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Research Article

The Electric Charge Property-Related Phenomena of Chromosomes and their Implications on the Construction, Function and Abnormalities of Chromosomes

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ABSTRACT

Introduction: We spent over two decades in an effort to search and study the same electric charge properties of chromosomes that were doubted, rejected and ignored in main stream theories and concepts in genetics and molecular biology.

Materials & Methods: All studies described in this publication were organized at the Human Genetics Laboratory, Munroe-Meyer Institute for Genetics and Rehabilitation, University of Nebraska Medical Center, USA. They provided chromosome materials, funding, technologies, consumptives and resources used in this study.

Results & Discusssion: Our searching revealed previously unnoticed similarities,magic numbers, and Fibonacci like spiralsin the construction of chromosomes and previously undescribed structures and events related to the density, measurement ofelectric current, and model for the interactions between negatively charged DNA and positively charged histones. We use the charge of chromosomes to reveal issues and to propose solutions concerning six fundamentally important events and constituents in the construction and function of chromosomes:the purpose of nucleosomes; the importance of heterochromatin; the primary mission of packing DNA into chromosomes;missions and mechanisms for homologous chromosomes, crossing over,and information systems

Conclusion: This publication presents novel ideas, findings and proposals concerning the electric charge property-related phenomena of chromosomes and their positive implications on the construction and function of chromosomes along with the negative effects that are responsible for the development of numerical and structural abnormalities of chromosomes seen in health conditions with a chromosomal etiology.

Keywords: Electric charge properties of chromosomes, Construction, Function and abnormalities of chromosomes

INTRODUCTION

The The electric charge property-related phenomena of DNA and chromosomeshave a long history famous with two remarkable episodes.

In the first episode,charge of chromosomes was extensively studied for nearly 140 years in several research areas.In cell biology, electric charge of chromosomes had been reported in the spindle apparatus of a cellsince Fol [1] discovered it. He considered that the functioning of the microtubules of the spindle apparatus was driven by electromagnetic forces created by existing electric currents and magnetic fields.During the next 145 years (1876 – 2020),the construction and electric function of the spindle apparatus has been studied by many researchers. Among them are the extended studies completed by Gagliardi[2-3] and Gagliardi andShain [4]. They reported electrostatic forces not only at the microtubules and other parts of the spindle apparatus, but also at the kinetochore and centromere of chromosomes where microtubules are attached during the division process. Also, long and short arms of

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chromosomes were reported as places where electrostatic forces are operative yet no information was provided for their origin or in regards to their mechanisms.

In electrical engineering, the electric effects on DNA, chromosomes and the human body have beenstudied for over 100 years. Tesla [5]was among the first who suggested that bodily tissues act like a “condenser”, which is the basic component for an equivalent electric circuit and only recently was considered to exist in the human body. According to Tesla, this unique property of the human tissues indicates an inherent ability for adaptation and perhaps innate compatibility with the presence of high-voltage electric fields.Lakhovsky[6] is credited as the first person to suggest that DNA acts as a self-inducting electric coil which allows cells to function like a tuned resonant circuit. This circuit is capable of vibrating sympathetically (resonating) to its resonant frequency when exposed to the range of frequencies output by the multi-wave oscillators. He indicated that cells,when subjected to a spectrum of vibrations, find their own frequency and start to oscillate in resonance.

In physics and biophysics, charges and related electric phenomena have been studied sinceMiescherdiscovered “nuclein” known today as DNA . During the last few decades, experimental studies with modern methods revealed the importance ofelectron transfer through DNA charge transfer dynamics in DNA, photoinduced electron transport in DNA and other phenomenon.During the last 25 years, the dynamics of electric charges and related electric effects in DNA systems were extensively studied with modern techniques and methods by many researchers. Among them were Kornyshev, Kornyshev and Leikin and Kornyshev and Wynveen who found that homologous chromosomes were using electrostatic interactions to locate and recognize their genes and alleles prior to recombination. This phenomenon not only takes place from a distance but also occurs without unzipping and in a protein free environment. Bouwman and DeLaat, Crane et al. and Fudenberg et al. suggested that electrostatics interactions play an important role in the communication between chromosomes. Forth et al. Sheinin et al. and Dame et al. reported that chromosomes were utilizing single-molecule unzipping and other forces for physical motion, dynamics, mechanisms, and regulation of molecular motors that translocate along DNA during replication and transcription. Zhao and Zhan found that electric fields in chromosomes are operative for completing major activities during mitosis and meiosis, including centrosome trafficking, chromosome assembly during mitosis and synapsis between homologous chromosomes in meiosis. Lund and Jönsson proposed the existence of a charge regulation in the functions of both the singular and double stranded forms of DNA. Daban found that chromosomes use various interaction energy components for controlling their shape, dimension and mechanical properties. Lastly, Bloom Bloomfield , Woodcock Manning and others studied the complex organization of DNA and histones into chromosomes as governed by charge interactions and coupled electric effects.

