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Power of molecules: The morphological-informational content of matter

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Abstract

Among the many questions that have occupied scholars of all historical periods for thousands of years, the question regarding the origin and evolution of matter is the most debated and far from having obtained a definitive answer.

If we exclude the theories proposed by quantum physics, which are considered the most plausible, for the rest we are groping in the dark.

In this article I'm going to try to give some answers, both on the mechanism of formation of molecules, and on their functional significance, without having the presumption of giving positive answers.

It should be considered an invitation to discussion, a rational comparison, among those interested in the topic.

In the article, I draw attention to an aspect, which I consider fundamental, and on which I have published several works.

This is the mode of iteration, communication and recognition between molecules, which is the fundamental stage to obtain any materially detectable and significant result for the emergence of new entities. It is also the event that allows random evolution and without an apparent preordained or pre-established end.

Even if the ultimate goal of this complex evolutionary activity is unknown to us, we cannot avoid seeking it.

Keywords: Conformation of molecules; Interaction and communication between molecules; Properties of molecules; Evolution of matter; Structure and function of proteins; Prion proteins

1. Introduction

What strange power do molecules have to be able to interact and influence each other and to change their state after the interaction?

The most trivial answer to this observation is that molecules and the atoms that compose them manifest their properties only when they interact with similar entities with shared characteristics and properties.

Let us imagine a molecule or an atom immersed in the most absolute vacuum, assuming that it exists, that is, a place devoid of space-time, and of any other physically detectable element.

Under these conditions the entity, whether atom or molecule, taken individually, expresses nothing, and if it has physical properties they cannot be revealed.

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It is only through interaction or contact with other entities or particles that it takes on its own characteristics.

During the long evolutionary process that has lasted billions of years, and is still ongoing, nascent molecules have had the opportunity to interact randomly, and in some cases merge, into new unique entities and increase their complexity to “experiment” with new structures with novel properties.

Even the properties of atoms described in Dmitri Mendeleev's periodic table were derived by observing the behavior of individual atoms in their interactions with others.

Because the chemical behavior of atoms can only be manifested by the effect produced by their interaction when they encounter other atoms.

Therefore, the definitions that characterize chemical substances as acids, bases, oxidants, reductants, as well as the types of bonds that unite them, and their states of aggregation, etc. are the expression of their mode of interaction, without which, the individual particles taken in isolation, are not detectable.

So, there is no base without the corresponding acid or an oxidant that does not couple with a reductant, it is always an interaction between pairs of different chemical species, e.g.:

$$HCl + H_2O\ H_3O+ + Cl^-$$

(Acid-Base Reaction, there is a transfer of Protons)

$$2Na + Cl_2 = 2NaCl$$

(Oxidation-Reduction or Redox Reaction, there is a transfer of electrons)

The energy transfers that occur between interacting substances also involve a change in their structure compared to the original one.

But what characterizes all molecules is their energy-informational content which individually identifies each molecule from all the others.

Thus, the shape, the charge, the energy of molecules, individually observed, are properties “crystallized” in their structure which leaves a unique and distinctive mark, which we can define as their *molecular imprint*, that is, the space-time that they physically occupy in their environment and the modifications that they produce with their presence [1-3].

As their size and complexity increases with the addition of new molecular groups, their energy-informational content increases in parallel, as does the ability to form complex macromolecular polymers, which can assume unique and unrepeatable informational or structural properties.

In nature, an extraordinary experimentation of new forms of aggregation and transformation of existing ones has been taking place for billions of years, and continues today without interruption.

For example, the addition of a phosphate group (PO_4) to low molecular weight molecules it increases their conformational energy content ($ADP + PO_4 \Longrightarrow ATP$), while if added to high molecular weight molecules, such as proteins, it changes their activation state with significant conformational variations.

Once we have established that the evolution and complexity of molecules are a consequence of contact/interaction and selective adaptation to their environment, we must ask ourselves how the transition that leads to the formation of macromolecular complexes occurs.

