the following chemical reaction:

Aldehyde + H_2O + O_2 → carboxylic acid + H_2O_2

Sulphite oxidase is a molybdo-heme enzyme that is important in sulfur metabolism catalyzing a final step in oxidation in sulphur molecule in right amino acid (cysteine) on inorganic sulphate, respectively catalyzes the oxidation of sulphite to sulphate.

Beside role of enzyme cofactor, molybdenum together with fluorine increase strength of bones and teeth and contribute to prevention of tooth decay.

Manganese (Mn)

Normal adult human has about 10-20 mg Mn, highest concentrations are found in liver, pancreas and kidney. The main function of manganese is to facilitate the deposition of calcium and phosphorus in bones, which is designed to prevent e.g. against osteoporosis. It applies even in the synthesis of thyroid hormone or sexual hormone.

Chromium (Cr)

Normal adult human has about 6 mg chromium. There are exits two chromium forms- trivalent and hexavalent. Trivalent Cr shows positive biological effects in the upper gastrointestinal tract, but only in very small amounts (hexavalent Cr is better absorbed, but only trivalent Cr is biologically active as an essential element). Hexavalent chromium is toxic for human body and his exposition can play role in pathogenesis of development tumour and skin disease. Role of trivalent chromium consist of metabolism of saccharides, when some studies indicates his positive influence to insulin function. On the other hand different studies didn't confirmed this influence, so chromium is not commonly used in clinical practice.

Copper (Cu)

The average-weight human body contains about 100-110 mg of copper, highest content is located in liver cells, central nervous system, kidneys and heart. The essentiality of Cu is the consequence of its role in metalloenzymes involving several critical biochemical pathways. Several of these enzymes are noted under: Superoxide dismutase, which metabolize the potentially damaging superoxide anion. Lysyl oxidase is a monoamine oxidase required for cross-linking collagen and elastin, the structural macromolecules of connective tissue.Dopamine β-hydroxylase, amine oxidase and tyrosinase are all Cu containing enzymes that interconvert the major neurotransmitters dopamine, noradrenaline and adrenaline, probable accounting for the high concentration of Cu in the brain. The latter enzyme, tyrosinase, is also a key step in pigment production. Ferroxidase (better known as ceruloplasmin before its role in mobilizing and oxidizing Fe from storage sites was recognized) is believed to account for 95 % of serum Cu, and appears to be a multifunctional protein serving as a major transport system for Cu as well. Copper is widely distributed by liver to the others tissues and the its excretion from the body.

Iron (Fe)

The average-weight human body contains approximately 4-5 g of iron. From this amount, about 60-70 % is present in haemoglobin in red blood cells, 15 % is bound to the iron storage protein ferritin, ~3-5 % is localized in muscle myoglobin, approximately 0.2 % occurs as a component of enzymes in respiratory chain and 0.004 % is bound to the serum transport protein transferrin. Iron allows transport of oxygen in the blood, is essential for many enzymes and is involved in production of energy. It's important for a number of vital functions: supports the growth, reproduction, wound healing and immune system. The complete absorption of iron requires copper, manganese and vitamin C.

Chemistry of Nutrients:

Saccharides:

Saccharides are not essential for humans and are commonly synthesized from various molecules like amino acids or glycerol.

The main role of monosaccharide and disaccharides is in being the main source of energyfor cells (as an energy source, they are inevitable for erythrocytes and neural cell). Polysaccharides (like glycogen in animals) function as an energy reservoir. Saccharides have important structural function as well – they are part of glycoproteins and glycolipidslocated in membranes, they are inevitable for nucleic acids and coenzyme synthesis and they form an important part of extracellular matter (for example by being a part of proteoglycans).

Monosaccharides and disaccharides:

In general they are white, crystalline substances soluble in water, neutral in nature (they do not dissociate in water solutions). They have polar character and the OH- groups are responsible for their sweet taste and strong hydration in solutions.

The most important saccharides found in diet are glucose, fructose and galactose. Concerning disaccharides, the most important ones are sucrose (α-Glc (1→2) β-Fru) used as a sweetener (table sugar), lactose (β-Gal (1→4) β-Glc) found in milk and maltose (α-Glc (1→4) β-Glc) found in malt.