In histology and embryology, a revolutionary discovery was made by Gurwitsch[28]who was the first to obtain experimental data on the electromagnetic phenomena “ Mitogenetic radiation” and “Biophotons” of chromosomes in mitosis, where light was emitted by the dividing cells during mitosis. Later, the same electric charge effects and related phenomena were confirmed when the photon counter multiplier was developed and used by the daughter of Gurwitsch .Her studies were repeated by many other researchers working in different countries - . Their studies found that “ Mitogenetic radiation ” and “ Biophotons ” were real phenomena, later renamed "Gurwitsch ray” in honor of the original founder.

In nanotechnology and electronics, substantial efforts are focused on possible practical applications of electric and electronic properties of DNA for development of new information systems and technology. Their rationale is that electronic phenomena related to DNA and chromosomes need to be studied and used in the design and production of a new range of electronic devices that are much smaller, faster and more energy efficient than the present semiconductor-based electronic devices. Among them are the ideas for the development of: a DNA-based super-fast computer chip ; memory devices which can store more information than trillions of compact discs ;construction and 'growth' of electronic parts by a sequence of specific molecular lithography ;building nano-biomolecular logical devices from DNA-based single-electron transistors and quantum-bit elements ;inventing DNA-based programmable circuits, wires and devices ;design of DNA origami ;; inventing a new generation of electric circuits, transistors and computers which could help to overcome the limitations of the currently used classical silicon-based electronics ; and using the spatial organization of a genome and its physical properties for constructing an effective mechanical communication device .

In genetics, charges and related electric phenomena of chromosomes were reported by Smith and Handmaker[40], Ohno et al. Verma et al. and others. They used the word charge to describe a strange phenomenon of human chromosomes where the satellites of two or more acrocentric chromosomes were considered to bechargedleading to the attraction and ultimate joining of the chromosomes into satellite associations. However, there were no additional studies and no explanation of what chargemeans and how, when, and why it appears in chromosomes.

In the other episode,the history of electric charge in chromosomes is famous with strong negative opinions, doubtsand rejections which has kept the ideas and findings out of the main stream concepts and theories in genetics and molecular biology where the construction, function and abnormalities of chromosomes are primarily studied.These negative opinions and notions occurred in 1933 after the Nobel Prize laureate in chemistry, Irving Langmuir , criticized and presented Gurwitsch’s discovery of “Mitogenetic radiation” and “Biophotons” as an example of a “pathological science” and "the science of things that aren't so”. The critical opinion of this Nobel Prize laureate is highly respected in genetics and molecular biology. Today many researchers continue to doubt

and reject ideas about the existence of electric charge properties and phenomena in DNA and at the chromosomal level.

Our research has been conducted over two decades in an effort tosearch and study the electric charge properties of chromosomes. Our purpose was to find answers for three fundamental questions. First, what is the basic mechanism for the charge and other electric and electronic property-related effects and phenomena of chromosomes? Second, can charge and its electric effects be used to solve issues concerning the structures, function and abnormalities of chromosomes? Third, is it possible to use charge and its phenomena to solve issues concerning the origin, prognosis, treatment, prevention and curing of cancers, Down syndrome, infertility, spontaneous abortions, mental, physical, and metabolic disorders and other human diseases, syndromes and health conditions with a chromosomal etiology? These questions and their answers led us to novel ideas, findings and proposals some of which werepresented in this publication.

MATERIALS & METHODS

The chromosome materials, classical and modern methods used in this study are identical with those described in detail in a previous publication .

RESULTS AND DISCUSSIONS

Our studies found three previously unnoticed similarity to the Tesla coil transformer, magic numbers and Fibonacci like spirals in the construction of chromosomes, nucleosomes and solenoids.

Chromosomes are similar to the Tesla coil transformer

This similarity was found by us during the previously described clinical diagnostic studies of human chromosomes and experimental studies with chromosomes of animals .
Particularly, we were surprised by the similarity of human acrocentric chromosomes 21 which is responsible for the development of Down syndrome. It was amazingly similar in construction, function and abnormality to the electric transformer invented by Nikola Tesla and known as the Tesla coil transformer. Detailed information for these similarities including their descriptions,illustrationsand discussions, were published .

Nucleosomes contained magic numbers in their construction

In mathematics, the " magic numbers " are comprised of the number eight plus endless ordinary numbers of 1, 2, 3, and so on as shown in Table 1.

Table 1. The multiples of the magic numbers 8 + 1 = 9 of nucleosomes.