In other words, how does the formation of molecular complexes and inorganic polymers occur, or the formation of sugars, amino acids, alcohols, aldehydes, and all the chemical species that form the extraordinary variety of substances present in nature?

Chemistry describes the interactions between molecules and the properties of the bonds that hold them together, but we do not know why and how the various types of bonds were produced.

It is said that the forces that hold molecules together are the product of the redistribution of valence electrons in the atoms that form them. And furthermore, that the bonds produced depend on the assortment of atoms that come into contact, because only particular atoms join together to form that type of bond.

We also hypothesize that the bonding between atoms that form molecules occurs to respond to their structural and energetic needs and that in doing so they reach a new equilibrium with a lower energetic content within the system to which they belong.

Even if this explanation may be sufficient, it does not explain why the molecules in turn bind together to form large polymeric macromolecules.

What kind of force or mechanism leads to their formation?

Why must a sugar be formed rather than an amino acid, and why do these link together to form starch polymers or proteins?

There is apparently no reason for this to happen.

It certainly does not happen spontaneously but some energetic conditions and the presence of atoms or molecules with suitable affinity are necessary.

From a philosophical-finalistic point of view, we might ask ourselves: when two atoms or molecules interact, does any exchange of information occur between them? Is there an explanation comparable to the meaning of why their interactions occur, of any interaction, a kind of semantics of interaction, analogous to that described by Linguistic Semiotics?

The attempt to give an explanation to the semantic aspect inherent in the formation of molecular complexes is very well described in the article by Terrence W. Deacon [4].

If this aspect is purely speculative, the question remains as to why two atoms or two molecules join together and what kind of attraction or energy drives one towards the other and to obtain what result?

Are these perhaps random events that, when combined, produce new entities, the validity and effectiveness of which is somehow verified by the environment? And in this sense, does the environment also play an active role? Or is it the system as a whole, molecules plus environment, that contains a mechanism for guiding the processes and a feedback control of the results obtained?

A fundamental and mysterious aspect of the mechanism that regulates the process of molecular evolution, and is at the same time the necessary and sufficient condition for its occurrence, is represented by the necessary presence of multiple molecules in the same place for any interaction to occur.

It can be argued that complex molecules are derived from the fusion of equal or different atoms, but the problem of their origin remains, and it is not a small problem.

Only quantum mechanics, through its postulates and formulas, has been able to make matter emerge from nothing. According to its theories, everything is derived from the "**singularity"**, an indefinite and abstract sempiternal entity, which for an incalculable number of billions of years has been quiescent, then at a certain moment, fixed at 13.8 billion years, has decided to start its activity generating all matter, as a result of the **Big Bang** and the phenomenon of **Inflation** [5-8].

"Hic Sunt Leones" (Here it is leones), the Romans used to say, to indicate the boundaries beyond which one could not or should not go. The same happens with the postulates on the origin of matter, we must accept them as they are, beyond which we cannot go.

All molecules possess an informational content that is inherent in their structure-conformation and in the energy content of the matter that forms them. The more complex their conformational structure, the greater the informational content.

But they also have another characteristic, in addition to being able to modify their structure and conformation in response to external stimuli, they are able to maintain the new morpho-energetic structure obtained.

In this way they have the ability to conserve and "memorise" in the new conformations the results of the events they have undergone.

This property finds its maximum manifestation in proteins that can simultaneously perform structural and functional activities.

It is a property that is also mainly used in macromolecules specialized in the transmission and storage of information, such as DNA and RNA.

In our brain, which is the organ responsible for receiving, recording and storing events, memory is stored in specific memory nuclei, the hippocampus and related centers, and the underlying molecular mechanism has been associated with "sprung" [9-10].

This mechanism consists in the formation of *dendritic spines*, and is postulated as the expression of the molecular plasticity with which the spines are endowed, and is considered the mechanism that nourishes and preserves memory.

We could therefore conclude by saying that memory is the property that molecules possess to modify their conformation in response to external stimuli, to conserve it and in some cases reproduce it.

It should be noted that the creator of this transformation is the external environment, which with its energetic transformations, is the efficient cause that shapes the molecules that must adapt to it in order to continue to exist.

