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# The Human Model for Chemistry Essentials of Life

**Jef Struyf***

A Retired Instructor of the Health and Technology Department, PBA Chemistry, of UCLeuven-Limburg, Belgium
*Corresponding author: jef.struyf@ucll.be

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**Abstract** Human models are presented that will evoke more interest in chemistry or help to overview a complex of reactions. The basic methodology is asking the question of human modeling in chemistry and the search for corresponding subjects. The Vigeland tetrahedral man model, its connections to carbon, and a human body resembling tetrahedron based model for biochemically relevant functional group reactions are presented. Chemical properties analog to four (human) limbs are detected for key actions in the chemistry of life. The human larynx is a model for the core of the neon electron configuration. The human body model is discussed for the chemical properties chirality, configuration and conformation, initiation, propagation and termination. Cube, human and chemical octets are presented. Human hand connections are established for the four basic biomolecules. Remarks and new viewpoints on proteinogenic amino acid fingers are presented. The genetic code and related properties that model the bones and joints structure of a human arm are further developed. The article proves that human models are possible, acceptable, convincing, desirable and interesting.

***Keywords:*** *biochemical education, biochemistry, chemical education, chemistry of life, periodic table, genetic code, genetic code structure, human models, human hands model, models in chemistry, octet, organic chemistry, functional group reactions, organic reactions overview, proteinogenic amino acids, tetrahedral model*

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## 1. Introduction

### 1.1. The Question of a Human Model

Humans are the only living beings that develop culture including science. This unique situation of humans may rise unique questions such as the one that is under investigation in this contribution and my previous article [1]. One of these questions is the modeling function of human in science. As I am a chemist, my interest lies in human models for chemistry. It is amazing that such models are not yet under investigation in chemistry. All chemistry concepts have a human connected origin and most chemists are aware of at least some of the proposed human related connections. It is instructive to collect and explore these connections more intensively, introduce new ones and publish them even if the subject is not yet exhaustively described.

### 1.2. Human Models in Education

Especially in education, human models will certainly evoke more interest and better demonstrate the glamour of chemistry. Some human models, such as the model for biochemically relevant functional group reactions, will much more clearly help in overviewing and interconnecting a rather complex subject. My previous article already establishes the human hands model for the essentials of the chemistry of life [1]. Some additional remarks on this model are added in the present article, which may help to address the questions that arise. The model needs to be confirmed by additional human properties that model chemistry essentials of life. The present article aims to provide this confirmation.

### 1.3. The Convincing Power of the Human Models

According to the human hands model, it will not be a surprise to detect chemistry correspondences to other structures of the human plan. Although the accidental nature of the described facts will be claimed, they nevertheless are in line with the modeling viewpoint. The various subjects that prove this confirmation are perhaps not so clearly convincing as are the human hands subjects. Some may even look somewhat speculative but nevertheless fit the idea of the modeling function. We may postulate a cooperative convincing effect in the various human models presented. The more correspondences we detect between human and the chemistry of life, the more convincing the idea of human models for chemistry becomes.

### 1.4. Applications of the Human Tetrahedron Model

The human limbs structure will be most clearly demonstrated by the Vigeland tetrahedral man [2]. The Vigeland human tetrahedron connects chemistry to art culture. A heterogenous tetrahedral human body model is used in a numerical evaluation of electromagnetic fields exposure on real human body models [3]. Reference [3] proves that a tetrahedral human body model is an effective tool in solving even complex problems. The model deserves to become more popular. Reference [4] points out: “The three dimensional (clothes) cutting method for polyhedron at least is dependent on the human body tetrahedron” [4]. It look likes that the human body tetrahedron is the model for a clothes cutting technic. Actually, the tetrahedral human body concept is not very popular. A Google search on “tetrahedral human body” and “human body tetrahedron” assessed on 19/11/2018 counts respectively six and one matches.

## 1.5. About the Content of the Article

In this contribution, especially the correspondences to the human limbs structure are investigated; the chemistry properties that are analog to acting by means of four human limbs. Four limbs is standard for all the vertebrates, but the human limbs structure fits the discussed correspondences best. The human models are about active quadruple or fourfold properties that correspond to human actions by means of four limbs. The appearance of quadruple properties in the chemistry of the life sciences is so often present that we may question its accidental nature. The article attempts to make the correspondences between human and carbon clear. We start with the Vigeland human tetrahedron and in the next sections we focus on more detailed cases in chemistry supporting the four limbs idea: a tetrahedron based model for biochemically relevant functional group reactions and the four limbs idea in the chemistry of life. A human hands model is introduced for the four basic (main, major) biomolecules. The human based model for chirality, configuration, conformation and, initiation, propagation and termination reactions will be discussed. Finally, additional remarks and viewpoints on the human hands and arm models are presented and developed further on.