1	X 8	+ 1	= 9
12	X 8	+ 2	= 98
123	X 8	+ 3	= 987
1234	X 8	+ 4	= 9876
12345	X 8	+ 5	= 98765
123456	X 8	+ 6	= 987654
1234567	X 8	+ 7	= 9876543
12345678	X 8	+ 8	= 98765432
123456789	X 8	+ 9	= 987654321

The same magic numbers 8 + 1 = 9exist in the construction of the nucleosome. The number eight consists of histones H2A, H2B, H3, H4 plus one ligation proteinH1 in a nucleosome shown in Figure 1.

Figure 1

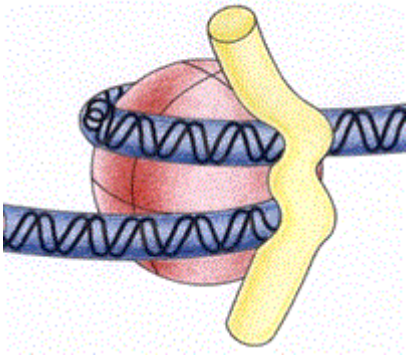

Figure 1. Schematic drawings of nucleosome: DNA (dark blue) turned twice around a ball of eight core octamer histones H2A, H2B, H3 and H4 (red) and supported by one ligation of protein H1 (yellow).

The Eight in the Latin language is "octo" and for this reason eight histones of the nucleosome are presented as "octamers". The existence of eight core histones and the ligation histone of nucleosomes was first proposed by Kornberg who received a Nobel Prize in 2006. The first description was published by Olinsand Olins and detailed descriptions were prepared by using scanning electron microscope (SEM),X-ray, and crystallography (XRC) diffraction by Jones and Marini et al. .Table 2 shows how the magic numbers are found in the construction of nucleosomes.

Table 2. The magic numbers of 8 + 1 = 9 in the construction of nucleosome.

Number of nucleosomes	X	Number of octamer histones	+	Number of H1 ligation proteins	=	Total number of octamer histones and ligation proteins

1	X	8	+	1	=	9	

Solenoids contained magic numbers and Fibonacci like spirals in their construction

The construction of the solenoid model of chromosomes was revealed by Finch and Klug [54], Jones [52] and others. Using nucleosome images obtained with the same modern methods, SEM and XRC, they found that solenoid of the 1st level is built of two loops of DNA each containing six nucleosomes with the total number consisting of the same magic numbers 12 x 8 + 2 = 98 of histones (Table 3).

Table 3. The magic numbers 12 x8+2=98 of histones in the construction of solenoids of the 1st level.

Level of organization of solenoids	Number of multiple nucleosomes in solenoid levels	X	Number of octamer histones per nucleosome	+	Number of limitation histones per level of solenoids	=	Total number of octamer histones and limitation histones
1	12	X	8		2		98

This number is a combination of 96 octamerhistones of 12 nucleosomes (12 x 8=96) plus two "limitation" histones. Studies with SAM showed that one of the ligation proteins is located at the beginning of the solenoid and the other is located at the end. The exact function of these two histones is not fully understood.

Due to technical reasons, the exact numbers of histones of the tightly packed and overlapping solenoids of the second and subsequent levels are difficult to count. However, pictures took with SEM and XRC suggest that they were found identical with multiplies of the magic numbers of 8+1=9 as shown in Table 1.

The magic numbers of histones found in the construction of nucleosomes and solenoid of the 1st level could be co-incidental or a real mathematically designed architecture. If real, they suggest that nucleosomes, solenoids and chromosomes are built of perfectly made spirals like those known in mathematics as the perfectly made and mathematically designed Divine spirals of Fibonacci.

The Divine spirals of Fibonacci are based on the phenomenaFibonacci numbers (Φ Phi), Fibonacci sequence, and Fibonacci (golden) ration. They were all discovered in India over 2000 years ago. In 1202, they along with the Arabic numbers, were introduced in Europe in a book (Libre abaci) published in the Latin language by a mathematician Leonardo of Pisa, later known as Fibonacci. Fibonacci numbers and sequence are endless sets of:

0+1=1

1+2=3

2+3=5

3+5=8

5+8=13

8+13=21

13+21=34

21+34=55

34+55=89

55+89=144.....

The Golden ratio of Fibonacci numbers is = 1.618. The most important mathematical concept for our study was the perfectly made, high order, multi-level Divine spirals of Fibonacci. They are found in the unique spiral arrangements of many living and non-living things. Among the living organisms, the most famous are the perfectly made spirals of seeds of sunflowers and shells of terrestrial sea and freshwater snails. Among the non-living things the most famous are the galaxies in cosmos arranged in a perfect spiral shape.

The same perfectly made, higher order, multi-level spirals are found in the chromosomes of all plants, animals and humans. They are built with billions of different combinations of DNA bases, histones, and other material to give variety in size and shape. Such perfectly made spirals could be built only with the mathematically based architecture like those described in details for Fibonacci's numbers, sequence, ratio and spirals.

