Chapter

The Influence of the Golden Ratio on the Erythrocyte

Marcy C. Purnell and Risa D. Ramsey

Abstract

Erythrocytes must maintain a biconcave discoid shape in order to efficiently operate and serve an important physiological role in an organism. The erythrocyte can be viewed as a toroidal dielectrophoretic (DEP) electromagnetic field (EMF)-driven cell that maintains its zeta potential via a dielectric constant (chloride anion) that resides between a negatively charged membrane surface and a positively charged Stern layer. There are ferromagnetic (iron) and ferroelectric (chloride anion) influences that may be crucial to the maintenance of this zeta potential. We hypothesize that within this uniquely shaped cell resides an interesting geometric mathematical measure, the Golden Ratio, that houses a DEP EMF may be driven/fueled by the zeta potential and may be critical for the efficient recycling of CO2 and the delivery of O2 to organisms.

Keywords: erythrocyte, chloride anion, Golden Ratio, dielectrophoretic field

1. Introduction

Erythrocytes have a distinct biconcave discoid shape that is necessary for their efficient delivery of oxygen as well as the recycling of carbon dioxide [1]. The mechanisms that drive and maintain this most abundant cell in the body and its unique shape (geometry) have been poorly defined and understood to date [2]. We hypothesize that the erythrocyte is a small toroidal dielectrophoretic electromagnetic field (DEP EMF)-driven cell that maintains its zeta potential via a dielectric constant (chloride anion) between the negatively charged plasma membrane surface and the positively charged Stern (cation) layer [3, 4].

The zeta potential/DEP EMF is driven by both the ferroelectric influences (chloride anion) and the ferromagnetic influences (iron cation) in order to maintain both the Golden Ratio, which is a function of phi (φ), and/or their signature biconcave discoid shape [3]. Within this unique cell's Golden Ratio resides a DEP electromagnetic field flow fractionation (EMFFF) process that carries out the efficient recycling of carbonic acid ($H_2CO_3^-$) into a proton (H^+) that participates in the regulation of hemoglobin and bicarbonate (HCO_3^-) involved in the acid/base balance of the organism [3]. It is important to explore and define the mechanisms that drive this unique cell to address wellness and chronic disease management [5].

2. Multiferroic influences on the erythrocyte's zeta potential

Upon examination of the red blood cell physiology, it is clear that both biochemical and electromagnetic influences may need to be defined and understood [6]. The

lack of internal membranes and a nucleus in this cell shows it potentially operates very differently from most other eukaryotic cells. The plasma and internal membranes of other cell types are known to operate with a differential across the membranes, while the erythrocyte operates with the differential on the surface of this torus [7]. Therefore, the surface charge dynamics of the erythrocyte may be critical to its functionality. The red blood cell can be considered a type of *capacitor* in the organism due to the fact that the surface area on a capacitor is very important with regard to its function and efficiency [8]. A capacitor stores potential energy in an electric field with one or more pairs of conductors that are separated by an insulator or dielectric medium. A discussion of the proposed hypothesis of the process of how this unique cell may store energy through electric and magnetic (multiferroic) influences in the presence of a dielectric medium (chloride anion) in order to drive its zeta potential will now be presented.

The interaction of electric and magnetic orders in metal-organic configurations is known to exhibit more than one primary ferroic properties (multiferroic), that include ferromagnetism, ferroelectricity, and ferroelasticity [9–14]. Ferromagnetism occurs when a spontaneous magnetism is changed or switched by another applied field, ferroelectricity when a spontaneous electric polarization is switchable by an applied electromagnetic field, and ferroelasticity when a deformation that is switchable by applied stress occurs with all in the same phase [11]. Ferromagnetism is also considered a form of permanent magnetism (like that of magnets) where the time of decay of the magnetic field and its influence are reversed (time reversal) [15]. The presence of the ferromagnetic metal, iron, in the red blood cell speaks to a ferromagnetic influence that is present to reverse the time of decay of the magnetic field (time-reversal) of the erythrocyte [16]. Some scientists have believed iron only exists in the body as a weak paramagnetic ion, but this concept should be re-evaluated if this magnetization is switchable or time reversal symmetry may be occurring in the body due to a ferromagnetic influence.

Ferroelectric influences are known to exhibit a spontaneous electrical polarization that is switchable in an applied (magnetic) field [10, 17]. When we examine the surface of the toroidal erythrocyte, we see in order for the erythrocyte to function optimally, there needs to be a separation of the negative surface membrane charge from the positively charged Stern layer (cation layer). Chloride has been shown to modulate the voltage-gated chloride ion channels via its enhanced ferroelectric state under the influence of a DEP EMF [18, 19]. The diamagnetic chloride anion may also act as a dielectric constant to separate the charges (electrical polarity change in the presence of a magnetic field leading to breaks in spatial inversion symmetry or how particles orient in relation to each other or in space) on the membrane surface of the erythrocyte (negative surface membrane and positive Stern layer) to create static current flow and quite possibly an area for stored energy immediately surrounding the red blood cell (**Figure 1**) [15, 17].