# 2. Similarities between Human and Carbon

## 2.1. The Vigeland Tetrahedral Man

The geometric connections of the human body depicted in a square and a circle by Da Vinci; The Vitruvian Man, are well known. An impressionism’s attempt to artfully depict the human body in a tetrahedron is done by Daniel Austin [5]. In the Vigeland Park in Oslo (Norway) we find, located on the bridge of the exposition, a bronze sculpture of a man who approximately forms by means of his two hands (fists) and two feet the four vertices of a human tetrahedron.

### 2.1.1. Description and Properties of Figure 1

Figure 1 is an image of this Vigeland sculpture [2]. I use this image to show a connection between human and carbon. If Vigeland was more aware about this tetrahedron structure, he probably would make this sculpture perfectly in line to a tetrahedron. The center of the torso’s diaphragm is the center of the tetrahedron. In the connection to carbon, the lines from this center along the arms and legs of the sculpture correspond to carbon bonds. In the Vigeland sculpture, especially the bonds along the legs are curved. A tetrahedral human body real life model causes the least strain by means of four curved bonds from the diaphragm center along the limbs and ending at the hands and feet. In general, human arms are shorter than legs but there are individuals that show nearly equal lengths for arms and legs. It looks like the Vigeland tetrahedral man approximately meets this length ratio.

### 2.1.2. Interpretations of Figure 1

Humans raise arms to celebrate victory and priests raise arms in religious celebrations. A victory can be dedicated to a decedent relative, the supernatural, God, or the cosmic forces. The Vigeland tetrahedral man clearly shows an expression of victory. The Vigeland tetrahedral man shows the synthesis and the balance of earth (the two legs and feet) and cosmic (the two upwards pointing arms and fists) forces. Humans and most plants have an upright, vertical posture. At least the plants are under the direct influence of a cosmic force, namely the power exercised by at least the sun. Real artists often have a sensitive feeling of reality. Vigeland was perhaps unconscious of this connection but he often refuses to give explanations about his sculptures.

### 2.1.3. Connection to a Cube

The title of the sculpture “Man running” illustrates the inability to characterize the sculpture in an optimal way. It is nearly impossible for a man to run using the twisted torso of the tetrahedral human conformation. Especially if also the next step in the tetrahedral run should be tetrahedral. Two subsequent steps in a tetrahedral “run” show the two tetrahedrons that can be constructed by means of the eight vertices of a cube. By this, we make the cubic crystallographic structure of the two “run connected” human tetrahedrons clear.

### 2.1.4. Connection to Carbon

By hands and feet, humans bond in the most physical way to their environment. The Vigeland’s tetrahedral man clearly shows the connection between human and carbon in bond making actions. Chemical bonding is a kind of acting. The tetrahedron structure of carbon single bonds resembles at the atomic level the Vigeland’s human tetrahedron. The human tetrahedron is a model for the carbon tetrahedron. Note the difference between human and carbon in this respect. For humans the tetrahedron is a conformation whereas for single bonded carbon it is a fixed configuration. The human limbs configuration supports a possible tetrahedral conformation. When we visited the Vigeland Park in Oslo in 1995, the connection with carbon was not mentioned in the Vigeland documentation, neither is it now on their web site. Finally, after Da Vinci’s human mathematical model, the chemical society proudly presents to the world the chemistry and crystallographic three dimensional equivalent: the Vigeland tetrahedral man.

**Figure 1**. The Vigeland tetrahedral man (Gustav Vigeland, Man Running, before 1930, Photo: Sidsel de Jong / Vigeland Museum)

## 2.2. The Human Resembling Properties of Carbon Chemistry

The Vigeland human tetrahedron is a strong indication for possible other connections between human and carbon, and stimulates further research.

### 2.2.1. The Unique Properties of Carbon Chemistry

In chemistry, tetrahedrons often refer to carbon and organic chemistry. We compare the position of human in social and life sciences with carbon in chemistry. We start with some highlights of carbon. The importance of carbon for chemistry is illustrated by the fact that organic chemistry sometimes is referred to as carbon chemistry. Every science related education has a course on organic (carbon) chemistry. No other course in a basic curriculum (bachelor) is so connected to a specific element. For organic chemistry hydrogen also is indispensable and oxygen, nitrogen and even sulfur are very important atoms. But carbon is the structure forming element due to its ability to form carbon based skeletal chains. From all atoms carbon is the most versatile, at least in its flexibility and innovative forces that allow it to form the most diverse carbon based skeletal structures. For the development of life many chemical elements are essential, but carbon has by its skeletal abilities a central and crucial position. Carbon has also a central position in the periodic table. Carbon is the first element of main group IVA (group 14). Regarding the main groups, group IVA is in the middle of groups IA (group 1) and VIIA (group 17). Due to its outer shell electron configuration, carbon has a valence of four.