The magic numbers, similarities and suggestions described above were the main reason and starting point of our studies and the search for electric charge properties and phenomena of DNA and chromosomes.

We studied three previously unstudied structures and events in the construction and function of DNA chromosomes that are related to their electric charge properties

The results of these studiesshowed that the electric charge effects at the DNA and chromosome level andare in support of our suggestion and proposals described in this publication.

Calculating the density of DNA and chromosomes

The density of packing DNA and histones into chromosomes is one of the main factors in studying the electrical effects and phenomena of chromosomes. Our calculations are based onthe information published by Klug and Passarge.According to these studies, each DNA molecule is packaged into a mitotic chromosome that is 10,000 times shorter than its extended length. We tried to provide a rough estimate of the density of an " average " chromatid by estimating its volume and mass. We estimated an "average" volume of 1.92325 x 10-18 m3. Next, the mass of an "average" chromatid is essentially twice the mass of DNA (since the respective mass of histones is approximately the mass of the DNA). The mass of the DNA in an " average " chromatid is approximately equal to (6.4x109 bp/cell x 650 Daltons/bp x 1.66x10-27 kg/Dalton) / (46 chromatids) = 1.50122 x 10-16 kg, whereas the total mass of the "average" chromatid would be twice that number (since adding the histones mass): 3.00243 x 10-16 kg. Now, taking into account the volume approximation of the chromatid, we have finally obtained that the density of an "average" chromatid is about 156.11 kg/m3. This density is similar to the density of balsa wood (130 kg/m3) or pressed wood (190 kg/m3) as reported by Falk.

Measuring electrical current and electrostatic interactions

The best way to provide evidence for the existence of charge and other electrical and electronic property-related phenomena of chromosomes is to measure the charge. However, in clinical genetics these studies are not available and therefore, we asked for help from specialists in physics and biophysics working in the USA, Japan, France and Russia. Under our request and materials provided by us, charge of DNA and chromosomes was measured by using methods that visualized the movement of remaining charge in a special part of the DNA by attaching a charged fluorescent dye to RPA; measured charge effects and forces known as the strain energy of homologous chromosomes;measured charge of chromosomes with the non-destructive thermal step method; and measured the effect of DNA molecules on streaming current. The methods utilized in these studies and the results obtained are described by Mizuno ,Mizuno et al. Kanev et al. Toureille[60], and Notingher et al. All results provided evidence in support for the existence of electric charges at the DNA and chromosome level.

We propose a model for the interactions between negatively charged DNA and positively charged histones.

Our proposal is based on the theoretical ideas and experimental studies of Mizuno , Toureille, Notingher et al. , Yoshikawa andWai-Ning Meiet al.We suggest that counter ions, with respect to the high density negative charge along the double stranded DNA structure and the positively charged histones, play essential roles in the self-organization and transitioning of DNA into a structure of a higher order.

Our goal was to explore the effect of the dielectric properties of these counter ions (as a result of the surviving, residual, excess) negative charge (on the portion of chromatin where the histones are wrapped) where they are operating normally versus where they are largely acetylated. We suggest that in the large and highly organized biological molecules, like chromosomes, the phenomena of a " charge " and its electrostatic and electrodynamic properties are associated with the billions of counter ions and their charge illustrated in Figure 2.

Figure 2

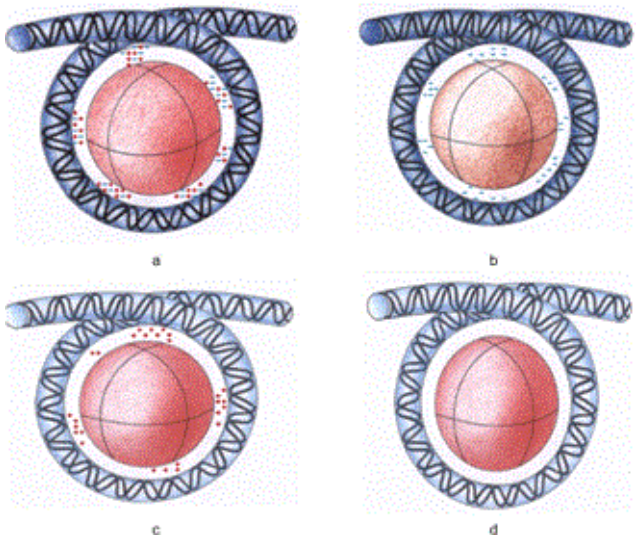

Figure 2. Schematic drawings of nucleosomes show the negatively charged DNA (dark blue), the positively charged histones (red) and the corresponding counter-ions (Fig 2a); Negatively charged DNA (dark blue) and a largely acetylated histone (brownish red) due to resulting excessive (surviving) negative charge (Fig. 2b); Largely phosphorylated DNA (light blue) and positively charged histones (red) show a resultant positive charge (Fig. 2c); Largely phosphorylated DNA (light blue) and largely acetylated histones (red) are characterized by zero charge, zero excessive (surviving) charge (Fig. 2d).