The most important derivatives of monosaccharides include:

a) Sugar alcohols

Sugar alcohols are formed through the reduction of carbonyl functional group into thehydroxyl group. For example glucitol (also called sorbitol) is formed by reduction ofglucose or fructose.

b) Polyhydroxy derivatives of carboxylic acids

They are created by oxidation of monosaccharides. When reacting with a weak oxidising agent, only the aldehydic group is oxidised and aldonic acids are produced. Stronger oxidising agents oxidise not only the aldehydic, but the primary hydroxy group at the end of the molecule as well. The resulting dicarboxylic acids are called aldaric acids. The oxidation of only the primary hydroxyl group of aldoses is possible as well. The reaction is in human body catalysed by enzymes and uronic acids are formed. For example glucose is oxidised to form a glucuronic acid, an important conjugating agent, that helps to excrete in water poorly soluble substances.

c) Deoxy sugars

Deoxy sugars are created by a reduction of the hydroxyl group of the saccharides. The most important deoxy sugar is deoxyribose, an important part of nucleic acids.

d) Amino sugars

These are formed by the substitution of hydroxy group for NH_2-group. Important amino sugar is D-glucosamine, constituent of the molecules found in extracellular matter.

e) Esters

Esters are formed by esterification, a reaction between hydroxyl group and H_3PO_4 (for example glucose-6-phosphate, derivative of glucose) or H_2SO_4 (part of the proteoglycans).

f) Glycosides

They can be formed by reaction between the OH- group and:

1. Alcohol (O-glycosidic bond): an example is a creation of disaccharides or polysaccharides or a bond between monosaccharides and proteins through Ser and Thr amino acids.

2. Amine (N-glycosidic bond): an example is a bond between the monosaccharide and protein through Asp or binding of ribose in nucleotides.

Substances that bind to the monosaccharides by the mean of the glycosidic bond, but themselves are not saccharides are called aglycones.

The most reactive group in the molecule of monosaccharide is the anomeric hydroxylgroup. When a glycosidic bond between anomeric OH- groups of two monosaccharides is created, the resulting disaccharide is non-reducing (it does not react with oxidising agent). In the case of a reaction between the anomeric hydroxyl group of one monosaccharide and other hydroxyl group of the second one, the disaccharide produced is reducing. Free aldoses (monosaccharides) are all reducing, examples of reducing disaccharides are lactose and maltose.

2) Polysaccharides and fibre

Polysaccharides are amorphous substances, either not soluble in water or creating colloidmixtures. They are termed glycanes and they can be made of one kind of monosaccharide only (for example glucose in the case of starch and glycogen) and we call the glucans, fructans, etc. or are made of different kinds of monosaccharides and their derivatives (for example glycosaminoglycanes).

The storage polysaccharides, like starch or glycogen, are partially soluble in water, whereas the structural polysaccharides, like cellulose, that have lots of intra- or intermolecular hydrogen bonds, are insoluble in water.

The **fibre** is a term for a relatively heterogeneous group of structural polysaccharides that the human enzymes are not able to cleave. Therefore it forms a non-absorbable, but nevertheless an important part of our diet. It increases the chyme volume and thus speeding up the intestinal peristalsis (decreasing the time toxic substances are in contact with the intestinal epithelium). Fiber also binds different exogenous and endogenous substancesand facilitates their elimination. Important examples are bile acids, that are formed from cholesterol and so their elimination aids its reduction in the body. The fiber can be divided into:

a) Soluble fiber (hemicellulose, pectines) is a portion of a fiber that can be cleaved bybacteria in a large intestine. The resulting short-chain fatty acids (acetic, propionic, butyric acid) are important energy source for colonocytes.

b) Non-soluble (cellulose): that even bacteria cannot cleave and so leaves the body undigested. Its importance lies in increasing the volume of the chyme and in supporting the peristaltic movements.