### 2.2.2. The Connection to Human

The properties of carbon mentioned above resemble to some extent human properties. I give a few examples. In view of our search, valence four can be easily connected to a human action with four limbs. The flexibility and innovative abilities of humans result in extremely high performances and results in all facets of social life (the social live octet): communication, economy, entertainment, politics, religion, social organization including family, activities (carts, dances, sports …) and technology. Just like carbon forms an electron octet by means of its bond connected atoms, humans are interconnected by the social life octet. Everyone is embedded in a more or less complex (skeletal structured) network of social interactions that also include non-human participations such as animals, plants, minerals, nature, and technical products (car, PC, smart phone, …). To some extent, what carbon is in chemistry are human beings in society and nature, and what humans are in the life sciences is carbon at the atomic and molecular level. Scientists mostly classify humans as animals. In the human and animal realm humans have a central, interconnecting position like carbon in the molecular realm. The human plan is the model to which all other life forms can be connected. Jos Verhulst demonstrates this human centered connection, besides in various publications, also in his book Developmental Dynamics [6].

## 2.3. Diamond and Graphite

A few typical carbon forms may attract our attention; diamond and graphite. The hardest and one of the smoothest minerals are comprised in one chemical element. It is our purpose to search the human related properties of diamond and graphite and we can find them at the psychical level of human organization. Diamonds are polished by other diamonds. We comparable develop (polish) our psychical structure at most in relations and even more in conflicting relations. Humans need each other to develop wisdom, starting at childhood in family, child care, and later on in education and social networks. In our souls, we figuratively have and need both these carbon forms but it depends on the circumstances which of them we should use most. For example, we need the figurative softness of graphite to make our relations smoothly and the hardness of diamond to conquer the evil in our own soul.

# 3. A Human Tetrahedron Based Model for Biochemically Relevant Functional Group Reactions

The Vigeland tetrahedral man invites us to develop a chemistry structure, a model that makes the human connected powers of chemistry visible. The biochemically relevant functional group reactions are a logical chemistry domain to demonstrate this quest. From a biochemical viewpoint, organic chemistry is in the first place the chemistry of the functional groups that are necessary for biochemistry. In this respect, the author developed a mnemonic model ([7], p. 8) resembling the human body [7]. Figure 2 is an improved version and is adapted to reference 8 [8]. In Figure 2, the idea of a tetrahedral model is reduced to a planar projection indicating reactions of which most are shown in the form of four limbs.

This model shows basic reactions of functional groups in view of their connection to the four main biomolecules: carbohydrates, lipids, proteins and nucleic acids.

### 3.1. Description of Figure 2

The main structure determining parameters of Figure 2 are the oxidation levels (OLs) of carbons that are bonded to a functional group or the functional group carbons. Figure 2 shows each of the functional groups on their corresponding OL. Because of the OL difference between reactants arrows are also used to connect reactants for reaction. The bold print reaction arrows on OL three bent downward according to gravitational forces and the ones on OL two bent upwards according to forces that make humans (and most plants) stand up. The bold print reaction arrows indicate the connection to the human tetrahedron in a planar projection. The model extends the reference [7] model with indications of the condensation reactions of aldehydes, ketones and esters in strong alkali conditions. The latter reactions are at OL two for aldehydes and ketones and at OL three for esters. They are important in respectively carbohydrate and fatty acid chemistry, both to change the chain length of respectively monosaccharides and fatty acids. The organic chemistry functional groups depicted on the limbs of the model are connected to the main biomolecules as follows: Hemi-acetals in the monosaccharide ring structure, acetals in the glycoside bonds of polysaccharides, imines for the biosynthesis of nucleobases and the formation of amino acids from imino acids, esters in triglycerides and derivatives, phosphodiesters in nucleic acids, and amides in the protein peptide bonds. The phosphodiesters need in Figure 2 phosphoric anhydrides, such as in ATP, instead of the RCOZ variable. Note that the Z-group can also be RCOO or OOCR, which already transforms RCOZ into an anhydride.

### 3.2. Additional Similarities to the Human Body

Alkanes (RH) and the R-groups of the various functional groups correspond to respectively the brain and the ubiquitous nerves. The OLs on the central axis of the figure correspond the spinal cord. The polymerization reaction of alkenes, although not a bio polymerization, corresponds to the repeating sequence of vertebrae from the spinal cord and the ribs of the thorax. The embryologic polymerization process for the formation of ribs and spinal cord is strictly restricted and follows heritable laws. The movements of the chest are mainly restricted to the breathing process, which can be regarded as a rhythmic propagation process. Alcohols and amines correspond to the lungs, aldehydes and ketones to the celiac plexus (solar plexus) and the $R^1COZ$ variable to the intestines. In reference [7], the heart position is assigned to the arenes (aromatic compounds). In Figure 2, they could be located on the left of the aldehydes and ketones but are omitted to focus on carbonyl reactions.