For short, these new models are named One Essential Charge Operating Unit (OECOU) of DNA and chromosomes.

The considerations presented above together with the measured electric current and electrostatic interactions showed that electric-charge phenomena are of fundamental importance for a realistic description of the structure and function of DNA and chromosomes.

We propose that the electric charge property-related phenomena of chromosomes should be included in the main stream theories and concept in genetics and molecular biology.

We use the charge of chromosomes to reveal issues and to propose solutions concerning six essentially important constituents and events in the constructionand function of chromosomes

The Purpose of Nucleosomes

Nucleosomes were discovered by Kornberg and Olins and Olins over 55years ago. Their purpose is still not fully understood. It is known that nucleosomes are built of histones that are wrapped with DNA, yet their purpose is not known. Lorch et al. , Han and Grunstein and Han et al. considered nucleosomes to be a general gene repressor, but no additional explanations were provided. At the same time (circa 1987 – 1988), it was known that the histones are positively

charged and that DNA has negative charges but the possible structural and functional roles of these electric charges was not discussed.

Using charge of chromosomes, we proposed that the main purpose of nucleosomes is to join in OECOU the negatively charged DNA and the positively charged histones described and illustratedabove. We also consider that these OECOUs play an important role in both the normal construction and function of DNA and chromosomes and in the development of breaks, translocations, fusions and other clinically important abnormalities of chromosomes.

The Importance Of Heterochromatin

T he heterochromatin was discovered by Heitz who in 1928 divided chromatin in two major groups – euchromatin which is light in color, loosely coiled and rich of genes for encoding important proteins and heterochromatin which is dark in color, tightly coiled, highly repetitive and free of genes for important proteins. About 98% of the human genome is comprised of heterochromatin.

Due to a lack of important genes, the heterochromatin is considered to be inert, genetically inactive, useless "junk" of DNA. Heterochromatin has been misunderstood, not well studied and not regarded in the clinical diagnostic work in genetics. This is one of the biggest mistakes and misunderstandings in genetics.

Using charge of chromosomes, we suggest that the heterochromatin is not useless " junk" but a very important constituent of DNA.Our proposal is based on the fact that heterochromatin is rich of negatively charged DNA and positively charged histones packed into nucleosomes which are as indicated above OECOUs. Based on this fact,we suggest that the heterochromatin has an important purpose and mission – to provide materials necessary to constitute the nucleosome which are the OECOU of chromosomes. Through these numerous OECOUs, the heterochromatin participates not only structurally but also " electrically " in the construction and function of chromosomes.

Our suggestion of the importance of heterochromatin received strong credible support by the results of mapping the human genome published by Raney et al. and the Human Genome Project (HGP) reported by Chial. These studies show that in the human genome, heterochromatin is the only genetic material that is more developed in humans compared with the genome of chimpanzee (Pan troglodytes). The chimpanzee has more genes – over 28,000 while the human has only 22,000 genes. The chimpanzee also has more chromosomes in number – 48 while the human has only 46 chromosomes. Furthermore, some of the same studies predict that about 68,000 more genes are available hidden in the human genome. In chimpanzees, it is suggested that there are twice as many hidden genes – about 160,000 in number. These findings show that the evolution of humans is advanced not by more chromosomes or more important genes as it has been suggested for many years, but by the same heterochromatin that was considered to be "useless junk" of DNA for nearly 100 years.

The primary mission of packing DNA into chromosomes

Spiralization, packaging, coiling, and braiding are different words used to describe the process in which DNA, histones and ligation proteins are organized in chromosomes. This process is known from the time 1870-1880 when Hertwig Van Benedenand Weismann discovered the process of mitosis and meiosis. They formulated the first hypotheses and concepts for the mechanism and the primary mission of spiralization and packaging of DNA into chromosomes.

The mechanism of spiralization of DNA was studied extensively with new methods and techniques . Never the less of these brilliantly made studies, we suggest that the mechanism of spiralization is still not fully described. Our suggestion is based on the previously unnoticed "magic numbers" and Fibonacci like spirals described above. They showed that the spirals of DNA are constructed with perfect mathematically designed architecture that was unknown until this publication.