3) Heteroglycosides

Apart from molecules made purely of saccharides, there exist substances consisting of saccharides and other compounds (aglycones). These are called heteroglycosides and examples include:

a) Proteoglycans contain long linear polysaccharide chains (that make up most of the molecule) bind to the protein. The chains consist of repeating amino-sugar and uronic acid dimers that are called glycosaminoglycanes.

b) Glycoproteins are proteins that have various parts of the molecule glycosylated (through O- or N- glycosidic bond) by short-branched molecules of oligosaccharides. Unlike proteoglycans, they do not contain uronic acids.

c) Glycolipids are substances of lipid nature, that have one or several monosaccharide units attached to their molecule.

Lipids:

Lipids are a group of chemically and structurally heterogeneous substances that share some characteristics. They are hydrophobic (and so poorly soluble in water and very well soluble in nonpolar solvents), their molecules contain alcohols and fatty acids and their biosynthesis usually starts with acetyl-CoA.

By term fatty acids we usually understand higher monocarboxylic acids (having 8 and more C atoms), that typically have odd number of carbon atoms. If they contain double bonds, they are usually isolated and in cis-configuration. Most of the fatty acids have 16 and 18 C atoms.

Human body can desaturate the molecule of fatty acid only up to the 9^{th} carbon atom. If the double bond occurs further in the molecule, the body is not able to synthesise and such FA must be obtained from a diet (and so is essential for human body).

The main essential FA is linoleic acid (18:2, with cis double bonds at 9 and 12 positions – that is why it is termed as ω-6) that can be found mainly in vegetable oils (like sunflower oil). Linoleic acid is used in biosynthesis of arachidonic acid (20:4; ω-6), that is an important precursor molecule of many important biologically active substances (for example prostaglandins, prostacyclins, leukotrienes and thromboxanes). Through their action is linoleic acid responsible for pro-inflammatory effects and increases the level of certain plasmatic lipids. α-linolenic acid (18:3, with cis double bonds at positions 9, 12 and 15 – termed as ω-3) can be mainly found in sea fish and other marine animals. Unlike the linoleic acid it reduces the plasmatic levels of cholesterol and TAG and so decreases the risk of cardiovascular diseases. It has anti-inflammatory effects as well.

Importance for human body

Lipids are the most reduced and so energetically richest nutrient. That is why they are important energy source for human body. However, there are tissues (like nerve tissue) that are unable to use them extensively in their metabolism. Due to their hydrophobic properties, they do not bind water (that would increase their weight) and so are the most effective energy storage molecules. In men, fat forms around 15

% of total body weight, in women the percentage is higher, around 20-25 %. This means, that an average man's body has around 10.5 kg of TAG, that is able to produce around 400 000 kJ of energy when oxidised.

Apart from having a function in energy metabolism, lipids have an important structuralfunction as they are a part of all cell membranes. Structural and mechanical function consists in providing a thermal insulation (for example subcutaneous fat or fat around organs) and an electrical insulation as well (for example myelin sheaths of neurons).

Lipids are solvents for many non-polar substances (like fat-soluble vitamins) and are startingcompounds for biosynthesis of many important substances (eicosanoids, steroid hormones, bile acids etc.)

Isoprenoids

Apart from lipids, our body contains another group of non-polar substances that are base on the molecule of isoprene and contain two or more such molecules in their structure. Isoprenoids can be divided into:

a) **Terpenoids** that have whole number of isoprene units.

b) **Steroids**, derivatives of triterpenoids (containing six isoprene units). The most important representative of steroids is cholesterol, a constituent of cell membranes and precursor molecule for other substances (bile acids, steroid hormones).

Proteins:

Proteins are macromolecular organic substances made of a chain of amino acids (AA) bound together through a peptide bond. Through simple covalent bond it binds amino group of one amino acid and carboxyl group of the other amino acid. A long chain of amino acids is formed through polycondensation, ended at one end with free amino group (N-terminus) and at the other end with free carboxyl group (C-terminus).

Peptides differ from proteins in having a shorter AA chain (less than 100 AAs) and their molecular weight is usually lower than 10 000.

The importance of proteins in human body is enormous. The perform various functions: structural (collagen, elastin ...), motoric (actin, myosin...), informational (protein hormones), protective (immunoglobulin's, complement, antigens,), transport (albumin), catalytic (enzymes) and other. At the same time they provide the only source of organically bound nitrogen.