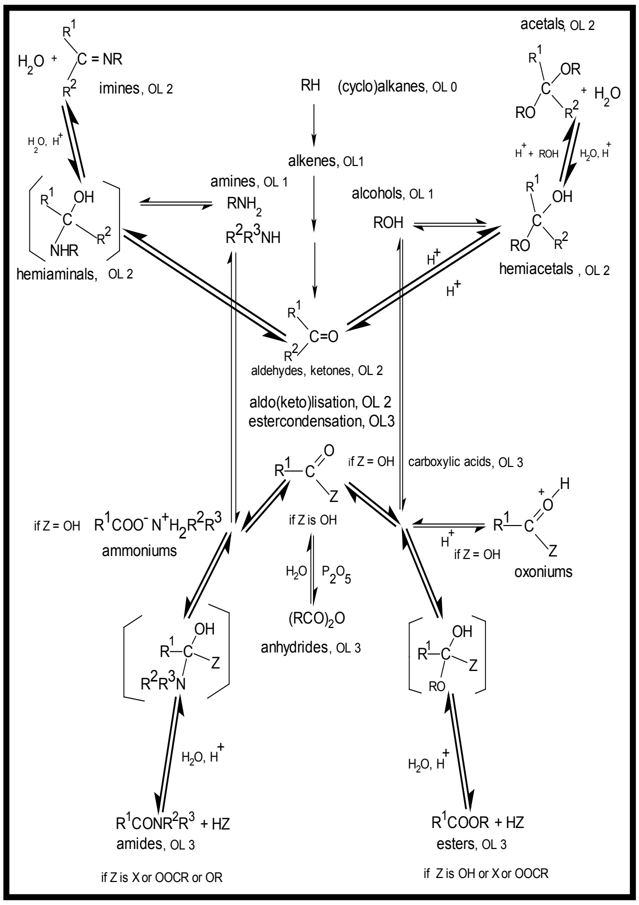


**Figure 2.** A Tetrahedron Based Model for Biochemically Relevant Functional Group Reactions

The comparable reaction conditions of aldolisation and ester condensation connect them together at the edge between the two OLs just as the diaphragm separates chest and intestine. It must be admitted that the location of the aldolisation and ester condensation is a little lower than it should be. Oxoniums and ammoniums should be at the hip position but are depicted outside for clarity. The symmetrical anhydrides, $(RCO)_2O$, correspond to the symmetrical testis or, in case of anhydrides located in the inside of the model, to the symmetrical ovaria or kidneys. Note that the functional groups for the bio polymerization reactions on the limbs of the model have no correspondence to a repeating sequence of identical bones in the limbs. Instead, we may point to an outside propagation of possible, flexible, repeating and unrestricted limb movements.

**Table 1. Some Connections between the Location of Functional Groups in the Model and the Human Body**

| Functional group | Biopolymers | Sequence of Identical Bones | Movements of the Chest |
|---|---|---|---|
| Alkenes | No | Vertebrae, Ribs | Restricted to Breathing |
| | | Sequence of Identical Bones in Limbs | Movements of the Limbs |
| Acetals | Polysaccharides | No | Unrestricted |
| Amides | Proteins | No | Unrestricted |
| Phosphodiesters | Nucleic Acids | No | Unrestricted |

### 3.3. Conclusion of Section 3

It cannot be denied that the total of biochemically relevant functional groups and reactions must have some potential that make this human connected model possible. The human body has a tetrahedron structure and the biochemical relevant organic reactions can be presented according to that human tetrahedron structure. The question may be raised that the human body plan evokes the necessary reactions to make life possible. Is that the reason why these reactions fit the model so well?

## 4. Four Limbs in Chemistry

### 4.1. Four Limbs in the Periodic Table

So far, we have demonstrated chemical acting resembling human acting in organic chemistry. Can we also trace four limbs in the periodic table? The number four is connected to four main characteristics of the periodic table for elements occurring in nature. An octet structure shows four electron pairs. There are four orbital levels; s, p, d and f. The increase of the number of electrons in the various orbitals is also four (2, 6, 10 and 14). The building up of orbitals from underlying shells shows four element blocks that realize a full orbital: the 3d-, 4d- and 5d blocks of transition metals and the 4f block of lanthanides. We may also propose a fifth quadruple connection. The noble gas configuration is in a split form present in three complementary pairs of main groups: IA and VIIA (1 and 17), IIA and VIA (2 and 16), IIIA and VA (13 and 15). The fourth group is group IVA(14). The elements of group 14 show half of a noble gas octet configuration on their outer electron shell. Together these three complementary pairs and group 14 result in four periodic table group entities that specifically are connected to the noble gases.