The purpose of spiralization was associated with a century old hypothesis for saving space in the tiny size of the nucleus where chromosomes are located. According to this hypothesis, the primary purpose of spiralization is to make the long DNA strands compact and easier to fit into the small size of the nucleus. Indeed, saving space has its merit concerning the so called " trapping effect " which affects the motion of macromolecules like DNA and other components such as histones, ligation proteins, and free ions in the nucleus as described byZhou et al. and Sharma.However, saving space is not enough to provide an appropriate explanation for all of the important events that occur. For example, if saving space is really the primary need of spiralization and packaging DNA and histones in chromosomes then:

(i) Packaging should be done in a simple way, by using only DNA material. On the contrary, packaging utilizes billions of histones and ligation proteins which result in an increased volume that occupies more space than DNA alone.

(ii) The DNA molecule should be built as a compact body with no empty space in and between the nucleotides and phosphate sugar. In fact, it is just the opposite. There are many empty spaces in and between the nucleotides and phosphate sugar.

(iii) Histones should be built as a single body with a shape appropriate for saving space. On the contrary, they are builtwith an oval shaped body consisting of eight parts (octamer) with an empty space between them which requires and occupies more space.

(iv) Chromosomes should be packed in the same or similar pattern or shape that would allow them to fit into a small space when they are arranged close to one another. Actually, chromosomes are packed into different sizes and shapes, possessing a different number of constrictions with some consisting of satellites and stalks which require even more space.

(v) The long thread of DNA should be coiled equally, like a reel, so that each coil possesses the same maximum tight frequency, however, the coils are made in just the opposite manner. In some areas, the coils are loosely arranged, while in other areas

they are arranged very tightly. Furthermore, the tightly arranged coils are different in structure and are designated by different names such as alpha, beta, and classical satellite DNA.

(vi) Once the DNA and histones are packaged into chromosomes, they should be kept packed - permanently. This event does not occur and after each cell division is completed, the packed structures of the chromosomes are dismantled and the DNA disperses into long strands like they were before packaging occurred.

(vii) Saving space could be a real reason for the spiralization and packing of DNA into chromosomes, only if the unpacked DNA and histones have a problem fitting inside the nucleus and therefore have to be located outside of it. This is not the case as DNA and histones are always in the nucleus, whether they are packed or unpacked. So in fact, there is no need for the DNA and histones to undergo packing in order to save space to fit inside the nucleus because this is their permanent residence.

Obviously, the century old hypothesis for the space saving purpose of packing DNA is incomplete and inaccurate.

Using our findings for charge, "magic" numbers and Fibonacci like spirals, we propose that spiralization and packing DNA and histones into chromosomes is a much more complex and diverse process than it was known before. We suggest that in addition to saving space, spiralization has at least one more previously unknown purpose. It is to build millions of nucleosomes that act as OECOUs as described above.

The Unknown Mechanisms of Homologous Chromosomes

Homologous chromosomes have been known since the first detailed descriptions and illustrations of chromosomes were published . For over 100 years, it has been known that homologs are using unique mechanisms to complete their precise communication, identification, location, and perfectly aligned pairing.

The problem is in the detailed understanding of these mechanisms. Particularly, it is difficult to understand how exactly two homologous chromosomes that are located in different places of the cell nucleus and separated by many other chromosomes are able:

(i) To communicate from a distance in the nucleus that is overcrowded with chromosomes.

(ii) To identify and locate exactly their homologous partner chromosome which is dispersed randomly among many other chromosomes in the overcrowded nucleus.

(iii) To perform the directed motion, exact pairing, and perfect alignment of these homologs.

So far there is no concept or suggestion for these unique mechanisms.

Using charge of chromosomes, we propose a solution for these century old questions and problems. Our suggestion is that chromosomes are using their own electrical signals and frequencies like those used today for wireless communication in every town and country. We suggest that the signals and frequencies used by the homologous chromosomes are specific for every one of the 23 pairs of human homologous chromosomes. In support of this suggestion is the fact that each pair of homologous chromosomes has their own specific size and shape. We hypothesize that the different size, shape and construction allow the homologous chromosomes of each pair to operate charge with different frequencies and signals that are necessary for their exact communication, identification and location among all the other chromosomes.

We suggest that the charge and electrical signals used by the chromosomes are similar to those found in other living cells, tissues and organs. The first electric impulse and phenomenon of the living tissue was recorded byGalvani. He studied the electrical patterns and signals from nerves and muscles of frogs (Rana ridibunda), known aselectromyogram(EMG) and electromyography (EMG). These aresome of the most widely used medical methods for diagnostic and prognostic work with the nerves and muscles.

The first electric impulse of the heart was recorded in 1872 by Muirhead. These impulses and their phenomena were studied extensively in cardiology and physiology and were found to be of utter importance to describe the construction and function of the heart. As a result of these studies, new methods and techniques were developed known as the electrocardiogram (ECG) and electrocardiograph (ECG). They were designed to measure the electric rhythms and signals of the heart. For over a century, the ECG has been one of the primary and most widely used medical tools for diagnostic and prognostic work with hearts.