2. The driving forces that assemble molecules

When two or more molecules in their random whirling motion meet, they can produce two events: they can collide, transferring energy to each other, and bounce off without producing anything new, or they can form a structurally and energetically stable union and bond into a new entity.

It all depends on the properties of the molecules and the energy they have to fuse.

In general, when all the nuclei of the atoms that we know were formed, a process known as "nucleation" in quantum mechanics, and when these were able to unite in the particular conditions of their environment, they gave rise to the infinite variety of molecules present in nature.

Some of the generated atoms are unstable, such as radioactive elements, which means that they naturally lose one or more nuclear particles, called nucleons (made up of protons or neutrons). The nuclei of unstable atoms are continuously transformed, until they reach a new state of stability that does not necessarily belong to the same chemical element from which they are derived.

For example, Thorium 232, one of the most abundant radioactive elements in the Earth's crust, by losing two neutrons and two protons, called alpha particles, is transformed into a nucleus of Radium 228, Fig.1.

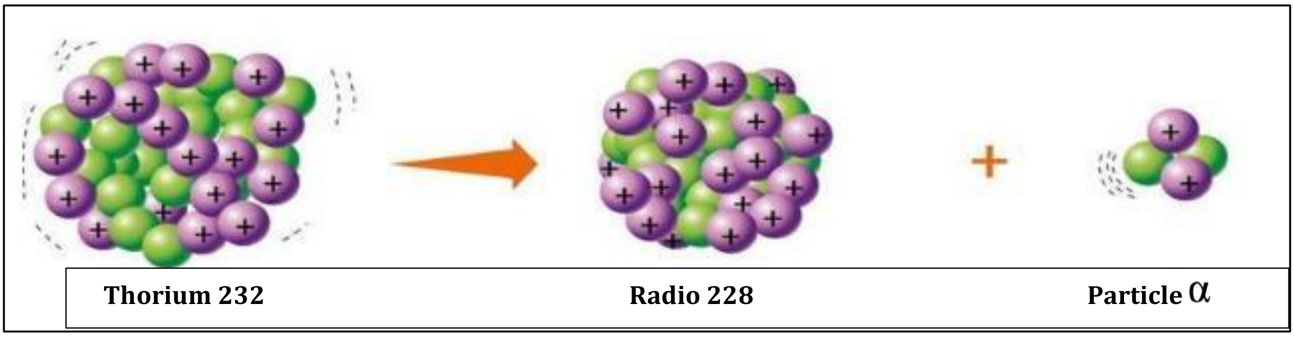

Figure 1 Radioactive decay

When multiple atoms bond together, they form complex aggregation states held together by different types of bonds.

Typically, the types of bonds and the energy that unites atoms define the physical state of matter, gas, liquid, solid or plasma.

Matter takes on shape and consistency when atomic particles join together to form physically knowable bodies.

Atoms, whatever their number and properties, taken separately produce nothing; they become real and recognizable when a means of knowledge, which is an integral part of the environment to which they belong, can observe and measure them, or when they come into contact with other atoms and communicate their properties to each other.

Thus, through their union, they can form new materially consistent entities.

In the event that they do unite, the material bodies they form may depend on the type and number of atoms that compose them.

When observing molecules and complex molecular structures in nature, one is astonished by the quantity, quality and shape they have taken. One might wonder what energetic pathways and preferential paths atoms and molecules have followed to form such a variety of shapes and structures, apparently meaningless but nevertheless capable of perfectly fulfilling their functions.

When we examine molecules, such as carbon nanotubules, fullerenes, proteins, DNA, enzymes, hormones, etc., and we could continue the list indefinitely, up to the star clusters that form galaxies, sometimes we are able to understand their functions and their morphogenetic state, other times they are completely unknown to us.

Many scientists attribute to the process of molecular formation and evolution a finalistic or deterministic design, which according to some responds to the laws of quantum mechanics, which consequently assumes the role that religions attribute to the Supreme Being.

