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BIOCHEMISTRY OF HUMAN BODY IN RESEMBLANCE TO ENGINEERING

***[1]Sandip Sarkar, [1]Arunava Chandra Chandra, [1]Dr. Dhrubo Jyoti Sen, [2]Dr. Dhananjoy Saha and [3]Dr. Sampa Dhabal**

[1]Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector–V, EM–4, Kolkata–700091, West Bengal, India.
[2]Deputy Director of Technical Education, Directorate of Technical Education, Bikash Bhavan, Salt Lake City, Kolkata–700091, West Bengal, India.
[3]Forensic Scientist, Kolkata, West Bengal, India.

Corresponding Author: Sandip Sarkar
Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector–V, EM–4, Kolkata–700091, West Bengal, India.

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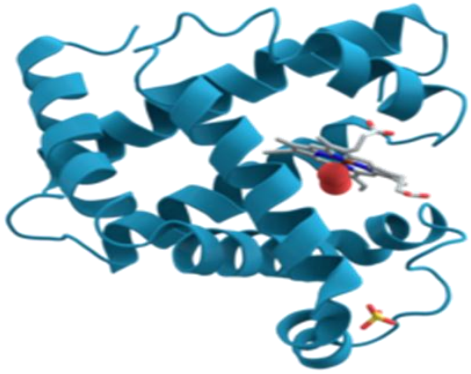
ABSTRACT

Biochemistry, sometimes called biological chemistry, is the study of chemical processes within and relating to living organisms. Biochemical processes give rise to the complexity of life. For instance, in every living cell, there is a crucial biological process, called respiration. This process is the conversion of glucose into a useful form of energy, which is ATP (adenosine triphosphate). The study of biochemistry uncovers the numerous chemical processes involved in converting glucose into carbon dioxide and water. A sub–discipline of both biology and chemistry, biochemistry can be divided into three fields: structural biology, enzymology and metabolism. Over the last decades of the 20th century, biochemistry has become successful at explaining living processes through these three disciplines. Almost all areas of the life sciences are being uncovered and developed by biochemical methodology and research. Biochemistry focuses on understanding the chemical basis which allows biological molecules to give rise to the processes that occur within living cells and between cells, which in turn relates greatly to the study and understanding of tissues and organs, as well as organism structure and function.

KEYWORDS: Glycolysis, Protein, Respiration, Aerobic, Biomolecules.

INTRODUCTION

Biochemistry is closely related to molecular biology, the study of the molecular mechanisms of biological phenomena. Much of biochemistry deals with the structures, functions, and interactions of biological macromolecules, such as proteins, nucleic acids, carbohydrates, and lipids, which provide the structure of cells and perform many of the functions associated with life. The chemistry of the cell also depends on the reactions of smaller molecules and ions. These can be inorganic (for example, water and metal ions) or organic (for example, the amino acids, which are used to synthesize proteins). The mechanisms by which cells harness energy from their environment via chemical reactions are known as metabolism. The findings of biochemistry are applied primarily in medicine, nutrition and agriculture. In medicine, biochemists investigate the causes and cures of diseases. In nutrition, they study how to maintain health and wellness and study the effects of nutritional deficiencies. In agriculture, biochemists investigate soil and fertilizers. They also try to discover ways to improve crop cultivation, crop storage, and pest control.[1]



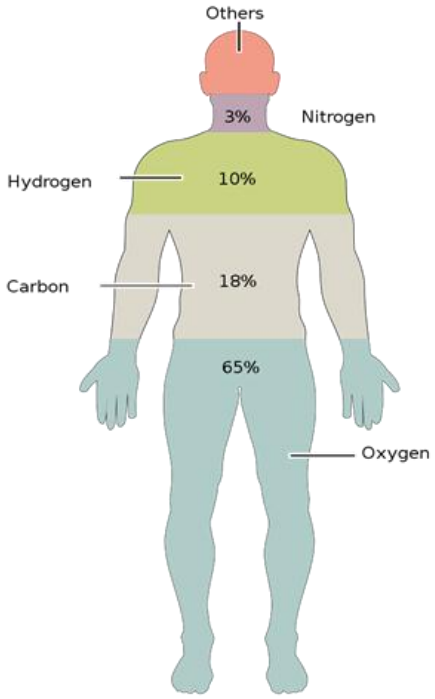
Figure–1: Key Components: – Biomolecules.

Starting materials: the chemical elements of life: Around two dozen chemical elements are essential to various kinds of biological life. Most rare elements on Earth are not needed by life (exceptions being selenium and iodine), while a few common ones (aluminum and titanium) are not used. Most organisms share element needs, but there are a few differences between plants and animals. For example, ocean algae use bromine, but land plants and animals seem to need none. All animals

require sodium, but some plants do not. Plants need boron and silicon, but animals may not (or may need ultra–small amounts).

Just six elements—carbon, hydrogen, nitrogen, oxygen, calcium and phosphorus—make up almost 99% of the mass of living cells, including those in the human body. In addition to the six major elements that compose most of the human body, humans require smaller amounts of possibly 18 more.

Biomolecules: The four main classes of molecules in biochemistry (often called biomolecules) are carbohydrates, lipids, proteins, and nucleic acids. Many biological molecules are polymers: in this terminology, monomers are relatively small macromolecules that are linked together to create large macromolecules known as polymers. When monomers are linked together to synthesize a biological polymer, they undergo a process called dehydration synthesis. Different macromolecules can assemble in larger complexes, often needed for biological activity.[2]



Figure–2: Human Body Components.

Carbohydrates: Two of the main functions of carbohydrates are energy storage and providing structure. One of the common sugars known as glucose is carbohydrate, but not all carbohydrates are sugars. There are more carbohydrates on Earth than any other known type of biomolecule; they are used to store energy and genetic information, as well as play important roles in cell to cell interactions and communications.

The simplest type of carbohydrate is a monosaccharide, which among other properties contains carbon, hydrogen, and oxygen, mostly in a ratio of 1:2:1 (generalized formula $C_nH_{2n}O_n$, where n is at least 3). Glucose ($C_6H_{12}O_6$) is one of the most important carbohydrates; others include fructose ($C_6H_{12}O_6$), the sugar commonly associated with the sweet taste of fruits, and deoxyribose ($C_5H_{10}O_4$), a component of DNA. A monosaccharide can switch between acyclic (open–chain) form and a cyclic form. The open–chain form can be turned into a ring of carbon atoms bridged by an oxygen atom created from the carbonyl group of one end and the hydroxyl group of another. The cyclic molecule has a hemiacetal or hemiketal group, depending on whether the linear form was an aldose or a ketose.