This unique cell's membrane surface must maintain a static current surface membrane flow to remain free of other erythrocytes, cations, platelets, oxidative proteins, etc., in order for the optimal surface membrane exchange of oxygen (O_2) for carbon dioxide (CO_2) to occur in the body. In addition, Band 3/AE1 is an anion channel that appears to be gated by the diamagnetic chloride anion. If the cations in the plasma are interfering with or occupying the space at the negative membrane surface area, the Cl^- is not able to adequately surround the membrane in order to be readily available to conduct an exchange for HCO_3^- in order to maintain cell neutrality as it exits the cell as well as other possible intracellular functions that will be discussed.

Ferroelasticity is another ferroic property that we see in the *modus operandi* of the erythrocyte with regard to spontaneous strain, which can be seen in the deformability that is required of the red blood cells as they traverse the shear forces that

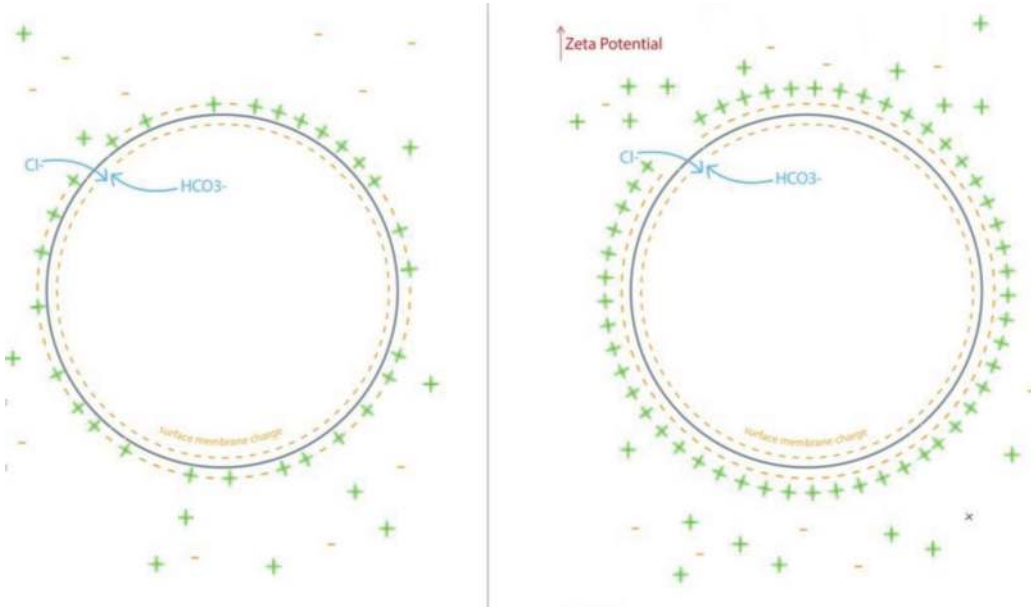

Figure 1.
Zeta potential of RBC. Decreased zeta potential is seen on the left with no separation of charges between the negative membrane surface and the Stern cation layer. Increased zeta potential on the right with separation of the negative surface membrane charge and the Stern cation layer (via ferroelectric change in chloride anion polarity).

exist in the vascular system. The shape memory effect can be seen as the erythrocyte deforms/flattens to traverse the smallest of capillaries in the microcirculation, without hemolysis (rupturing) to return to its previous biconcave discoid shape as it re-enters the circulation [20].

An interruption in the field driven by ferroelectric properties of chloride anion polarity (ferroelectric spatial inversion symmetry) and/or ferromagnetic properties of iron (ferromagnetic time reversal) may decrease or weaken the zeta potential. The zeta potential is a good measure of the electrical repulsive forces between particles as a function of distance. The zeta potential is also the critical control mechanism that offers stability of colloidal dispersions among the blood components [21]. The zeta potential (ζ) (Eq. (1)) equals the ionic strength (viscosity) of the medium (ŋ), electronegative charge of the RBC membrane (electrophoretic mobility) (μ), divided by the dielectric constant (ε).

$$\zeta = 4\pi \eta\,(\mu) / (\varepsilon) \tag{1}$$

The calculation of the zeta potential using the Smoluchowski equation (Eq. (2)) depicts electrophoretic mobility (μ) as equal to electric permittivity of the liquid (ε) divided by the viscosity (ŋ) of the plasma (Eq. (2)). This is applicable when there is a thin double layer, stable zeta potential, with large colloidal particles (RBCs) and high ionic strength.