These laws do not transcend the universe, but are conceived as inherent to the universe. It is, in essence, an admission of the absence of plausible explanations of phenomena, which can be surreptitiously interpreted only with arbitrary formulas and diagrams.

No less impervious is the mechanistic conception, which is unable to explain the intimate mechanisms that govern natural phenomena.

Perhaps the least traumatic intellectual position is to resign oneself and assume a rational fatalism and accept events for what they are.

With this cautious epistemic approach, we try to describe molecular complexes and their behaviors, focusing on the thermodynamic evolutions that occur within their structures.

In order to do this, we must make an imaginary leap into the past of a few billion years, to arrive at the moment in which the Earth and the first complex molecules were formed, avoiding, however, any theoretical speculation on how this happened because it would complicate the description of the process, which as mentioned we ignore [11-12].

In biology, we distinguish complex molecules, or macromolecules, based on the activity they perform in structural and functional. This distinction is actually useful only from a didactic point of view, since in biological systems, macromolecules of the same class often perform both functions.

For example, carbohydrates (sugars) have both functional and energetic (starch, glycogen) and structural (cell wall of plants and bacteria) activities, lipids serve as energy reserves (fat reserves) or as fundamental structural elements of cell membranes, phospholipids.

Basically, macromolecules are all made up of the same chemical elements but differently organised, which are as follows Table 1:

Table 1 Most common chemical elements in nature

Element	Atomic symbol	% in Body mass
Oxygen	O	65.0%
Carbon	C	18.5%
Hydrogen	H	9.5%
Nitrogen	N	3.3%
Calcium	Ca	1.5%
Phosphorus	P	1.0%
Potassium	K	0.4%
Sulphur	S	0.30%
Sodium	Na	0.20%
Chlorine	Cl	0.20%
Magnesium	Mg	0.10%
Iodine	I	0.10%
Iron	Fe	0.10%

We have previously argued that a substance is characterized by its structural conformation and associated energy content, which according to quantum mechanics manifests itself at all levels, from the atomic to the macromolecular, in the form of electromagnetic activity in its various declinations.

An important aspect that strikes us about molecular structures, the meaning of which we do not understand, is the presence of asymmetry. Asymmetry is the lack of orderly distribution of the parts of an object such that a geometric element (a point, a line, a surface) can be identified in such a way that each point of the object placed on one part of it corresponds, at an equal distance, to a point on the other part [12-16].

This very interesting and difficult to interpret property has always attracted the attention of researchers who have not been able to give an explanation for this phenomenon yet.

Thus, all active biological molecules do not have a center of symmetry, and belong to only one category, among the possible mirror forms they assume, called enantiomers, which are of the D type or the L type, Fig. 2.

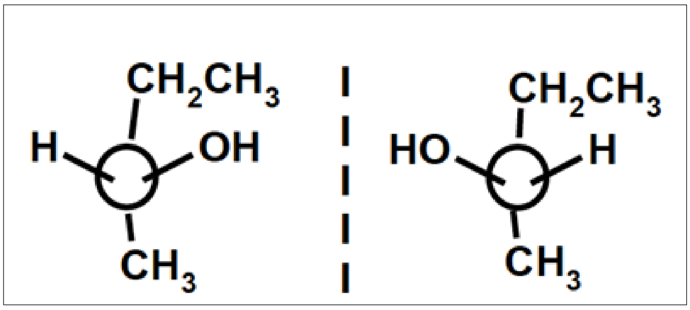

Figure 2 Example of Stereoisomers that are Not Superimposable mirror images are called ENANTIOMERS

Other important molecules, such as sugars, have multiple chiral centers (they are not superimposable on their mirror image) and therefore exist as multiple optical isomers. Only the sugars of the D series are important for humans, just as only L-amino acids enter into the “construction” of proteins. Enzymes, that is biological catalysts, are stereospecific and recognize only optical isomers of one type.

The most intriguing aspect of this property is that it is in antithesis to biological organisms which instead exhibit various types of symmetry.