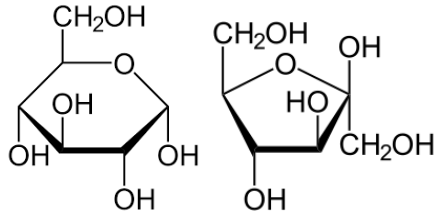
In these cyclic forms, the ring usually has 5 or 6 atoms. These forms are called furanoses and pyranoses, respectively—by analogy with furan and pyran, the simplest compounds with the same carbon–oxygen ring (although they lack the carbon–carbon double bonds of these two molecules). For example, the aldohexose glucose may form a hemiacetal linkage between the hydroxyl on carbon 1 and the oxygen on carbon 4, yielding a molecule with a 5–membered ring, called glucofuranose. The same reaction can take place between carbons 1 and 5 to form a molecule with a 6–membered ring, called glucopyranose. Cyclic forms with a 7–atom ring called heptoses are rare.

Two monosaccharides can be joined together by a glycosidic or ether bond into a disaccharide through a dehydration reaction during which a molecule of water is released. The reverse reaction in which the glycosidic bond of a disaccharide is broken into two monosaccharides is termed hydrolysis. The best–known disaccharide is sucrose or ordinary sugar, which consists of a glucose molecule and a fructose molecule joined together. Another important disaccharide is lactose found in milk, consisting of a glucose molecule and a galactose molecule. Lactose may be hydrolyzed by lactase, and deficiency in this enzyme results in lactose intolerance.[3]

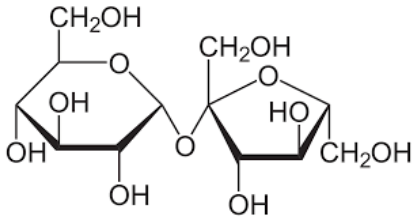
When a few (around three to six) monosaccharides are joined, it is called an oligosaccharide (oligo– meaning "few"). These molecules tend to be used as markers and signals, as well as having some other uses. Many monosaccharides joined together form a polysaccharide. They can be joined together in one long linear chain, or they may be branched. Two of the most common polysaccharides are cellulose and glycogen, both consisting of repeating glucose monomers. Cellulose is an important structural component of plant's cell walls and glycogen is used as a form of energy storage in animals.[4]

Sugar can be characterized by having reducing or non–reducing ends. A reducing end of a carbohydrate is a carbon atom that can be in equilibrium with the open–chain aldehyde (aldose) or keto form (ketose). If the joining of monomers takes place at such a carbon atom, the free hydroxy group of the pyranose or furanose form

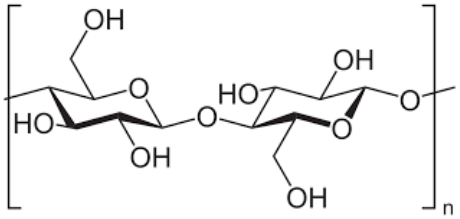
is exchanged with an OH–side–chain of another sugar, yielding a full acetal. This prevents opening of the chain to the aldehyde or keto form and renders the modified residue non–reducing. Lactose contains a reducing end at its glucose moiety, whereas the galactose moiety forms a full acetal with the C4–OH group of glucose. Saccharose does not have a reducing end because of full acetal formation between the **aldehyde carbon of glucose (C1) and the keto carbon of fructose (C2).**



Figure–3: Glucose & Fructose, a monosaccharide.



Figure–4: A molecule of sucrose (glucose + fructose), a disaccharide.

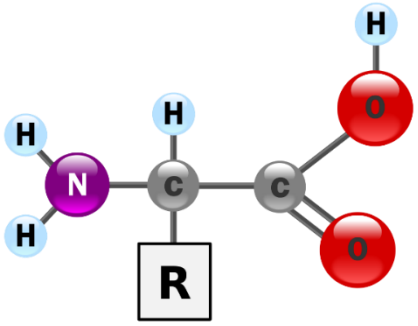


Figure–5: Cellulose, a polysaccharide made up of several thousand glucose units.

Proteins: Proteins are very large molecules—macro–biopolymers—made from monomers called amino acids. An amino acid consists of an alpha carbon atom attached to an amino group, $–NH_2$, a carboxylic acid group, –COOH (although these exist as $–NH^{3+}$ and $–COO^-$ under physiologic conditions as zwitterion), a simple hydrogen atom, and a side chain commonly denoted as "–R". The side chain "R" is different for each amino acid of which there are 20 standard ones. It is this "R" group that made each amino acid different, and the properties of the side–chains greatly influence the overall three–dimensional conformation of a protein. Some amino acids have functions by themselves or in a modified form; for instance, glutamate functions as an important neurotransmitter. Amino acids can be joined via a peptide bond. In this dehydration synthesis, a water molecule is removed and the peptide bond connects the nitrogen of one amino acid amino group to the carbon of the other's carboxylic acid group. The resulting molecule is called a dipeptide, and short stretches of amino acids (usually, fewer than thirty) are called peptides or polypeptides. Longer stretches merit the title proteins. As an example, the important blood serum protein albumin contains 585 amino acid residues.[5]

Generic amino acids (1) in neutral form, (2) as they exist physiologically, and (3) joined together as a dipeptide.