### 4.2. Four Limbs in Biochemistry

Four related groups of biomolecules are like functional limbs in biochemical actions. We will distinguish here in the first place the four limbs represented by the four types of basic biomolecules: carbohydrates, lipids, nucleic acids, and proteins. Specific functional groups of these biomolecules are already the limbs in the organic chemistry model for biochemically relevant functional groups (Figure 2). Note that these four types of biomolecules are connected to each other. By the cellular metabolism especially carbohydrates, lipids and proteins can be interconverted. Proteins are connected to nucleic acids (DNA and RNA) by the genetic code. In proteins, the twenty proteinogenic amino acid fingers [1] can be sorted in four groups based on cyclic and polar properties; 1) non-cyclic non polar-, 2) non-cyclic uncharged polar-, 3) non-cyclic charged polar- and 4) cyclic side chains (Reference [1], Figure 2). The structure of proteins and DNA shows four levels: primary, secondary, tertiary and quaternary structure. The latter structure often consists of four (limb) chains. Best known examples are hemoglobin, the tetramers in the phosphorylase family and the antibodies. Especially for the antibodies the four chains are concerned in the "handling" of antigens. The human metaphase chromosomes show four "arms"; two short arms and two long arms. There are four nucleobases in DNA and RNA: adenine (A), guanine (G), cytosine (C), and the fourth is thymine (T) in DNA and uracil (U) in RNA. In the composition of the DNA double helix we can distinguish four levels: phosphates, deoxyriboses, nucleobases and the hydrogen bonds between the two complementary nucleobase pairs: AT and GC. The genetic code is already presented in four concentric circles [9], which indicate an evolutionary process in the genesis of the code in four steps. In organic chemistry and biochemistry, chirality mostly is related to the presence of four different substituents on a central carbon. Life has a striking preference to use chiral structures. The four substituents on the alpha chiral carbon of amino acids show four levels of substituent organization. Following increasing complexity these four substituent levels are; an atom (hydrogen), a functional group on the chiral carbon (the amino group), a carbon based functional group (carboxyl acid), and one of the twenty possible side chains (except for the side chain of glycine; hydrogen).

## 5. Human Hand Model for the Four Basic Biomolecules

The four basic biomolecules (carbohydrates, lipids, nucleic acids, proteins) in action can be compared to four limbs that show four acting hands and should show correspondingly five subdivisions (fingers) for each of the basic molecules. The four basic biomolecules are compared to four hands, and not to two hands and two feet, because they do not need feet specializations for their actions. Can we show five subdivisions for each of the four basic biomolecules? It looks a nearly impossible mission to divide each basic type of biomolecules into five subdivisions (fingers). We will try to demonstrate the biochemical fingers on the base of structure as well as on function. Although other divisions will be claimed, the proposed ones will remain valid.

### 5.1. Human Hand Model for the Lipids

Wikipedia shows a lipid subdivision octet: fatty acids, glycerolipids, glycerophospholipids, sphingolipids, sterol lipids, prenol lipids, saccharolipids and polyketides [10]. We can neglect the polyketides and the saccharolipids as they respectively are secondary metabolites and microbial components. Furthermore, saccharolipids can be classified at the carbohydrate fingers. Sterols and prenols have isopentenyl pyrophosphate as a precursor and can therefore be grouped together as the isoprenoids or terpenoids. The fatty acids include their derivatives (e.g., prostaglandins) and the glycerophospholipids include plasmalogens and cardiolipin. Correspondingly the five structural lipid fingers are: fatty acids, glycerolipids, glycerophospholipids, sphingolipids and isoprenoids. The five functional lipid fingers are: energy and energy storage (glycerolipids), membranes including transport across the membranes, hormones (steroids), vitamins (A, D, E and K), and defense (prostaglandins in inflammation and immunity).

### 5.2. Human Hand Model for the Carbohydrates

We distinguish five types of carbohydrates that are presented as the five structural carbohydrate fingers: monosaccharides, di- and oligosaccharides, polysaccharides, heterosides (glycoproteins, nucleosides and saccharolipids), and glucosaminoglycans or mucopolysaccharides. The five functional carbohydrate fingers are: energy (glucose) and energy storage (starch, glycogen), defense (carbohydrate antigens [11]), detoxication (glucuronic conjugates) protection [12] (digestive protection, glycemic protection, heart protection and muscle breakdown protection) and structure (glucoseaminoglycans, cellulose).

### 5.3. Human Hand model for Nucleic Acids in Protein Biosynthesis

A human hand model can be detected in the nucleic acid chemistry regarding protein biosynthesis. The five nucleic acid fingers are: nuclear DNA and mitochondrial DNA, mRNA, r-RNA and t-RNA. Note also that nucleic acids act by means of five different atoms: carbon, hydrogen, nitrogen, oxygen and phosphor. The five functional fingers of human nucleic acids are: coding (DNA, mRNA), non-coding DNA, structure (ribosomal RNA), catalyst (ribozymes) and transport (aminoacyl-t-RNA).

### 5.4. Human Hand Model for the Proteins

Note that we already have compared the twenty proteinogenic amino acids with twenty fingers [[1], 3.0 p. 119-120]. The presented five protein subdivisions are: simple proteins, metalloproteins, phosphoproteins, chromoproteins and conjugates to other basic biomolecules (carbohydrates, lipids and nucleic acids). Note that fibrous proteins are already a functional classification. A human hand model can also be proposed for the five different atoms (carbon, hydrogen, oxygen, nitrogen and sulfur) that proteins need to construct their structure for actions. A human hand model for protein function may be as follows: enzymes and transport (transport proteins catalyze the transport process), hormones (insulin), signaling including receptors, defense (antibodies) and fibers (collagen). Storage proteins (casein, ferritin and ovalbumin) can be viewed as a special case of transport proteins. For example, casein (milk) transports proteins to the growing baby.