The role of organs in the energy metabolism:

Liver:

Liver cells (hepatocytes) have a unique role in the intermediate metabolism. They play a vital role in providing homeostasis, synthesis of various molecules, intermediate metabolism and regulation of storage and release of energy. Liver takes part in metabolism of all nutrients.

1) Liver and the metabolism of saccharides

Liver plays an important role in short-term (within hours) and long-term (in the range of days to weeks) glycemic regulation (so-called glucostatic function of liver). When the level of glucose in *vena portae* rises after the meal, liver starts the process of glycogen synthesis, which uses the glucose from the blood. The opposite process takes place during fasting, when the blood glucose level drops. The glucose is added to the bloodstream through the glycogenolysis (the breakdown of the stored glycogen) or gluconeogenesis (when the glycogen stores are depleted). The degradation of fructose and galactose also takes place in liver.

2) Liver and the metabolism of lipids

Some pathways of lipid metabolism are unique to the liver (like ketone bodies synthesis), but most take place in other tissues as well (though liver is often quantitatively the most important organ). Oxidation of fatty acids takes place here and speeds up during fasting to the point where more energy is produced than the liver needs. From the excessive acetyl-CoA the ketone bodies are synthesised. Liver cannot utilities the ketone bodies and releases them into the bloodstream, where they serve as an alternative energy source.

Liver also plays a crucial role in the metabolism of lipoproteins. It synthesises VLDL particles, some HDL, convert IDL to LDL and degrades chylomicron remnants, HDL and portion of LDL.
The synthesis of cholesterol takes place here as well.

3) Liver and the metabolism of proteins and amino acids

Some reactions of protein and amino acid metabolism take place only in liver (ureasynthesis), while others can be performed by other tissues as well (amino acids deaminations and transaminations, synthesis of nonessential AA, ...).

Liver synthesises, with the exception of immunoglobulines, all plasmatic proteins (e.g. albumin or coagulation factors).

Kidneys:

The processes of concentrating the urine and the transport of substances that happen in kidneys require large amounts of energy. That is why the ATP consumption, especially in the renal cortex, is high. ATP is produced by oxidative metabolism of glucose, lactate, fatty acids and amino acids.

Kidneys are, after the liver, the second most important site of gluconeogenesis (mainly during fasting). Its main substrate is the carbon skeleton of amino acids (especially glutamine). Ammonia, a product of these reactions, is secreted directly into the urine, where it acts as a buffer.

Skeletal muscles:

Active skeletal muscle consumes huge amount of energy. ATP regeneration takes place through the aerobic and anaerobic glycolysis, degradation of fatty acids and from creatine phosphate as well.

Skeletal muscle plays an important role in the metabolism of amino acids – primarily branched amino acids (valine, leucine, isoleucine). The carbon skeletons obtained in this process are used to synthesise energy and the amino groups serve as a substrate for synthesis of alanine, glutamine and glutamate. These amino acids are subsequently released in relatively large quantities into the bloodstream. Liver can use the alanine produced by skeletal muscles in glucose regeneration (the alanine cycle).

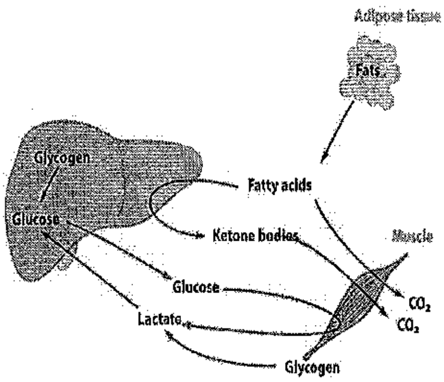
Adipose tissue:

Postprandially (after eating, when insulin has a predominant effect), the adipose tissue serves as the storage place for TAG. It stores lipids obtained from food and those synthesised in liver as well. During periods of fasting (due to the effect of glucagon) lipolysis takes place – the breakdown of lipid to fatty acids and glycerol.

Brain:

Glucose is the main energy substrate for the brain. The daily consumption is around 120 g, but during adapted fasting (which occurs approximately after 3 weeks without an adequate supply of energy), the brain can cover up to the 50 % of its energy need from the oxidation of ketone bodies.