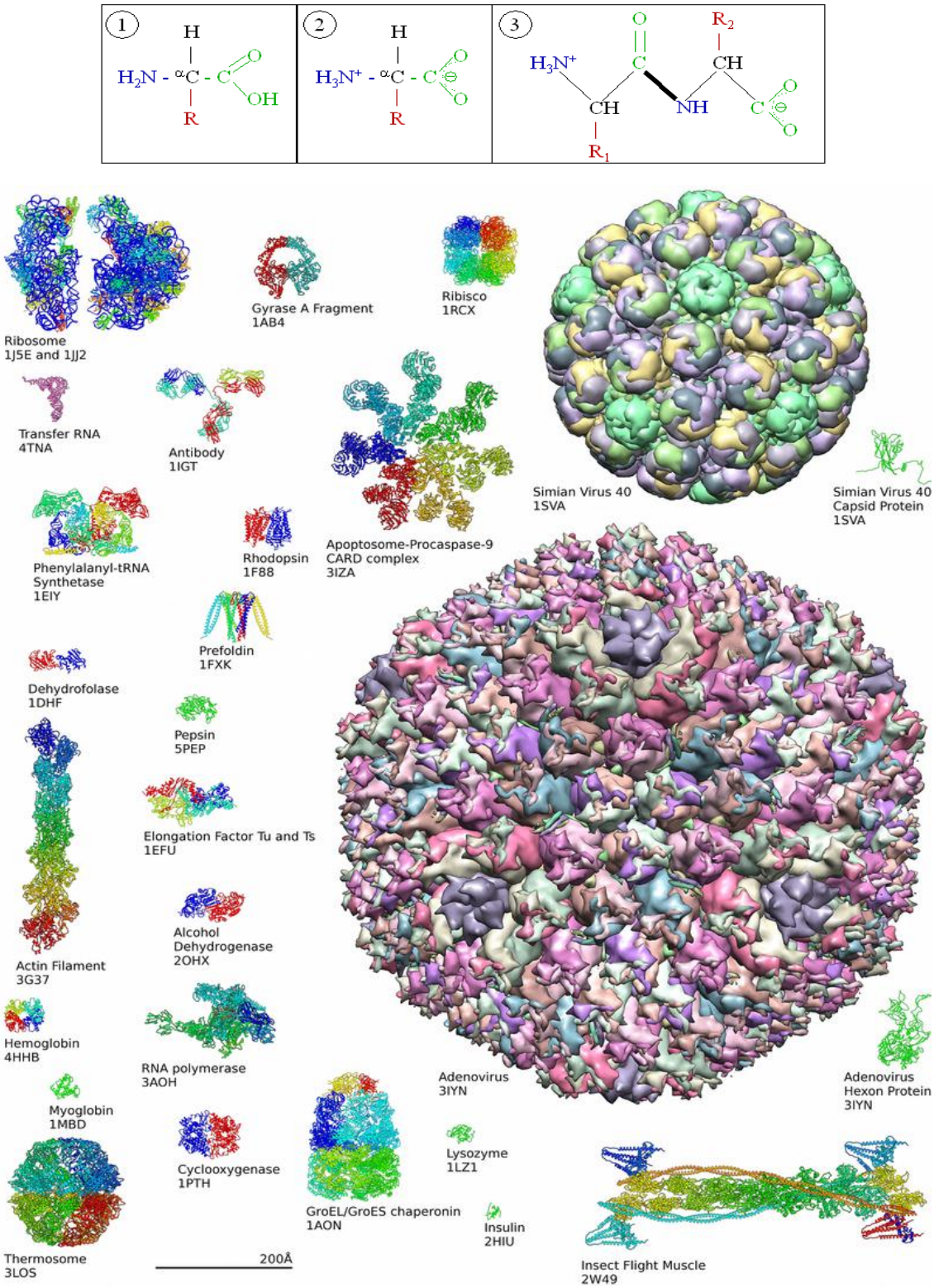
Proteins can have structural and/or functional roles. For instance, movements of the proteins actin and myosin ultimately are responsible for the contraction of skeletal muscle. One property many proteins have is that they specifically bind to a certain molecule or class of molecules—they may be extremely selective in what they bind. Antibodies are an example of proteins that attach to one specific type of molecule. Antibodies are composed of heavy and light chains. Two heavy chains would be linked to two light chains through disulfide linkages between their amino acids. Antibodies are specific through variation based on differences in the N–terminal domain.[6] The enzyme–linked immunosorbent assay (ELISA), which uses antibodies, is one of the most sensitive tests modern medicine uses to detect various biomolecules. Probably the most important proteins, however, are the enzymes. Virtually every reaction in a living cell requires an enzyme to lower the activation energy of the reaction. These molecules recognize specific reactant molecules called substrates; they then catalyze the reaction between them. By lowering the activation energy, the enzyme speeds up that reaction by a rate of 1011 or more; a reaction that would normally take over 3,000 years to complete spontaneously might take less than a second with an enzyme. The enzyme itself is not used up in the process and is free to catalyze the same reaction with a new set of substrates. Using various modifiers, the activity of the enzyme can be regulated, enabling control of the biochemistry of the cell as a whole.[7]



Figure–6: The general structure of an α–amino acid, with the amino group on the left and the carboxyl group on the right.

The structure of proteins is traditionally described in a hierarchy of four levels. The primary structure of a protein consists of its linear sequence of amino acids; for instance, "alanine–glycine–tryptophan–serine–glutamate–asparagine–glycine–lysine–…". Secondary structure is concerned with local morphology (morphology being the study of structure). Some

combinations of amino acids will tend to curl up in a coil called an α–helix or into a sheet called a β–sheet; some α–helixes can be seen in the hemoglobin schematic above. Tertiary structure is the entire three–dimensional shape of the protein. This shape is determined by the sequence of amino acids. In fact, a single change can change the entire structure. The alpha chain of hemoglobin contains 146 amino acid residues; substitution of the glutamate residue at position 6 with a valine residue changes the behavior of hemoglobin so much that it results in sickle–cell disease. Finally, quaternary structure is concerned with the structure of a protein with multiple peptide subunits, like hemoglobin with its four subunits. Not all proteins have more than one subunit.[8]



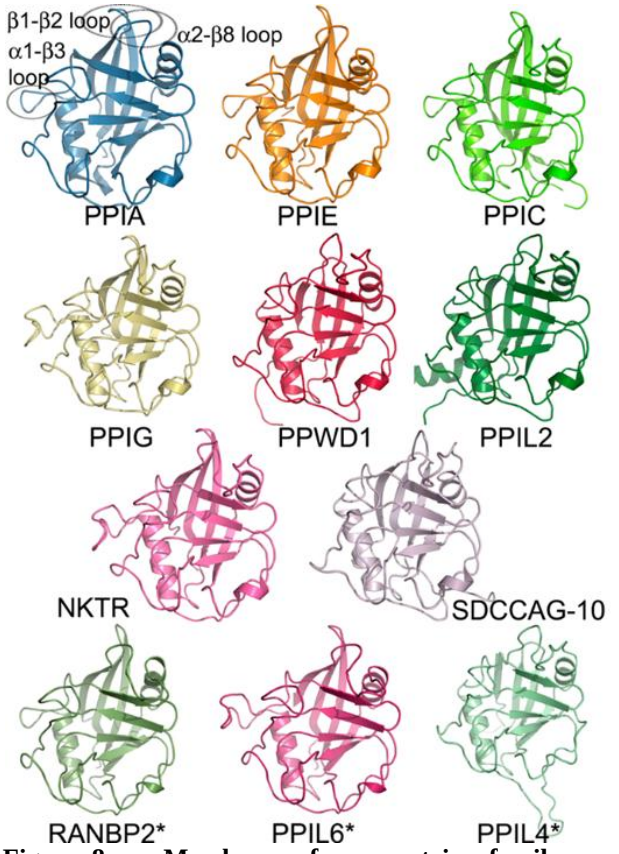
Figure–7: Examples of protein structures.

Ingested proteins are usually broken up into single amino acids or dipeptides in the small intestine and then absorbed. They can then be joined to form new proteins. Intermediate products of glycolysis, the citric acid cycle, and the pentose phosphate pathway can be used to form all twenty amino acids, and most bacteria and plants possess all the necessary enzymes to synthesize them. Humans and other mammals, however, can synthesize only half of them. They cannot synthesize isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Because they must be ingested, these are the essential amino acids. Mammals do possess the enzymes to synthesize alanine, asparagine, aspartate, cysteine, glutamate, glutamine, glycine, proline, serine, and tyrosine, the nonessential amino acids. While they can synthesize arginine and histidine, they cannot produce it in sufficient amounts for young, growing animals, and so these are often considered essential amino acids.