## 6. Other Human Models in Chemistry

### 6.1. Human Actions as a Model for Protein Actions

An analogy between proteins and humans is already mentioned in reference [1]: “In some way, protein functioning resembles human functioning. Managers, estate agents, teachers, … all act comparable as to enzyme proteins, they all catalyze the process in which they are involved”. Proteins contain in their amino acid sequence the reaction potential of nearly all organic chemistry functional groups. One could expect a wealth of chemical reactivity. In contrast, proteins function in a very specific way thereby using only a select and limited part of their structure and side chains in their active site. Comparable, humans also often use a limited selection of their possibilities in their professional work.

### 6.2. The Larynx Core

If both arms and hands are stretched and are in one line with each other, they form the diameter of a sphere created by turning the stretched arms around. The larynx (nearly) is the center of this sphere; the core of the NECA (Neon Electron Configuration Analogy) structure of the human hands [[1], 2.3 p.118]. In the stretched arms sphere, the NECA hands correspond to the electron cloud. By means of the vocal cords in the larynx we can communicate are thoughts in the most natural way. The communication of our thoughts is the core of our physical existence. The English language has an octet of the major parts of speech [13]. These parts are: noun, pronoun, verb, adjective, adverb, preposition, conjunction and interjection.

### 6.3. Cube, Human and Chemical Octets

We already connected the two human tetrahedrons for the two subsequent steps in a “tetrahedral run” to a cube. A cube has a vertices octet. A few octets are typical for humans, although they are not common knowledge. The length of an ideal human body tends to be eight times the height of a human head [14]. The ideal human body length is an octet of the human head height. We previously presented the social live octet and the octet of the parts of speech. Some chemistry octets are: the classic octet rule for the valence electrons, the reaction type octet in the NECA structure of organic chemistry [8] and the octets for the codon structures: abN, abPy and abPu [[1], Table 1]. The ab part of a codon presents the 16 dinucleotide combinations for the first two nucleotides of a codon, and Py and Pu respectively are abbreviations for a pyrimidine (Py) and a purine (Pu) nucleotide for the third nucleotide of a codon.

### 6.4. The Human Standard (Model) for Configuration, Conformation, Chirality, Initiation, Propagation and Termination

#### 6.4.1. Model for Configuration and Conformation

Configuration and conformation are very important concepts in organic chemistry and biochemistry. The conformation of proteins is extremely complex and specific, unique conformations are necessary for protein function. Configuration and conformation concepts are also applicable to organisms. Especially, the human face including its component configuration is extremely potent in demonstrating the most diverse mimicking conformations. Human conformations are well known as body language. Body language is a general concept for humans and animals. The mimicking potential of humans is far richer than what any animal can produce. Animals are restricted in their body language to the features of their species. In this respect, we also may call the human body morphology the standard configuration for all higher animals. Each of these animals develops this standard in a specific and unilateral direction. We may conclude that humans also define the body morphology (configuration) and body language (conformation) standards. The configuration and conformation concepts applied to humans are less in use but are in fact the standard for their use in chemistry.

#### 6.4.2. Model for Chirality

Human hands are non-superimposable mirror images and frequently used to demonstrate chirality. By this fact, it becomes clear that human hands are the model of chirality.

#### 6.4.3. Model for Initiation, Propagation and Termination

The initiation, propagation and termination reactions in photochemical halogenation of alkanes and in polymerization reactions resemble many typical human actions. For example, if I want to paint a room many actions are necessary before the effective start of the painting process; they are the initiation actions. The painting of the room is the propagation action. The painting process is a nearly endless repeat of the same propagation (painting) actions. All actions needed to finish the job are the termination actions. This shows that human acting is the model for initiation, propagation and termination in chemistry.

## 7. Additional Information and Remarks on the Proteinogenic Amino Acid Fingers

The proteinogenic amino acid fingers are presented and discussed in reference [[1], p. 119-120]. Remember that the amino acid fingers refer to the amino acid side chains. “We may say that proteins act, handle, by hand and feet and have therefore 20 fingers; i.e. 20 amino acid side chains.” The amino acid toes have the status of fingers because they don’t need the specific (feet) specialization for walking. Additional information and remarks are shown hereafter.

### 7.1. Polarity of Methionine

Most readers will have problems with the author’s choice to sort methionine as a polar amino acid because most authors classify methionine as non-polar. The electronegativity (Pauling scale) of carbon and sulfur is respectively 2.55 and 2.58 [15]. Consequently, methionine has a (very low) polarity. Due to its sulfur atom methionine is very polarizable as is demonstrated in the formation of 5’S-adenosylmethionine. As an amino acid thumb, methionine should deviate from the other polar non-charged amino acids. Methionine deviates by its sulfur content and additionally by its very low polarity.