Following figure shows the interaction of our organs during physical activity:



Metabolism is a complicated chemical process, so it's not surprising that many people think of it in its simplest sense: as something that influences how easily our bodies gain or lose weight. That's where calories come in. A calorie is a unit that measures how much energy a particular food provides to the body. A chocolate bar has more calories than an apple, so it provides the body with more energy — and sometimes that can be too much of a good thing. Just as a car stores gas in the gas tank until it is needed to fuel the engine, the body stores calories — primarily as fat. If you overfill a car's gas tank, it spills over onto the pavement. Likewise, if a person eats too many calories, they "spill over" in the form of excess fat on the body.

The number of **calories** someone burns in a day is affected by how much that person exercises, the amount of fat and muscle in his or her body, and the person's basal metabolic rate (BMR). BMR is the rate at which the body "burns" energy, in the form of calories, while at rest. BMR can play a role in a person's tendency to gain weight. For example, someone with a low BMR (who burns fewer calories while at rest or sleeping) will tend to gain more pounds of body fat over time compared with a similar-sized person with an average BMR who eats the same amount of food and gets the same amount of exercise.

To some extent, **BMR** is inherited — passed on through the genes we get from our parents. Sometimes, health problems can affect someone's BMR. But people can change their BMR in some ways. For example: by exercising more, a person burns more calories during the extra activity and becomes more physically fit, thus increasing his or her BMR. BMR is also influenced by body composition — people with more muscle and less fat generally have higher BMRs.

Things That Can Go Wrong With Metabolism

Most of the time, our metabolism works well without us giving it any thought. But sometimes a person's metabolism can cause major problem in the form of a metabolic disorder. In a broad sense, a metabolic disorder is any disease that is caused by an abnormal chemical reaction in the body's cells.

Most disorders of metabolism involve either abnormal levels of enzymes or hormones or problems with how those enzymes or hormones work. When the metabolism of body chemicals is blocked or defective, it can cause a buildup of toxic substances in the body or a lack of substances needed for normal body function, either of which can cause serious symptoms.

Metabolic diseases and conditions include:

Hyperthyroidism: Hyperthyroidism is caused by an overactive thyroid gland. The thyroid releases too much of the hormone thyroxin, so a person's BMR is high. It causes symptoms such as weight loss, increased heart rate and blood pressure, protruding eyes, and a swelling in the neck from an enlarged thyroid (goitre). The disease may be controlled with medicines or through surgery or radiation treatments.

Hypothyroidism: Hypothyroidism is caused by a non-existent or underactive thyroid gland. The thyroid releases too little thyroxin, so a person's BMR is low. Untreated hypothyroidism can lead to brain and growth problems in infants and children. Hypothyroidism slows body processes and causes tiredness, slow heart rate, weight gain, and constipation. Teens who have it can be treated with oral thyroid hormone.

Inborn errors of metabolism: Metabolic diseases that are inherited are called inborn errors of metabolism. When babies are born, they're tested for many of these. Inborn errors of metabolism include galactosemia (babies born with this do not have enough of the enzyme that breaks down the sugar in milk, called galactose) and phenylketonuria (this is due to a defect in the enzyme that breaks down the amino acid phenylalanine, needed for normal growth and protein production). Inborn errors of metabolism can sometimes lead to serious problems if they're not controlled with diet or medicine from an early age.

Type 1 diabetes: Type 1 diabeteshappens when the pancreas doesn't make and secrete enough insulin. Symptoms of this disease include excessive thirst and peeing, hunger, and weight loss. Over time, the disease can cause kidney problems, pain due to nerve damage, blindness, and heart and blood vessel disease. Teens with type 1 diabetes need regular insulin injections and should control their blood sugar levels to reduce the risk of developing problems from diabetes.

Type 2 diabetes: Type 2 diabetes happens when the body can't respond normally to insulin. Symptoms are similar to those of type 1 diabetes. Many children and teens who develop type 2 diabetes are overweight, and this is thought to play a role in their decreased responsiveness to insulin. Some teens can be treated successfully with dietary changes, exercise, and oral medicine; others will need insulin injections. Controlling blood sugar levels reduces the risk of developing the same kinds of long-term health problems that happen with type 1 diabetes.