The first electric impulse and phenomenon of the brain was recorded in 1875 by Caton . Like the impulses of the heart, this finding was considered important and studied in neurology and physiology. As a result of these studies, the electroencephalography technique and the use of theelectroencephalogram (EEG)techniques were developed for measuring the electric rhythms and signals of the brain. For over 100 years, the EEG has been one of the most widely used medical methods for diagnostic and prognostic work with the brain.

Electric impulses and signals of chromosomes were not studied in genetics. We suggest that if studied, they would be found to be of utter importance not only to better understand the construction and function of chromosomes but also to provide the information to develop tools to measure the exact electric rhythm and signals of chromosomes. Furthermore, we hypothesize that if available, these signals would be used for solving problems concerning not only construction and function of chromosomes like those described above but also to explain the mechanisms responsible for the development of human diseases, syndromes and health conditions with a chromosomal etiology.

The Previously Unnoticed Crossing Over And Segregations of Chromosomes

The phenomena of crossing over was described byJanssens . He used " chiasmatypy " to describe the connection site (chiasmata) where two of the four chromatids are crossing over. Chiasmatypy was not accepted and nor used in genetics until the new name " crossing over " was used by Morgan [and others to replace the chiasmatypy. The widely accepted theory presented the phenomena of crossing over and the separation of chromosomes with three strictly formulated characteristics: 1) crossing over and separation of chromosomes are completely random, not directed and uncontrolled events; 2) these events occurred in places where chromosomes, genes and/or alleles are identical; and 3) these processesresults in diversification, adaptation and evolution of living things by making two identical chromosomes, genes and/or alleles different.

However, studies previous to Janssens were widely accepted and revealed numerous cases in which the crossing over and segregations of chromosomes were just the opposite. These studies revealed that crossing over and separation of chromosomes were directed and controlled events that occurred in places where chromosomes, genes and/or alleles were different. They are processes that result in the diversification, adaptation and evolution of living things by making two and more different chromosomes, genes and/or alleles similar and capable to work together in synchrony. This type of crossing over and segregation has typically been documented and studied in hybrid animals and plants. For example:

A mule is a product of a strictly controlled and directed re-arrangement of genetically important material located in genes and chromosomes of two animals belonging to two different species, with a different number of chromosomes, and different genotypes and phenotypes. The parent animals are horse (Equus caballus)and donkeys (Equus asinus). According to Proops et al. [82] horses possess 64 chromosomes in their karyotype and donkeys possess 62 chromosomes in their karyotype. Live hybrid mules, with a chance for normal development, are born with 63 chromosomes. This is not random, but is a strictly controlled and directed number that is exactly intermediate of the chromosome numbers of its parents. The genotype and phenotype of mules are different from those of the horse or donkey. Again, the phenotype of a mule is not random but is a strictly controlled and directed selection of characteristics which are intermediate to those of its biological parents. The same strictly controlled and directed mechanism of chromosomal crossing over is known to exist in many other hybrids of animals and plants. A sheep-goat hybrid which is born from mating a sheep (Ovis aries) that has 54 chromosomes with a goat (Capra hircus) that has 60 chromosomes. Live hybrids, with chance for normal development, are born with complements of 57 chromosomes, which again is intermediate to the chromosome makeup of sheep and goats.Today, from all known hybrids the most famous and important in human history are those of: wheat (Triticus vulgaris), developed in Egypt; rice (Oryza sativa), developed in China; and corn (Zea mays), developed in Mayancivilizations in Central and South America. They are all a product of millennia long, strictly directed and controlled hybridizations and re-arrangements of genetically important materials.

The question is how exactly chromosomes, genes and alleles recognize and rearrange to become similar and capable to work in symmetry when each are very different in number and construction. The answer was provided recently by Kornyshev and Wynveenwho found that homologous chromosomes were " using" electrostatic interactions to locate and recognize their genes and alleles prior to recombination. This finding is in support of our proposals that crossing over and recombination of genes and alleles are processes tightly associated with the electric charge properties of chromosomes. These charge based processes are not fully understood and further studies are required.

Two Concepts for the Information Systems Of Dna And Chromosomes

The first structural-informational concept was coined in genetics when Boveri,Sutton and Morgan proposed and published the chromosome gene theory in 1911. About 60 years later this theory became known as the "Letter language of life". The letters are from purines and pyrimidine bases found by Watson andCrick in the construction of the double helix of DNA, indicated with letters " a "- for adenine, "g" for guanine, "c" for cytosine, and "t" for thymine. These four bases carry information for all living matter which is able to be stored and transmitted from one generation to another. The unique four bases are widely accepted concepts in genetics, cell, and molecular genetics [Collins].