### 7.2. An Alternative Amino Acid Finger Pattern for the Non-cyclic Non-polar Side Chains

| Thumb | Index | Middle | Ring | Pinky |
|---|---|---|---|---|
| Glycine | Valine | Leucine | Isoleucine | Alanine |

Some arguments favor an alternative amino acid finger pattern in the first group of Figure 2 from reference [1]: the non-cyclic non-polar side chains. Glycine has the smallest side chain and reference [1] therefore describes glycine as an amino acid pinky finger. But, glycine is most deviating in its group because the glycine side chain (-H) is the only non-hydrocarbon side chain of the group and the most important property of glycine in proteins is chain elongation, which is, in accordance to the next remark, in line with an amino acid thumb. Alanine is the smallest hydrocarbon side chain of the group and is therefore better designated as an amino acid pinky finger. Valine is the second in chain length and corresponds to the index finger. Leucine and isoleucine respectively may correspond to the middle and ring fingers.

### 7.3. Chain Properties of Amino Acid Thumbs

The amino acid side chain thumbs according to reference [1] and section 7.2. are: glycine, methionine, cysteine and proline. It is remarkable that the amino acid thumbs not only deviate from the other members of their group by their structure but furthermore typically show in some way chain properties or more pronounced chain properties. Proline produces nicks in the protein chain. Cysteine produces disulfide bridges, which cross-link the chain or in between chains. Methionine is an alkylation reagent as S-adenosylmethionine. In alkylation, methionine is converted into homocysteine, which corresponds to a decrease in chain length of the side chain. Glycine doesn’t really have a side chain. In proteins, glycine only causes chain elongation. Glycine appears in the protein sequence only if chain elongation is necessary. All the other amino acid side chains, although they also cause chain elongation, mostly function by their acid-base and/or hydrophilic-hydrophobic properties of their side chains. Although the glycine side chain (-H) is mostly classified as hydrophobic, it has a negligible influence on the hydrophilic and hydrophobic properties of a protein and shows no acid-base properties.

### 7.4. Amino Acid Pairs in Proteinogenic Amino Acids

It is a remarkable fact that 16 proteinogenic amino acids can be grouped into 8 pairs in which the components of each pair are strongly or even very strongly structurally related. Each amino acid group (hand) of Figure 2 in reference [1] contains two of these pairs. Group 1: valine-alanine and leucine-isoleucine, Group 2: threonine-serine and glutamine-asparagine, Group 3: glutamic acid-aspartic acid and arginine-lysine and for Group 4: tyrosine-phenylalanine and tryptophan-histidine. In each of the amino acid groups, these pairs respectively correspond to the index-pinky and middle-ring finger pairs.

### 7. 5. A Recognizable Pattern of Amino Acid Fingers in a Proteinogenic Hand

A proteinogenic hand is one of the four amino acid side chain groups presented in Figure 2 of reference [1]. The in section 7.4, described amino acid finger pairs show in each group (hand) a pattern in chain structure and composition that is certainly not random. This pattern, although there are differences, tends to be similar in the four groups. The first pair of each group shows a decrease in chain length. For the tyrosine-phenylalanine pair, the decrease comes from a loss of the hydroxyl group. The second pair contains the isomers (leucine-isoleucine) and all the nitrogen derivatives.

### 7.6. Pointing Ability of Real Human Fingers

Many readers try to disprove the sequence of decreasing pointing ability that can be defined for the four most resembling human fingers. The proposed sequence of decreasing ability is: index, pinky, middle, and ring finger. Some people change and put more strain on the fist conformation compared to the initial one (when pointing with the index finger), to acquire a more comfortable pointing ability for the middle and ring fingers. It must be clear that throughout the intended pointing experiment, the fist conformation should not change. The proposed pointing sequence is valuable for most people but of course we may expect exceptions due to the human ability to improve the flexibility of their fingers by exercise. Index, middle, ring and pinky fingers differ in length but their general appearance is rather similar. Based on the pointing ability and the finger length of the real human hand fingers, we divide these four similar fingers into two pairs: the index-pinky and middle-ring finger pairs. Due to the specialization of the feet for walking the toes are not anymore able to be investigated in a “fist analog” pointing experiment.

### 7.7. Difference between Real Finger Pairs and Amino Acid Finger Pairs

In contrast to the real fingers, the two pairs of amino acid fingers in especially the second, third and fourth group (amino acid hands) of five amino acid fingers each functionally differ strongly. This functional difference of the amino acid fingers corresponds to the functional difference in pointing ability.

### 7.8. Correspondence between Amino Acid Side Chain Length and Finger Length

The amino acid side chain (finger) lengths are in accordance to results of J. Manning [16] on human finger lengths. “The 2D:4D digit ratio (index to ring finger) is sexually dimorphic: although the second digit (index finger) is typically shorter (than the ring finger) in both females and males, the difference between the lengths of the two digits is greater in males than in females.” The correspondence between side chain and real finger length is much more clear for 2D and 5D (the index and pinky fingers).

### 7.9. Paired Human Metacarpal Bones and Corresponding Finger Pairs

By comparing the metacarpal human hand bones by X-ray images [17], we can distinguish two pairs of corresponding metacarpals by form, length and thickness: the pair pointing to the index and middle fingers and the pair pointing to the ring and pinky fingers. Correspondingly, the index and middle fingers are the thicker finger pair and the ring and pinky fingers are the thinner finger pair.