How Junk Food Wrecks Your Body

Junk food refers to highly processed foods that are generally high in calories, refined carbs and unhealthy fats. They're also low in filling nutrients like protein and fiber.

Some examples include French fries, potato chips, sugary drinks and most pizzas.

Junk food is widely available, cheap and convenient. Also, it's often heavily marketed, especially to children, and promoted with misleading health claims.

While it is tasty, it is usually not very filling and is easy to overeat.

Interestingly, junk food may also affect your brain in a very powerful way, especially when consumed often and in excessive amounts.

It may trigger a massive release of dopamine, a neurotransmitter that helps control your brain's reward and pleasure centre.

When your brain is flooded with dopamine in such unnatural amounts, it can cause food addiction in some people.

Junk food does no good to our body. It can only harm us internally and daily consumption of

junk food eventually makes the brain weak and non-functional. The side effects of eating junk food are so strong that one can't come out of its clutches easily. Therefore it is necessary to keep a check on the consumption of junk food.

Though junk food is a treat to the taste buds, yet they have immense side effects. The junk food is so addictive that it usually asks our body and brain to consume more. Over the period of time, the increased knowledge about different cuisines and junk food has eventually resulted in increased cases of obesity, heart-related problems, diabetes, memory loss etc. According to the studies done by the researchers, consumption of junk food in excess has eventually trapped the lives and well being of children. The more we consume the junk, the less we start taking in nutrients and essential vitamins. Regular consumption of junk food also slows down the process of brain functioning.

Side effects of eating junk food:

- **Worsen appetite controlling power:** Consumption of excess junk food puts brain in dilemma. The brain receives mixed signals that make it difficult for the brain to know, whether the body needs food or not. It might eventually lead to overeating. In order to ensure the proper functioning of the brain, the body requires omega 3 and omega 6 daily. However, any deficiency of the same eventually leads in making the brain weak. It even makes it difficult for the body to digest the food.
- **Leads to depression:** Junk food is high in fats and thus increases the calorie intake as well. We must consider the fact that the functioning of the brain depends on the food we intake. It eventually leads the body and brain fall into the trap of depression and despair. Thus, it becomes incapable for the body to deal with any kind of stress. Losing the right quantity of amino acid from the body also makes the body fall into depression.

  A lot of studies have shown that eating foods high in sugar and fat actually changes the chemical activity of the brain making it more dependent on such foods. A study conducted at the University of Montreal on mice showed that they suffered with withdrawal symptoms after their regular junk food diet was discontinued. In humans, these withdrawal symptoms can lead to the inability to deal with stress, make you feel depressed and eventually you would turn back to those foods to comfort yourself and handle these feelings. Soon, you may be caught in a vicious cycle even before you know it. Also, by consuming too much fast food you may lose out on essential nutrients like amino acid tryptophan, the lack of which can increase feelings of depression. An imbalance of fatty acids is another reason why people who consume more junk food are at a higher risk of depression.
- **Boosts cravings:** Consumption of junk food leads to increase the level of blood sugar. It may give temporary satiation but sooner turns you irritable. Very low level of sugar is also not good and leads to anxiety issues and confusion. However, high level of sugar leads to more cravings and more irritation.

  Eating a sugary cupcake or doughnut may temporarily spike your blood sugar levels making you feel happy and satisfied but as soon as they return to normal you are left feeling all the more irritable.

  Fast food is packed with refined carbohydrates which cause your blood sugar levels to fluctuate rapidly. If your sugar levels dip to a very low level, it can cause anxiety, confusion and fatigue. With high content of sugar and fats, you tend to eat too fast and too much to satisfy your cravings. This can inculcate an impatient behaviour while dealing with other things. Fast foods and processed foods may be laden with artificial flavourings and preservatives like sodium benzoate that tends to increase hyperactivity.

  Fast foods are specially designed to be addictive in nature with high levels of salts, sugars and fats that make you crave them. The addictive nature of fast food can make your brain crave them even when you are not hungry.
- **Leads to loss of memory:** Eating only junk food and craving for more, leads you to lose your memory gradually. There is a sudden inflammation of the brain especially in the (hippocampus part of the brain). There goes a chemical reaction inside the brain which leads to loss of memory. High sugar diet suppresses the functions of the brain known as Brain Derived Neutrophic Factor. It is actually responsible for concentration and memory.