If the amino group is removed from an amino acid, it leaves behind a carbon skeleton called an α–keto acid. Enzymes called transaminases can easily transfer the amino group from one amino acid (making it an α–keto acid) to another α–keto acid (making it an amino acid). This is important in the biosynthesis of amino acids, as for many of the pathways, intermediates from other biochemical pathways are converted to the α–keto acid skeleton, and then an amino group is added, often via transamination. The amino acids may then be linked together to form a protein.[9]

A similar process is used to break down proteins. It is first hydrolyzed into its component amino acids. Free ammonia (NH_3), existing as the ammonium ion (NH^{4+}) in blood, is toxic to life forms. A suitable method for excreting it must therefore exist. Different tactics have evolved in different animals, depending on the animals' needs. Unicellular organisms simply release the ammonia into the environment. Likewise, bony fish can release the ammonia into the water where it is quickly diluted. In general, mammals convert the ammonia into urea, via the urea cycle.[10]

In order to determine whether two proteins are related, or in other words to decide whether they are homologous or not, scientists use sequence–comparison methods. Methods like sequence alignments and structural alignments are powerful tools that help scientists identify homologies between related molecules. The relevance of finding homologies among proteins goes beyond forming an evolutionary pattern of protein families. By finding how similar two protein sequences are, we acquire knowledge about their structure and therefore their function.



Figure–8: Members of a protein family, as represented by the structures of the isomerase domains.

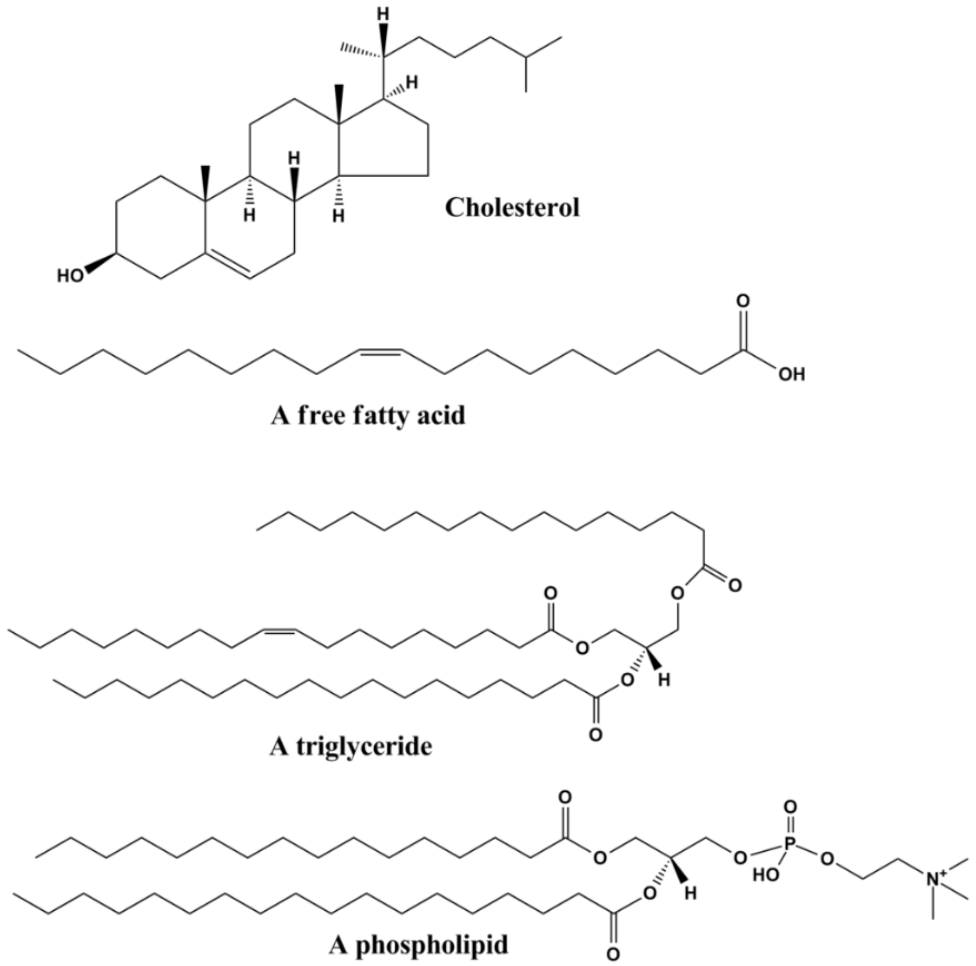
Lipids: Lipids comprise a diverse range of molecules and to some extent is a catchall for relatively water–insoluble or nonpolar compounds of biological origin, including waxes, fatty acids, fatty–acid derived phospholipids, sphingolipids, glycolipids, and terpenoids (e.g., retinoids and steroids). Some lipids are linear, open–chain aliphatic molecules, while others have ring structures. Some are aromatic (with a cyclic [ring] and planar [flat] structure) while others are not. Some are flexible, while others are rigid.[11]

Lipids are usually made from one molecule of glycerol combined with other molecules. In triglycerides, the main group of bulk lipids, there is one molecule of glycerol and three fatty acids. Fatty acids are considered the monomer in that case, and may be saturated (no double bonds in the carbon chain) or unsaturated (one or more double bonds in the carbon chain).

Most lipids have some polar character in addition to being largely nonpolar. In general, the bulk of their structure is nonpolar or hydrophobic ("water–fearing"), meaning that it does not interact well with polar solvents like water. Another part of their structure is polar or hydrophilic ("water–loving") and will tend to associate with polar solvents like water. This makes them amphiphilic molecules (having both hydrophobic and hydrophilic portions). In the case of cholesterol, the polar group is a mere –OH (hydroxyl or alcohol). In the case

of phospholipids, the polar groups are considerably larger and more polar, as described below.

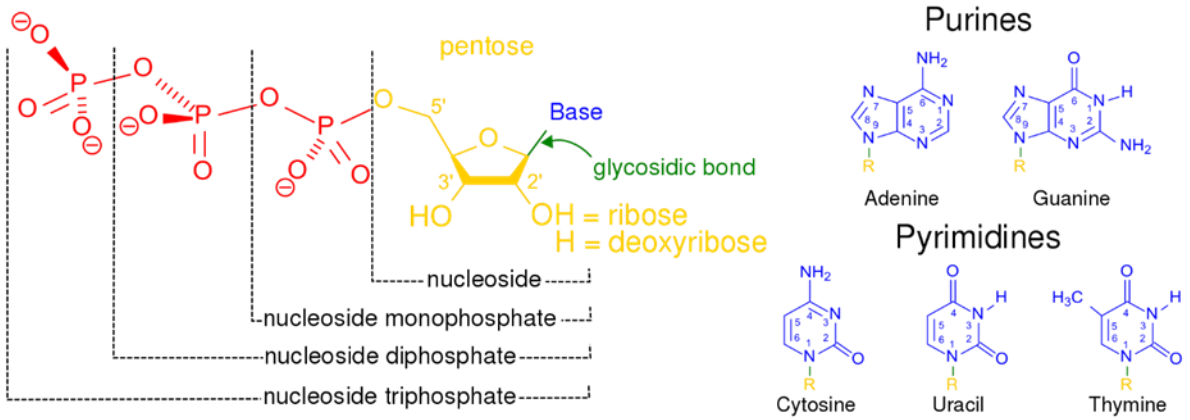
Lipids are an integral part of our daily diet. Most oils and milk products that we use for cooking and eating like butter, cheese, ghee etc., are composed of fats. Vegetable oils are rich in various polyunsaturated fatty acids (PUFA). Lipid–containing foods undergo digestion within the body and are broken into fatty acids and glycerol, which are the final degradation products of fats and lipids. Lipids, especially phospholipids, are also used in various pharmaceutical products, either as co–solubilizes (e.g., in parenteral infusions) or else as drug carrier components (e.g., in a liposome or transferosome).[12]