### 7.10. Conclusion on the Human Hands Model for Proteinogenic Amino Acids

The human hands properties that concerns finger pairs are: the finger length-pointing ability and the finger thickness. Both result in two finger pairs for each hand; index-pinky fingers and middle-ring fingers for the first property pair. For the finger thickness property, the two pairs are the index-middle and the ring-pinky fingers. The proteinogenic amino acid fingers show in each group (proteinogenic hand) two pairs of related amino acids. The additional information and remarks of this section further on support the human hands model for the proteinogenic amino acids and their contribution to protein structure and function. The human hands model, the eight amino acid finger pairs and their recognizable pattern in each proteinogenic hand are very remarkable determinations for the proteinogenic amino acids that should be selected only by chance and by fitting to their purpose. There is also not yet a theory to explain the restriction to 20 proteinogenic amino acids. The human hands model is a possible and reasonable explanation.

### 7.11. Addendum to the Human Hands Model: The Specificity of the Aminoacyl-tRNA Synthetases

There are two classes of aminoacyl-tRNA synthetases [18]. Each class is specific for 10 proteinogenic amino acids. The synthetases specific for arginine, cysteine, glutamic acid, glutamine, isoleucine, leucine, methionine, tyrosine, tryptophan and valine belong to class I synthetases. The synthetases specific for alanine, aspartic acid, glycine, histidine, lysine, phenylalanine, proline, serine, and threonine belong to class-II synthetases. The two classes divides the proteinogenic amino acids in two groups of 10, just like we have 10 fingers and 10 toes. Most amino acids in the two groups can be paired, but they don’t correspond to the four groups of Figure 2 in reference [1].

## 8. Additional Remarks on the Correspondence between the Genetic Code Developmental Structure and the Structure of the Human Arm

We remember that the genetic code developmental structure is a transformation of the vertebrate mitochondrial into nuclear universal code [[1], 5.2 p.121-122]. Many readers of reference [1] will have problems with the genetic code correspondences to the number of phalanges finger bones for the human arm model. The present section gives additional information in this respect and connects the genetic code correspondences to the proteinogenic amino acid fingers.

### 8.1. Number Correspondence between the Finger Bones and Specific Nuclear Codons

We search for a correspondence between the number of specific universal codons and the number of finger phalanges bones. Five nuclear codons (yellow highlight in lower part of Table 1 from reference [1]) that have no abN nor one of the spliced abN structures; (abPy or abPu), are derived from four pairs of mitochondrial spliced abN codons (turquoise highlighting in Table 1 from reference [1]). These five nuclear codons code for three amino acids (Met, Trp and Ile). Three of the latter codons code for isoleucine and two of these codons each codes for a single amino acid. Three and two codons respectively can correspond to fingers with three and two (the thumb) phalanges bones. If we add this remark to the already described correspondences from reference [1], we follow the human arm model for the genetic code correspondences downwards from upper arm till individual finger type for the number of the arm, hand and finger bones.

### 8.2. Number Correspondence between the Finger Bones and Amino Acid Structure

Now we connect the codon correspondences of the human arm model to the proteinogenic amino acid fingers. Amino acids show three supra-atomic structures; the alfa amino, the alfa carboxylic acid and the side chain. The first two of them form the peptide bonds of the protein chain. In view of the presentation of the proteinogenic amino acid as protein fingers, we point to the numerical (two and three) correspondence of the in this section discussed properties to the number of phalanges bones in human hand fingers. Each thumb has two phalanges bones, which correspond to the two functional groups that are involved in peptide bonding; the alfa amino and alfa carboxyl groups. Note that we previously already connected amino acid thumbs to chain properties. Each other finger has three phalanges bones, which corresponds to the three supra-atomic structures on the central carbon of amino acids. By this, we interconnect the human hands model for proteins to the genetic code transformation.

## 9. Conclusion

The article proves that human models are possible, acceptable, convincing, desirable, and interesting. While my previous article "The human hands model for the essentials of the chemistry of life" sets expectations by introducing the human hands as a model, this article extrapolates this idea to the complete human existence thereby confirming and extending these expectations. It discusses a wealth of human connected correspondences and similarities in chemistry. Vigeland human tetrahedron is a model for the carbon tetrahedron and two subsequent steps of this model, model the two cube-vertices-tetrahedrons in a cube. Quadruple chemical actions resembling actions by means of four limbs are detected for the periodic table and for biochemistry. The human hand model is developed by structure and function for the four basic biomolecules: carbohydrates, lipids, nucleic acids and proteins. The human larynx is the core of a NECA sphere of the human hands. The present article confirms the human hands and arm models of reference [1] and develops them further on. The human hands model clearly explains the selection of and the restriction to 20 proteinogenic amino acids.

## Abbreviations

NECA Neon Electron Configuration Analogy
OL(s) Oxidation Level(s)

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