The possible explanation of the phenomenon could be that the adoption of a single molecular structure, among the possible enantiomeric ones, has the advantage of giving a unique, unmistakable and recognizable response in all biological systems, at the moment in which the steric coupling between the molecules active in the metabolic processes occurs.

Having a unique shape for each molecule, which is represented by its "*molecular imprinting"* or unique three-dimensional molecular imprint, offers biological systems the guarantee of an orderly and rational effective functioning, avoiding chaos and useless and unproductive confusion.

And this is what we observe when examining the molecules present in living systems, we find a single class of amino acids, carbohydrates, glycerides and fatty acids, as well as in informational molecules, in neurotransmitters, in hormones, and so on.

This is what happens in molecules that perform functional activity, while complex structural macromolecules, such as polymers, respond to a different morphogenetic logic. In this case, the essential role that comes into play is the three-dimensional conformation, which can assume infinite forms (primary structure, secondary structure, tertiary and quaternary), based on the sequence of the constituent monomers Fig.3.

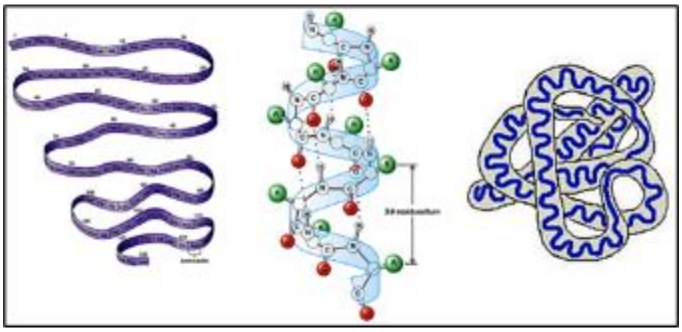

Figure 3 Protein Primary structure (Left) Secondary structure (in the Center) Tertiary structure (Right)

So, if we want to hypothesize the fundamental rules that guide the formation of matter, we can summarize them as follows:

Uniqueness of the constituent elements, atoms, molecules, macromolecules, each of which has a unique and unmistakable three-dimensional structure, which is the **steric imprint** that distinguishes them;

Consequently, each one has a unique and unmistakable energetic, electromagnetic and charge content detectable with appropriate instrumental methods;

As the level of structural complexity increases, the possibility of incorrect functional coupling between different entities is reduced, which instead occurs on the basis of steric affinities and complementary energy content, examples: substrate enzyme, receptor effector molecule, and so on.

These properties have guided and continue to guide molecular evolution and that of living beings towards different and continually evolving forms and expressions, while those currently existing have reached a dynamic equilibrium with the external environment.

3. Morphogenesis of biological macromolecules

After acquiring the ability to form unique macromolecular complexes and to recognize each other, molecules have taken a fundamental evolutionary step: they have learned to cooperate synergistically.

If with the single contact and fusion between similar molecules it was possible to obtain structures capable of fulfilling increasingly complex functional roles in an effective way, with the cooperation and coordinated organization of the individual operations, it was possible to exponentially accelerate the evolution towards ancestral life forms [17-18].

In this way it was possible to divide the morphogenetic activities by assigning them to specialized groups of macromolecules.

This is what we observe in current living systems, where vital functions are divided between molecules that act in a synchronous and rigidly coordinated way.

Metabolism, protein synthesis, reproduction, etc. are just a few examples of the perfect homeostatic functioning present in all cell types.

In fig.4 we report the scheme of sugar metabolism (Left) and oxidative phosphorylation (Right).