  A study published in the American Journal of Clinical Nutrition in 2011 showed that healthy people who ate junk food for only 5 days performed poorly on cognitive tests that measured attention, speed, and mood. It concluded that eating junk food for just five days regularly can deteriorate your memory. This probably stems from the fact that a poor or toxic diet can cause certain chemical reactions that lead to inflammation in the hippocampus area of the brain which is associated with memory and special recognition.

Diets that are high in sugar and fat can suppress the activity of a brain peptide called BDNF (brain-derived neurotrophic factor) that helps with learning and memory formation. Moreover, the brain contains synapses which are responsible for learning and memory. Eating too many calories can interfere with the healthy production and functioning of these synapses.

- **Digestive system is hampered**
  Two main diseases known as gastroesophageal reflux disease (GERD) and irritable bowel syndrome (IBS) take place due to fatty junk food. Since it is deep fried, the oil gets stuck at the walls of the stomach lining.
  The spices included in them also lead to irritation and inflammation in the body. There is lack of fiber which leads to constipation. Trying different yoga poses can deteriorate the issues.
- Metabolizingfood requiresenergy, which is referred to as the thermic effect of food. Processed junk food requiresless energy from your body to digest because it's high in refined ingredients.
- **Increase in the risk of heart diseases**
  Fast food is known to be loaded with fats that lead to plaque formation. Junk food can damage the linings of the blood vessels and also the levels of cholesterol increase in the body.
  The blood vessels are blocked which means there is less blood supply to the heart. There are chances of heart attack arising. Fats accumulate around and so it is advised you stick to a healthy routine.
- **Kidney stones occur**
  The processed salt present in fast food items can look tempting but they lead to harmful effects on the body. The enzymes in it are known to upgrade your cravings. High levels of fats and sodium can lead to hypertension. Kidneys filter the toxins and to see them function better, learn to say no to junk food.
  Kidney stone is very common problem and there are many cause of kidney stone..fast food is one of them..If you are suffering from this problem then you can apply some home remedies for kidney stone and get rid of it.
- **Damage to your liver**
  Eating junk food every single day is known to have adverse effects on the liver. Just like alcohol, excessive consumption of fast food means your liver is deteriorating in its functioning. People who don't exercise and only rely on oily food items will notice a change in their lifestyle. The high level of trans fat get deposited in the liver leading to many other issues. Change your diet plans and notice yourself be more active.
- **Reproductive system**
  The ingredients can also have an impact on fertility. The chemicals present in these oily items can interrupt the development of hormones in the body. When there is exposure to these chemicals, there are immense effects that take place in the reproductive system.
- **Risk of cancer**
  Lack of fibre is also the reason why junk food can be fatal. Increased levels of fat in the body can lead to colorectal cancer. A research also showcased that men who relied on fried food items developed prostate cancer. Hence, it is advised you attain a healthy habit of exercising and eating green vegetables instead.
- **Risk of dementia**

This has been one of the scariest discoveries associated with the consumption of junk food. You may know that insulin is produced in the pancreas and helps in the transportation of glucose to fuel the body. Insulin is also produced in the brain where it helps in carrying signals between nerve cells and forming memories. A study conducted at the Brown University shows that too much fatty food and sweets can substantially increase the insulin levels in our body.

Just like in the case of Type 2 Diabetes, with higher levels of insulin, the brain stops responding to this hormone and become resistant to it. This can restrict our ability to think, recall or create memories, thus increasing the risk of dementia. Researcher Suzanne de la Monte, M.D., a professor of pathology, neurology, and neurosurgery at Rhode Island Hospital and the Alpert Medical School of Brown

University was the first to uncover this association. Following this discovery, most scientists refer to Alzheimer's as a form of diabetes of the brain.

- **Insulin Resistance**

  Insulin resistance is when your body's cells stop responding to the hormone insulin.This can lead to higher blood sugar levels.

  Insulin resistance is a major risk factor for metabolic syndrome, type 2 diabetes and other serious diseases .The consumption of processed foods has been associated with an increased risk of insulin resistance.