Figure–9: Structures of some common lipids. At the top are cholesterol and oleic acid. The middle structure is a triglyceride composed of oleoyl, stearoyl, and palmitoyl chains attached to a glycerol backbone. At the bottom is the common phospholipid, phosphatidylcholine.

Nucleic acids: Nucleic acids, so–called because of their prevalence in cellular nuclei, is the generic name of the family of biopolymers. They are complex, high–molecular–weight biochemical macromolecules that can convey genetic information in all living cells and viruses. The monomers are called nucleotides, and each consists of three components: a nitrogenous heterocyclic base (either a purine or a pyrimidine), a pentose sugar, and a phosphate group.[13]

The most common nucleic acids are deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). The phosphate group and the sugar of each nucleotide bond with each other to form the backbone of the nucleic acid, while the sequence of nitrogenous bases stores the information. The most common nitrogenous bases are adenine, cytosine, guanine, thymine, and uracil. The nitrogenous bases of each strand of a nucleic acid will form hydrogen bonds with certain other nitrogenous bases in a complementary strand of nucleic acid (similar to a zipper). Adenine binds with thymine and uracil, thymine binds only with adenine, and cytosine and guanine can bind only with one another. Aside from the genetic material of the cell, nucleic acids often play a role as second messengers, as well as forming the base molecule for adenosine triphosphate (ATP), the primary energy–carrier molecule found in all living organisms. Also, the nitrogenous bases possible in the two nucleic acids are different: adenine, cytosine, and guanine occur in both RNA and DNA, while thymine occurs only in DNA and uracil occurs in RNA.[14]



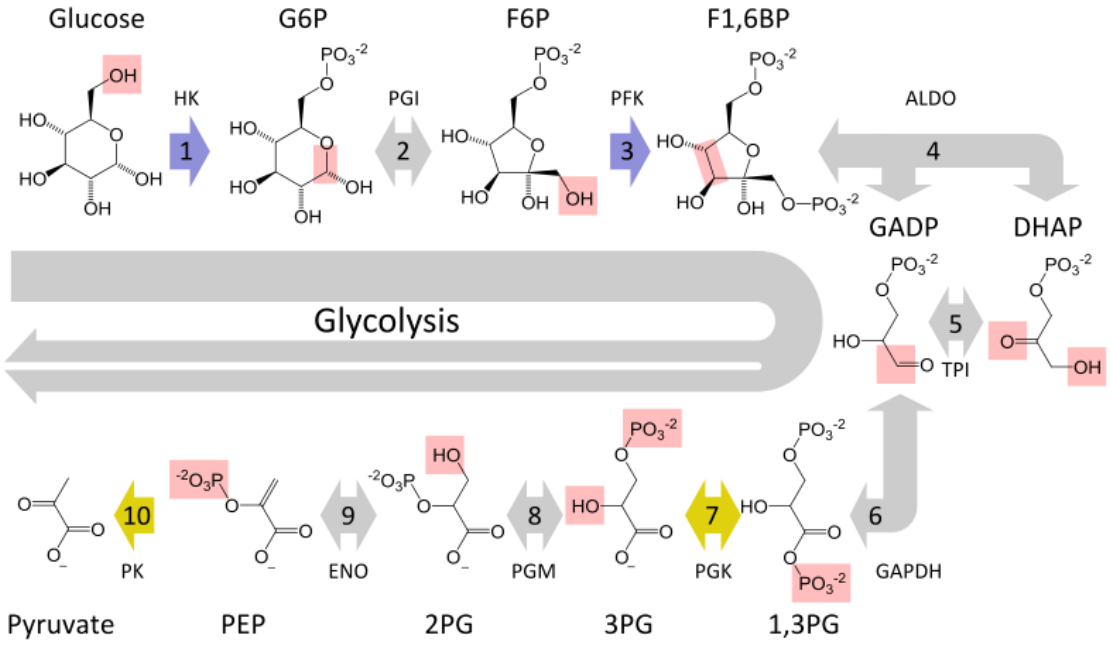
Figure–10: Structural elements of common nucleic acid constituents. Because they contain at least one phosphate group, the compounds marked nucleoside monophosphate, nucleoside diphosphate and nucleoside triphosphate are all nucleotides (not simply phosphate–lacking nucleosides).

Metabolism

Carbohydrates as energy source: Glucose is an energy source in most life forms. For instance, polysaccharides are broken down into their monomers by enzymes (glycogen phosphorylase removes glucose residues from glycogen, a polysaccharide). Disaccharides like lactose or sucrose are cleaved into their two component monosaccharides.[15]

Glycolysis (anaerobic): Glucose is mainly metabolized by a very important ten–step pathway called glycolysis, the net result of which is to break down one molecule of glucose into two molecules of pyruvate. This also produces a net two molecules of ATP, the energy currency of cells, along with two reducing equivalents of converting NAD^+ (nicotinamide adenine dinucleotide: oxidized form) to NADH (nicotinamide adenine dinucleotide: reduced form). This does not require oxygen; if no oxygen is available (or the cell cannot use oxygen), the NAD is restored by converting the pyruvate to lactate (lactic acid) (e.g., in humans) or to ethanol plus carbon dioxide (e.g., in yeast). Other monosaccharides like galactose and fructose can be converted into intermediates of the glycolytic pathway.[16]