The second electric-charge dynamical information mechanism concept in DNA and chromosomes is based on electric charge effects and phenomena. This charge-based information system has been popular and extensively studies in nanotechnology and electronics. As indicated above, charge-based information systems of DNA were studied in an effort to use them for the design and production of a new range of electronic devices that are much smaller, faster and more energy efficient than the present semiconductor-based electronic devices. During the last 30 years, this concept was extensively studied by Gariaev and Pitkanen and Gariaev et al. They proposed the existence of long-range interactive forces and languages at the DNA level with notions to be part of a " DNA quantum biocomputer " , " DNA phantom effect " and " Wave-based genetics". They suggested that DNA could carry and transfer genetic information in the form of special physical fields and methods, including sound and images and perform strategic management functions concerned with biosystems, biochemical systems, and actual physiological conditions. These proposals contained ideas which are imaginative and speculative and further studies are necessary for providing evidence in proof and confirmation. These concepts are doubted, rejected, not studied nor included in the main stream concepts and theories in the field of genetics.

We suggest that both – the chromosome gene theory and the electric charge effects information systems exist but further studies are needed. Based on our studies and results described in this publication, we suggest that the first information system

known as the language of lifeexists at the DNA level where purine and pyrimidine bases are located. The second charge-based information system exists at the chromosome level where interactions between positively charged histones wrapped with negatively charge DNA is available.

We use the charge of chromosomes to reveal issues and to propose solutions concerning the numerical and structural abnormalities of chromosomes

Unfortunately, the electric charge property-related phenomena of chromosomes described above do not always have a positive effect on the construction and function of chromosomes. Occasionally, they may have a negative destabilizing effect instead. This creates the development of breaks, translocations, fusions, non-disjunction events and other abnormalities of chromosomes which are found in patients suffering from cancer, Down syndrome, infertility, spontaneous abortion, mental and physical disabilities and other diseases and syndromes with a chromosomal etiology. For this reason, it is very important to correctly understand the mechanism(s) responsible for the development of numerical, structural and functional abnormalities of chromosomes. We have studied the numerical abnormalities of chromosomes caused by the destabilizing effects of charge of chromosomes. These abnormalities and their implication on Down, Turner, Patau and other syndromes associated with aneuploidies are described in a separate publication.

CONCLUSION

Our studies showed that the electric charge property-related phenomena of chromosomes are operative in the functioning and play a fundamentally important role in their construction and function. As aresult of our studies, the electric charge of chromosomes has been:

1) Characterized by previously unnoticed similarity in the physical construction of chromosomes and the Tesla coil transformer; the magic numbers in the construction of nucleosomes; and the Fibonacci like spirals in the construction of solenoids. They showed that many of the essentially important events and constituents in the construction and function of chromosomes are associated with charge based purpose, mission and/or mechanisms.

2) Calculated, measured and presented by the dynamic interactions between the negatively charged DNA and positively charged histones. These studies have indicated that the electrical charge and phenomena of DNA and chromosomes are real scientifically proven phenomena.

3) Used to reveal issues and to propose solutions concerning six of the essentially important constituents and events in the construction and function of chromosomes: the purpose of nucleosomes; the importance of heterochromatin; the primary mission of packing DNA into chromosomes; the unknown mechanisms of homologous chromosomes; the existence of strictly controlled and directed crossing over and segregations of chromosomes; andtwo concepts for the information systems of DNA and chromosomes.

Our studies reiterated that the existence and the importance of the electric charge property-related phenomena of chromosomes has been misunderstood, doubted, rejected, ignored and not included in the main stream theories and concept in genetics and molecular biology where the construction, function and abnormalities of chromosomes are primarily studied. Ultimately, we propose that the electric charge property-related phenomena of chromosomes should be included in the main stream theories and concept in genetics and molecular biology.

We use the electric charge of chromosomes to reveal issues and to propose solutions concerning the mechanisms that are responsible for the development of structural and numerical abnormalities of chromosomes that are causing cancer, Down syndrome, infertility, spontaneous abortions, mental and physical disabilities and other human diseases, syndromes and health conditions with a chromosomal etiology. They will be described in a separate publication.

We are aware of the fact that occasionally in genetics, ideas and findings concerning electrical charge properties of DNA and chromosomes are often subjects of doubts and rejections which occur blindly before their re-examination. To avoid this type of misunderstanding, before publishthese novel ideas, findings and proposals,we presented them for public discussions and critical opinions in 10 conferences and congresses attended by specialists in genetics, molecular biology, chemistry, biochemistry, physics and biophysics. Six of these presentations and discussions were atconferences held in the USA [91-96] and four presentations were at international meetings held in America, Asia and Europe [97-100].We have now been issued the approval for publication by theauthorities of the University of Nebraska Medical Center where these studies were completed when the late Professor Warren Sanger was the director,organizer and co-author of this research.

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