  A small study in 12 healthy men reported changes in the ability of skeletal muscle to process glucose after only five days on a diet rich in fatty processed foods).

  The researchers concluded that a diet comprised of high-fat junk foods may lead to insulin resistance in the long term.

  Furthermore, the results of a 15-year study indicate that your risk of developing insulin resistance may double when you visit a fast food restaurant more than twice per week, compared to less frequently.

  This implies that eating junk food on a regular basis may promote insulin resistance.

Sugar-Sweetened Beverages may slow down your metabolism

Of all the junk foods out there, sugary drinks may very well be the worst for your body.

When consumed in excess, they may contribute to all sorts of health problems, including obesity, heart disease, metabolic syndrome and type 2 diabetes.

These issues are mainly attributed to their high levels of fructose, a simple sugar primarily metabolized by the liver.

When you consume a lot of fructose, the liver may become overloaded and turn some of it into fat.

Sugar-based sweeteners like table sugar (sucrose) and high-fructose corn syrup are around 50% fructose and commonly found in sugary drinks.

When consumed in large amounts in the form of added sugars, fructose may alter fullness signals, impair the response of the "hunger hormone" ghrelin after meals and promote fat storage around the belly.

Additionally, it may slow down your metabolism.

In one study, overweight and obese people consumed drinks that were sweetened with fructose and provided 25% of their daily calorie intakes. During a 10-week period, they experienced a significant drop in resting energy expenditure.

This suggests that the fructose in sugary drinks may decrease the number of calories you burn, at least when consumed in excess.

It's Not Only About the Calories

Decreasing your calorie intake is important if you want to lose weight.

However, the calorie content of your food isn't the only thing that matters.

The quality of the foods you eat is just as important.

For example, eating 100 calories of French fries can have vastly different effects on your body than 100 calories of quinoa.

Most commercial French fries are high in unhealthy fats, refined carbs and salt, while quinoa is rich in protein, fiber and many vitamins.

First of all, you burn more calories metabolizing whole foods than junk foods. Also, you burn more calories by consuming high-protein foods, compared to foods high in unhealthy fats and refined carbs.

Moreover, high-protein foods may reduce your appetite, curb your cravings and impact hormones that regulate your weight.

Therefore, calories from whole foods like quinoa are usually more satiating than calories from processed junk foods like French fries.

Before you start restricting your calorie intake to lose weight, consider making better food choices and choosing more nutritious, high-quality foods.

The Bottom Line

It's no surprise that junk food is low in healthy nutrients and high in ingredients like sugar and salt. But new animal research suggests that a diet high in junk food might harm the kidneys in a similar way to type-2 diabetes.

Junk food does more to your insides than simply add fat around the middle; it can also disrupt hormones, change a person's sense of taste and even raise the risk for mental health problems. A 2015 study published in the journal *Mayo Clinic Proceedings* found that a calorie from sugar is much more dangerous to the body than a calorie from other carbohydrates, like starch. Added sugars were linked to poor insulin levels and blood sugar, as well as harmful fat storage around the belly, which promotes problems like inflammation and high blood pressure.

Another studypublished in the *American Journal of Clinical Nutrition* looked at questionnaires from around 70,000 women and found that diets higher in added sugar and refined grains, like white bread, were associated with a higher risk for depression a few years later. Sugar had an especially strong link, and healthier foods, like fiber, fruits and vegetables appeared to have a protective effect. The study only found a correlation, but overeating sugars and refined starches can increase inflammation and risk for heart disease, both of which have been linked to depression, the study authors said. Eating junk food can increase the risk for insulin resistance, which has been associated with cognitive problems also found among people with depression.

Eating junk food can also change the way our bodies react to certain foods; a small April 2015 study found that just five days of eating processed food was enough to dramatically alter a healthy person's metabolism. A diet high in processed food can also expose people to chemicals they may not know they're eating. People who ate at least 35% of their total calories from fast food in the past 24 hours had up to 40% higher levels of phthalates—chemicals that have been linked to issues like hormone disruption and lower sperm count.

Taken together, the latest research shows that food affects the body in myriad ways and bolsters the case to cut back on processed foods. **"Junk is not food, and food is not junk,"** says Katz. **"Junk should not be a food group."**

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