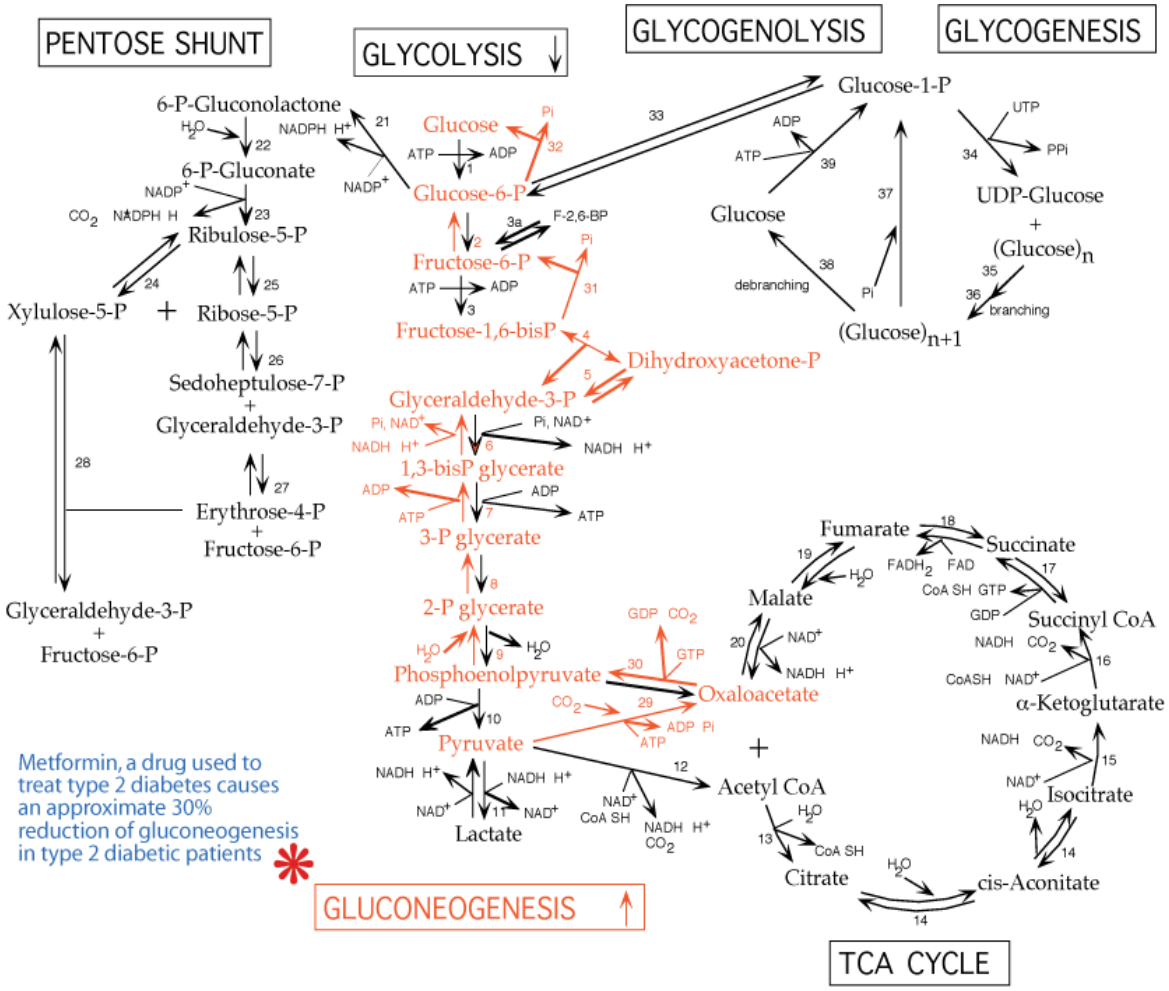
Aerobic: In aerobic cells with sufficient oxygen, as in most human cells, the pyruvate is further metabolized. It is irreversibly converted to acetyl–CoA, giving off one carbon atom as the waste product carbon dioxide, generating another reducing equivalent as NADH. The two molecules acetyl–CoA (from one molecule of glucose) then enter the citric acid cycle, producing two molecules of ATP, six more NADH molecules and two reduced (ubi)quinones (via FADH2 as enzyme–bound cofactor), and releasing the remaining carbon atoms as carbon dioxide.[17]



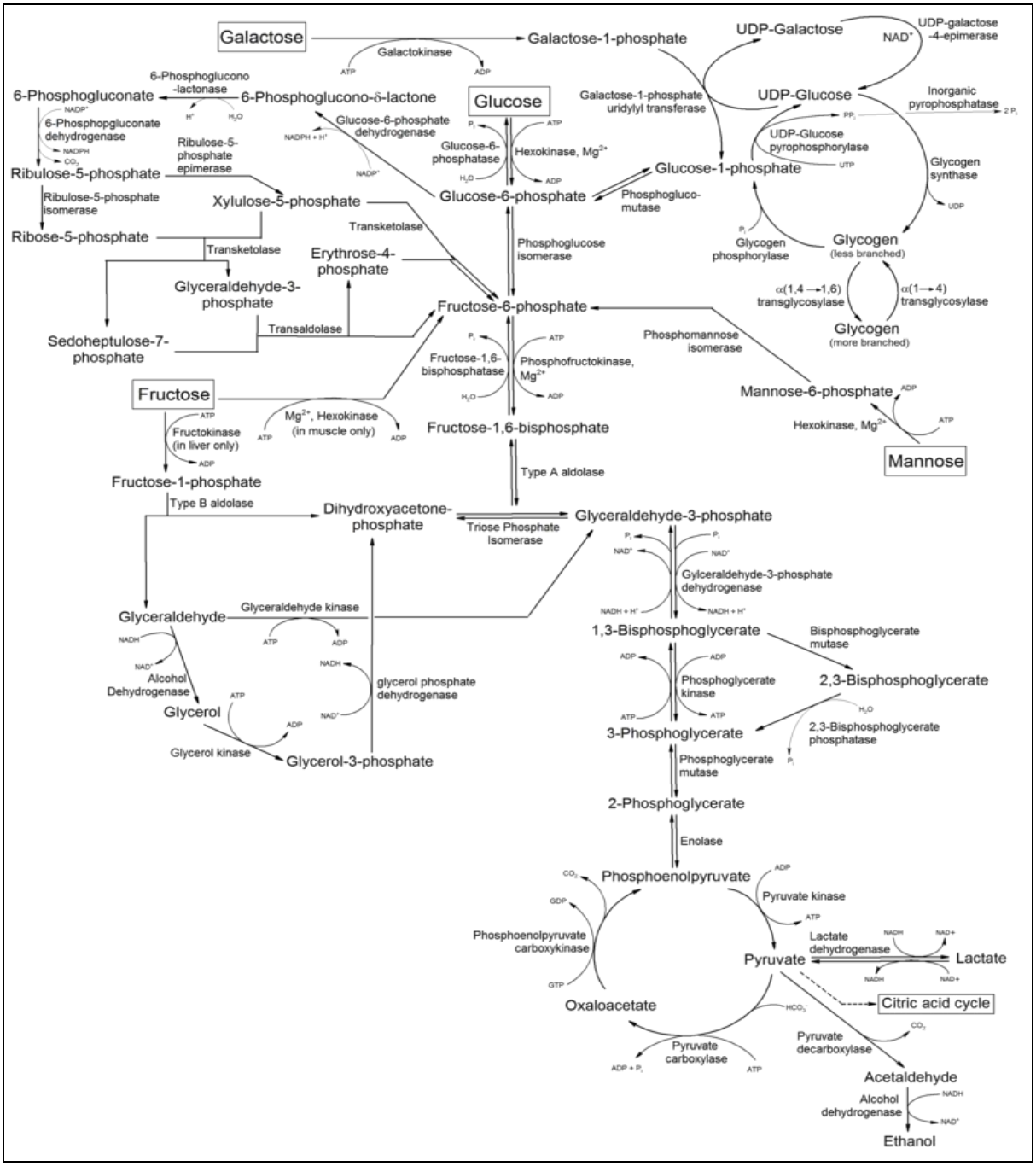
Figure–11: Glycolytic Pathway.