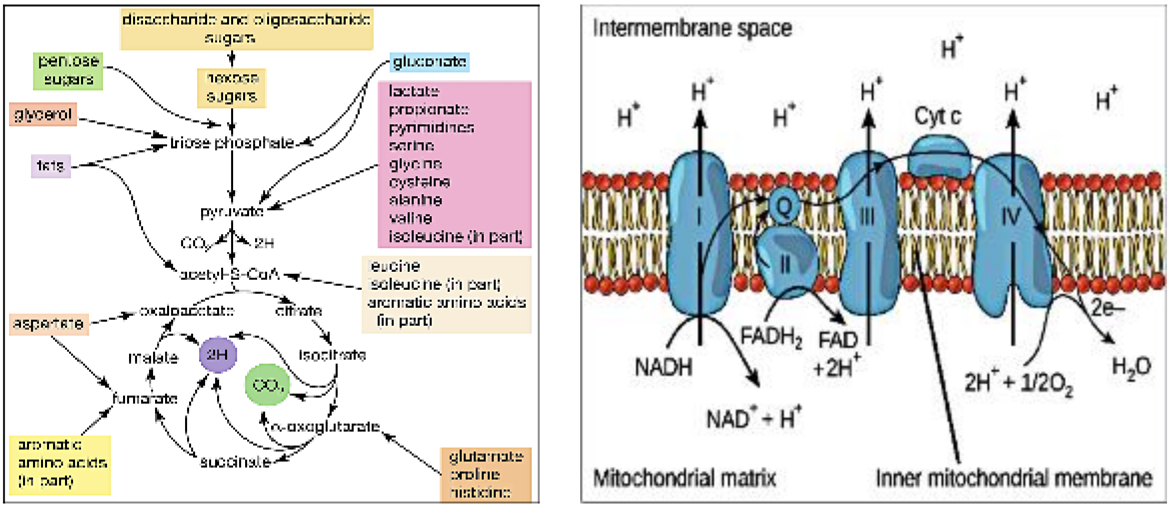

Figure 4 Example of coordinated and synergistic molecular transmission

4. Spiral and helix shapes increase the informational and energetic content

In nature and in the universe, there are numerous examples of structures that have a spiral or helical conformation, or have a branched polymeric conformation, while no structure assumes the linear dimension [19].

This phenomenon is repeated at the microscopic and macroscopic levels.

In Fig. 5 we report some examples of these structures.

One might ask why these structures are so widespread in nature, and what conformational or energetic reason privileges them?

If we look at the shape of spirals and helices, we can find possible explanations.

A spiral is a flat open curve generated by a point P rotating around a fixed origin (“pole” of the spiral), while increasing or decreasing its distance from it according to a given law.

A helix is a curve in three-dimensional space, represented by a line wrapped at a constant angle around a cylinder.

If we compare a spiral or helical shape to a linear one, we can observe that the first two shapes can accommodate a greater amount of information than the linear shape and can also contain a greater amount of energy accumulated in the folding of the coils.

Let's think about the example of a spring, DNA, alpha helix proteins (collagen), etc.

The only linear form found in nature is the beta sheet, which in any case is folded and can accommodate more information and energy than the pure linear form.

In the DNA contained in chromosomes, there is a supercoiling of the structure that can contain billions of pieces of information in a microscopic dimension Fig.5.