The produced NADH and quinol molecules then feed into the enzyme complexes of the respiratory chain, an electron transport system transferring the electrons ultimately to oxygen and conserving the released energy in the form of a proton gradient over a membrane (inner mitochondrial membrane in eukaryotes). Thus, oxygen is reduced to water and the original electron acceptors NAD+ and quinone are regenerated. This is why humans breathe in oxygen and breathe out carbon dioxide. The energy released from transferring the electrons from high–energy states in NADH and quinol is conserved first as proton gradient and converted to ATP via ATP synthase. This generates an additional 28 molecules of ATP (24 from the 8 NADH + 4 from the 2 quinols), totaling to 32 molecules of ATP conserved per degraded glucose (two from glycolysis + two from the citrate cycle). It is clear that using oxygen to completely oxidize glucose provides an organism with far more energy than any oxygen–independent metabolic feature, and this is thought to be the reason why complex life appeared only after Earth's atmosphere accumulated large amounts of oxygen.[18]

Gluconeogenesis: In vertebrates, vigorously contracting skeletal muscles (during weightlifting or sprinting, for example) do not receive enough oxygen to meet the energy demand, and so they shift to anaerobic metabolism, converting glucose to lactate. The combination of glucose from noncarbohydrates origin, such as fat and proteins. This only happens when glycogen supplies in the liver are worn out. The pathway is a crucial reversal of glycolysis from pyruvate to glucose and can utilize many sources like amino acids, glycerol and Krebs Cycle. Large scale protein and fat catabolism usually occur when those suffer from starvation or certain endocrine disorders. The liver regenerates the glucose, using a process called gluconeogenesis. This process is not quite the opposite of glycolysis, and actually requires three times the amount of energy gained from glycolysis (six molecules of ATP are used, compared to the two gained in glycolysis). Analogous to the above reactions, the glucose produced can then undergo glycolysis in tissues that need energy, be stored as glycogen (or starch in plants), or be converted to other monosaccharides or joined into di– or oligosaccharides. The combined pathways of glycolysis during exercise, lactate's crossing via the bloodstream to the liver, subsequent gluconeogenesis and release of glucose into the bloodstream is called the Cori cycle.[19]



Figure–12: Gluconeogenesis pathway with key molecules and enzymes. Many steps are the opposite of those found in the glycolysis.



Figure–13: Metabolism of common monosaccharides, including glycolysis, gluconeogenesis, glycogenesis and glycogenolysis in a glance.

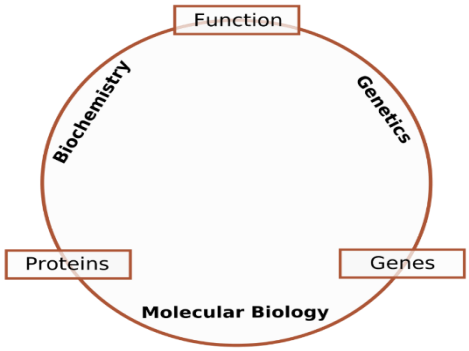
Relationship to other "molecular–scale" biological sciences: Researchers in biochemistry use specific techniques native to biochemistry, but increasingly combine these with techniques and ideas developed in the fields of genetics, molecular biology, and biophysics. There is not a defined line between these disciplines. Biochemistry studies the chemistry required for biological activity of molecules, molecular biology studies their biological activity, genetics studies their heredity, which happens to be carried by their genome. This is shown in the following schematic that depicts one possible view of the relationships between the fields:

- **Biochemistry** is the study of the chemical substances and vital processes occurring in live organisms. Biochemists focus heavily on the role, function, and structure of biomolecules. The study of the chemistry behind biological processes and the synthesis of biologically active molecules are examples of biochemistry. Biochemistry studies life at the atomic and molecular level.[20]
- **Genetics** is the study of the effect of genetic differences in organisms. This can often be inferred by the absence of a normal component (e.g. one gene). The study of "mutants" – organisms that lack one or more functional components with respect to the so–called

"wild type" or normal phenotype. Genetic interactions (epistasis) can often confound simple interpretations of such "knockout" studies.

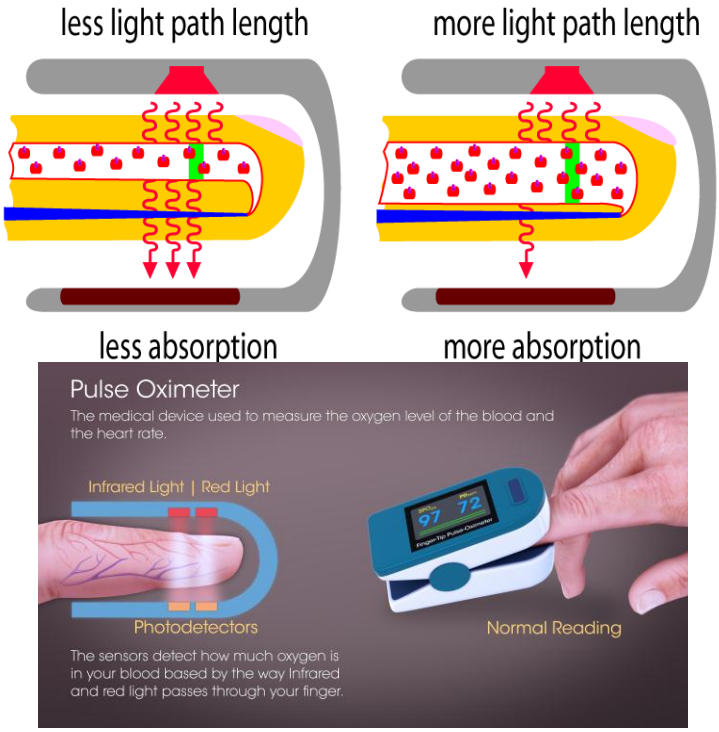
- **Molecular biology** is the study of molecular underpinnings of the processes of replication, transcription, translation, and cell function. The central dogma of molecular biology where genetic material is transcribed into RNA and then translated into protein, despite being oversimplified, still provides a good starting point for understanding the field. The picture has been revised in light of emerging novel roles for RNA. Molecular Biology studies life at the molecular and cellular level.

'Chemical biology' seeks to develop new tools based on small molecules that allow minimal perturbation of biological systems while providing detailed information about their function. Further, chemical biology employs biological systems to create non–natural hybrids between biomolecules and synthetic devices (for example emptied viral capsids that can deliver gene therapy or drug molecules).[21]



Figure–14: Cycle of Biomolecular chemistry.