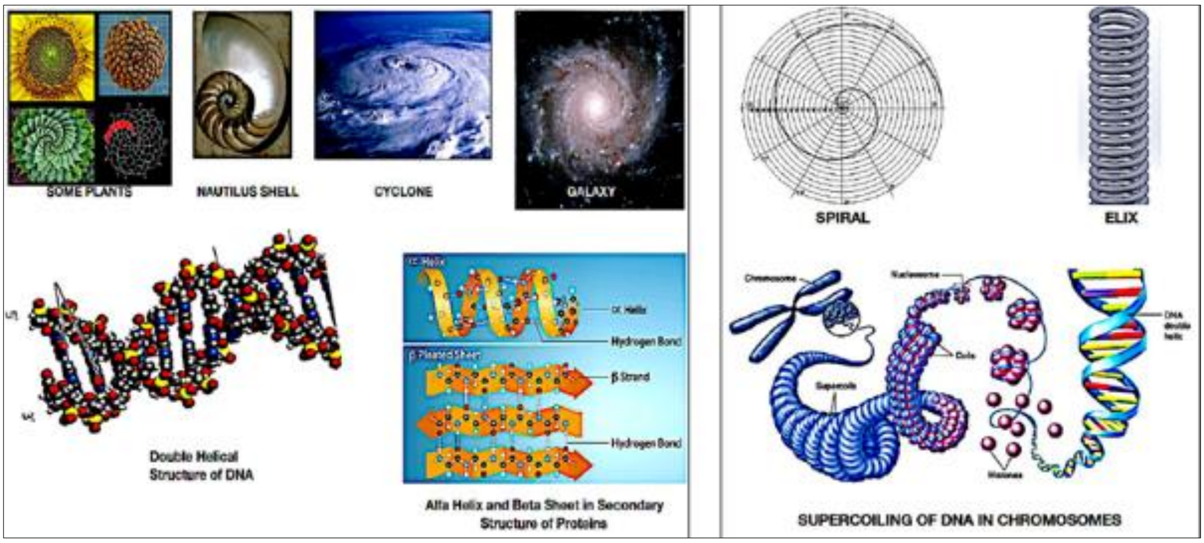

Figure 5 Example of spiral and helical forms present in nature

Another advantage of spiral or helical shapes is that they can contain information both along the spiral or helical line and within it.

The other macromolecular forms widespread in nature are formed by branched polymers.

Both in the group of carbohydrates (sugars), as well as in the group of lipids (fats) and proteins we can observe the formation of complex polymers that assume different structures.

In the sugar group, we find polymeric complexes that perform both energetic functions, in starch and glycogen, and structural functions, in cellulose in plants, amino sugars in the cell wall of bacteria.

Similar behavior is observed in the group of fats that form storage polymers and structural complexes, such as cell membranes.

Even in the case of the polymers just described, the reason for the formation of complex structures must be sought in their plasticity and functional adaptability and in the simultaneous ability to accumulate notable quantities of energy in the very limited spaces available inside the cells.

Of all the structures described, those that present the most extraordinary structural and functional capacity are proteins.

The term protein means "first, principal", derives from the Greek π ρωτεῖος "which occupies the first position", and indicates that they are of fundamental biological importance, present in all living organisms as the main components of cellular protoplasm, and constituents of enzymes, antibodies, respiratory pigments, numerous hormones, sensory receptors, ion channels, etc.

They share the extraordinary ability to assume the most varied forms; their name recalls that of Proteus, a marine deity from Greek mythology, who had the ability to take any animal form or the form of an element (fire, wind or water) to escape from whoever questioned him.

In nature there are an incalculable number of these structures, many of which have an unknown mechanism of formation, such as prion proteins.

5. The Strange Case of Prion Proteins

All proteins have a major structural and functional role in cellular metabolism, some of them also perform a singular reproductive activity.

As mentioned above, proteins are polymers that can assume infinite conformations, which is why they are the most abundant macromolecules in nature.

We know that some of them are able to replicate, like prions, and give rise to serious diseases.

Prions have been discovered in nerve cells. The normal form of the prion protein, PrP, is found on the surface of nerve cells, but when it assumes the incorrect shape, it clumps into long fibrils that block the normal functioning of the brain.

The Central Dogma of Biology states that the flow of genetic information is unidirectional: it starts from nucleic acids and ends up in proteins, without considering a reverse path according to the scheme:

DNA → messenger RNA → Protein

Thus, according to this principle, polymerization reactions directed by molecular templates (DNA and RNA), allow for the accurate storage and processing of the information they contain, and translate it into the sequence of the innumerable polymeric proteins present in nature.

Prions, however, have a particular characteristic: if they assume the wrong shape, they can transform other proteins and make them assume the same shape. In this way a small number of incorrect prions can modify an entire population of normal prions by converting them one by one into the wrong shape with a cascade action, similar to dominoes [20-23].

The normal and correct conformation of the human prion **PrP** has two short beta- sheet -like folds and three alpha helices, two of which are linked by a disulfide bridge, Fig.6.

The fragments of the prion chain containing alpha- Helices can assume a beta- Sheets structure and induce, by contact, other peptides to transform into beta- Sheets and aggregate with the previous ones.