Biomolecules are important for the functioning of living organisms. ... These molecules perform or trigger important biochemical reactions in living organisms. When studying biomolecules, one can understand the physiological function that regulates the proper growth and development of a human body.



Figure–15: Oxymeter.

Pulse oximetry is a non–invasive method for monitoring a person's oxygen saturation. Though its reading of peripheral oxygen saturation (SpO_2) is not always identical to the more desirable reading of arterial oxygen saturation (SaO_2) from arterial blood gas analysis, the two are correlated well enough that the safe, convenient, noninvasive, inexpensive pulse oximetry method is valuable for measuring oxygen saturation in clinical use. In its most common (transmissive) application mode, a sensor device is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. The device passes two wavelengths of light through the body part to a photodetector. It measures the changing absorbance at each of the wavelengths, allowing it to determine the absorbances due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) nail polish. Reflectance pulse oximetry is a less common alternative to transmissive pulse oximetry. This method does not require a thin section of the person's body and is therefore well suited to a universal application such as the feet, forehead, and chest, but it also has some limitations. Vasodilation and pooling of venous blood in the head due to compromised venous return to the heart

can cause a combination of arterial and venous pulsations in the forehead region and lead to spurious SpO_2 results. Such conditions occur while undergoing anesthesia with endotracheal intubation and mechanical ventilation or in patients in the Trendelenburg position.

Figure–17: VO_2max.

The basic definition of VO_2 max is the maximum amount of oxygen your body can use during exercise. VO_2 max (also maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake or maximal aerobic capacity) is the maximum rate of oxygen consumption as measured during incremental exercise, most typically on a motorized treadmill. Maximal oxygen consumption reflects the aerobic physical fitness of the individual, and is an important determinant of their endurance capacity during prolonged, sub–maximal exercise. The name is derived from V–volume, O_2 – oxygen, max – maximum. VO_2 max is expressed either as an absolute rate in (for example) liters of oxygen per minute (L/min) or as a relative rate in (for example) milliliters of oxygen per kilogram of body mass per minute (e.g., mL/(kg·min)). The latter expression is often used to compare the performance of endurance sports athletes. However, VO_2 max generally does not vary linearly with body mass, either among individuals within a species or among species, so comparisons of the performance capacities of individuals or species that differ in body size must be done with appropriate statistical procedures, such as analysis of covariance.

Conclusion: Our understanding of biochemistry has had and will continue to have extensive effects on many aspects of human endeavor. First, biochemistry is an intrinsically beautiful and fascinating body of knowledge. We now know the essence and many of the details of the most fundamental processes in biochemistry, such as how a single molecule of DNA replicates to generate two identical copies of itself and how the sequence of bases in a DNA molecule determines the sequence of amino acids in an encoded protein. Our ability to describe these processes in detailed, mechanistic terms places a firm chemical foundation under other biological sciences. Moreover, the realization that we can understand essential life processes, such as the transmission of hereditary information, as chemical structures and their reactions has significant philosophical implications. What does it mean, biochemically, to be human? What are the biochemical differences between a human being, a chimpanzee, a mouse, and a fruit fly? Are we more similar than we are different?.

Second, biochemistry is greatly influencing medicine and other fields. The molecular lesions causing sickle–cell anemia, cystic fibrosis, hemophilia, and many other genetic diseases have been elucidated at the biochemical level. Some of the molecular events that contribute to cancer development have been identified. An understanding of the underlying defects opens the door to the discovery of effective therapies. Biochemistry makes possible the rational design of new drugs, including specific inhibitors of enzymes required for the replication of viruses such as human immunodeficiency virus (HIV). Genetically engineered bacteria or other organisms can be used as "factories" to produce valuable proteins such as insulin and stimulators of blood–cell development. Biochemistry is also contributing richly to clinical diagnostics. For example, elevated levels of telltale enzymes in the blood reveal whether a patient has recently had a myocardial infarction (heart attack). DNA probes are coming into play in the precise diagnosis of inherited disorders, infectious diseases, and cancers. Agriculture, too, is benefiting from advances in biochemistry with the development of more effective, environmentally safer herbicides and pesticides and the creation of genetically engineered plants that are, for example, more resistant to insects. All of these endeavors are being accelerated by the advances in genomic sequencing.

Third, advances in biochemistry are enabling researchers to tackle some of the most exciting questions in biology and medicine. How does a fertilized egg give rise to cells as different as those in muscle, brain, and liver? How do the senses work? What are the molecular bases for mental disorders such as Alzheimer disease and schizophrenia? How does the immune system distinguish between self and no self? What are the molecular mechanisms of short–term and long–term memory? The answers to such questions, which once seemed remote,

have been partly uncovered and are likely to be more thoroughly revealed in the near future.

Because all living organisms on Earth are linked by a common origin, evolution provides a powerful organizing theme for biochemistry. This book is organized to emphasize the unifying principles revealed by evolutionary considerations. We begin in the next chapter with a brief tour along a plausible evolutionary path from the formation of some of the chemicals that we now associate with living organisms through the evolution of the processes essential for the development of complex, multicellular organisms. The remainder of Part I of the book more fully introduces the most important classes of biochemicals as well as catalysis and regulation. Part II, Transducing and Storing Energy, describes how energy from chemicals or from sunlight is converted into usable forms and how this conversion is regulated. As we will see, a small set of molecules such as adenosine triphosphate (ATP) act as energy currencies that allow energy, however captured, to be utilized in a variety of biochemical processes. This part of the text examines the important pathways for the conversion of environmental energy into molecules such as ATP and uncovers many unifying principles. Part III, Synthesizing the Molecules of Life, illustrates the use of the molecules discussed in Part II to synthesize key molecular building blocks, such as the bases of DNA and amino acids, and then shows how these precursors are assembled into DNA, RNA, and proteins. In Parts II and III, we will highlight the relation between the reactions within each pathway and between those in different pathways so as to suggest how these individual reactions may have combined early in evolutionary history to produce the necessary molecules. From the student's perspective, the existence of features common to several pathways enables material mastered in one context to be readily applied to new contexts. Part IV, Responding to Environmental Changes, explores some of the mechanisms that cells and multicellular organisms have evolved to detect and respond to changes in the environment. The topics range from general mechanisms, common to all organisms, for regulating the expression of genes to the sensory systems used by human beings and other complex organisms. In many cases, we can now see how these elaborate systems evolved from pathways that existed earlier in evolutionary history. Many of the sections in Part IV link biochemistry with other fields such as cell biology, immunology, and neuroscience. We are now ready to begin our journey into biochemistry with events that took place more than 3 billion years ago.

CONCLUSION

Chemistry originated from bio system is biochemistry which is the controlling authority to check the malfunction inside the body. Similarly, the automation of engineered technology is the admiration of toolbar of architecture design of technology transfer to mankind.

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