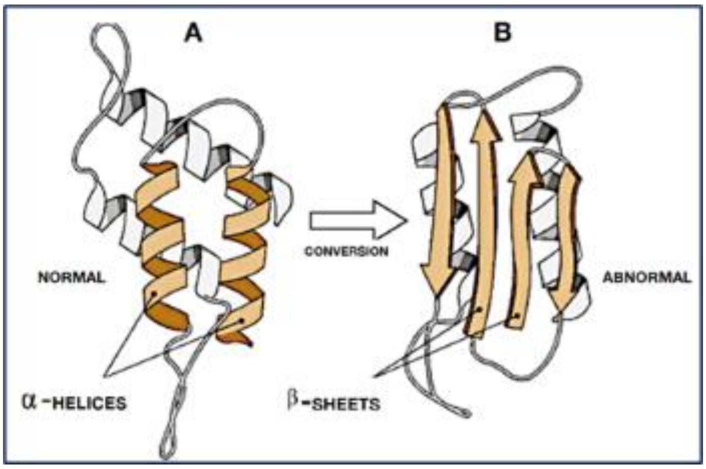

Figure 6 Schematic mechanism of the transition from normal to pathological prion

A malformed prion with beta- Sheets can thus transform thousands of normal prions like dominoes. In this sense, prions can replicate and become "**infectious**" [24-28].

This is an example about the importance of the conformational structure of molecules for their biological activity, and of the information content they carry, and finally of their ability to reproduce.

We know that prions in their normal form are found in nerve cells, but their exact function has not been determined with certainty yet. Their irreversible pathogenic effect manifests itself when they transform the portions of alpha helix into Beta Sheets, due to incorrect folding of the molecules, which aggregate into macromolecular complexes inside the cells, preventing their physiological functioning.

Due to this characteristic, prion-like proteins are considered capable of having given rise to probiotic life forms [29].

6. Conclusion

From the description of the properties of the molecules that we have presented in this article, we can draw a summary and draw some useful conclusions for further investigation.

- All the atoms and molecules that form the material things present in nature have a unique and distinctive conformation and energy content, defined as a molecular imprint, which carries useful information in the selection of similar structures that can give rise to a process of evolutionary improvement that best responds to environmental adaptation;
- The interaction between different molecules is an unavoidable necessity to give life to complex structures, the single molecules isolated in the sidereal vacuum, do not produce any effect and have no reason to exist.
- As the complexity of macromolecules increases, their conformational content and the possibility of modifying the steric arrangement in response to functional needs or environmental stimuli increases. This is one of the main characteristics of proteins that makes them capable of performing functional and structural tasks. Actin, Myosin, Tubulins, channel and receptor proteins are some examples.
- And in some cases, they are able to reproduce, like Prions;
- Another aspect is the ability acquired during evolution to organize themselves into complex supramolecular systems or complex polymeric apparatuses, capable of cooperating synergistically and in a coordinated manner, which even contains a feedback system to control the effectiveness of operations. Metabolism, protein synthesis, DNA duplication, cellular reproduction, etc. are examples of the power that molecules have when they interact and communicate with each other.

In order to conclude, I'd like to highlight what in my opinion explains the origin and evolution of molecules, it is precisely the ability to interact and communicate with each other to form matter, and it is the most relevant aspect that characterizes them, because through their interaction they can manifest the properties they carry and experiment with new possibilities of aggregation.

This article responds to the need, shared by many researchers, to propose answers to the numerous questions that plague the human mind.

Of all the questions that have occupied scholars for millennia, the most mysterious and the one that will probably never find an answer is related to the origin of matter and the universe.

But this depends on the limited system of knowledge that nature has endowed us with, to be able to face similar questions, but on the other hand it has endowed us with an innate curiosity that pushes us to want to know our world, and this makes us feel alive and gives meaning to our life.

I conclude with a message to take home, repeating Descartes' motto:

"Dubito, ergo cogito, ergo sum", (I have doubts, therefore I think, therefore I exist).

Compliance with ethical standards

Disclosure of conflict of interest

The Author declares that he has no conflicts of interest for this article

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