$$\mu = \varepsilon\xi / \eta \tag{2}$$

Characteristic-based algorithms such as the zeta potential equation have limitations as they only govern measures in one spatial dimension in time where the direction of the phase velocity degenerates into an either positive or negative direction. We propose that the zeta potential (Eq. (1)) *also* requires an interaction between a break in time reversal (from ferromagnetic influence on serum iron) and spatial inversion symmetry (from ferroelectric influence in chloride) that maintains

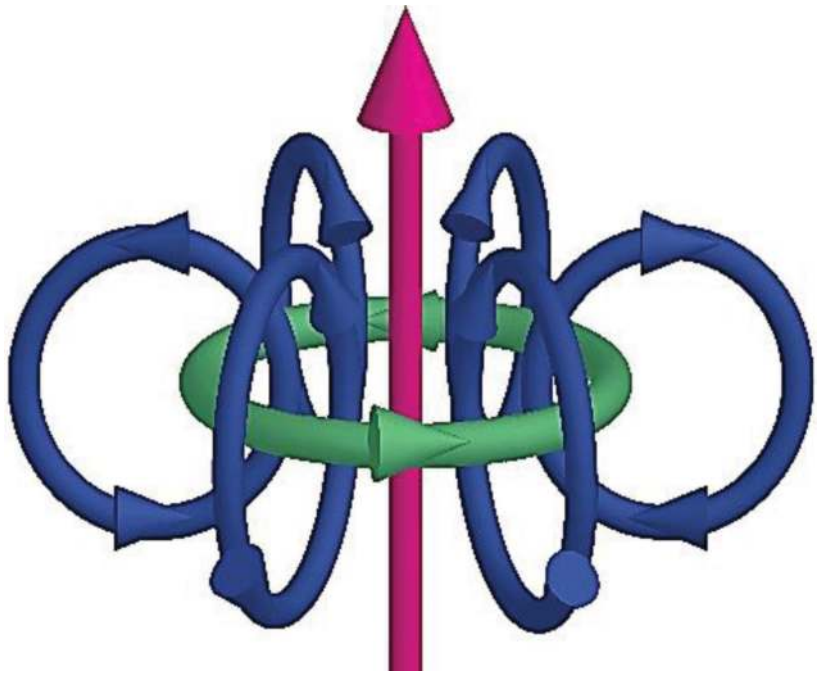

Figure 2.
Magnetic toroidal flow of the erythrocyte that may be fueled by the electrostatic field/zeta potential on the membrane surface. The green arrows represent the central separation chamber (pDEP and nDEP flow) with external separating forces being applied perpendicular to the flow (blue arrows) (Purnell et al. [3]).

separation of negative surface membrane area from the Stern layer (**Figure 2**). In order to add these measures to the zeta potential equation, multidimensional equations will be required to be split into multiple one-dimensional space-time formulations using both eigenvalues and eigenvectors.

The sign of the eigenvalue is an indicator of the direction of signal transmission, while the eigenvectors are the elements that are essential for diagonalizing the coefficient matrices. In the temporal-spatial planes, t-ξ, t-ŋ, and t-ζ, eigenvalues are found by solving the sixth-degree characteristic equation that factors in the coefficient matrices [22]. It is also known that $\sigma = \sqrt{\mu/\varepsilon}$ contains the dimension of electric resistance. In space, it is commonly referred to as the impedance of lossless dielectric media [23]. Eigenvectors can explain the different coordinates (time points) of movements of a molecule at possible vectors and the eigenvalues can be used to describe the movement in and around the complex molecule [24]. Therefore, we hypothesize that the zeta potential may be most efficiently governed with consideration given to temporal-spatial changes that drive these multiferroic influences of ferromagnetism, ferroelectricity, and ferroelasticity that may be occurring in the red blood cell physiology.

2.1 Toroidal characteristics of the erythrocyte

It is known that an electric dipole consists of a pair of opposing charges and the magnetic dipole maintains a current loop [7]. The toroidal dipole is different because the currents flow on the surface of a torus. The red blood cell's unique design is a toroid where static currents need to flow on the surface of the torus in order to maintain efficient separation (possibly under the influence of the ferroelectric changes in the dielectric constant, chloride) of the positively charged Stern layer and the negative surface membrane charge [7]. This configuration of the external field is thought to be identically zero and the surface static currents create a magnetic field

that is confined *within* the torus [7]. Therefore, this would lead to no interaction between the toroidal dipoles and the internal electric and magnetic fields [7].

The red blood cell may be viewed as exhibiting breaks in both ferroelectric (magnetic field driven, electric-spatial inversion symmetry) and ferromagnetic (magnetic-time reversal) influences that exhibit long-range order [25, 26]. Consequently, the red blood cell can be considered as a member of the toroidal multipole family since its physiology appears to require electric multipoles (red arrow) and magnetic multipoles (blue circles) that are driven by multiferroic influences (**Figure 2**). Theoretical works with toroidal resonances in natural media still remain in their infancy and tools to measure these phenomena are yet to be developed [27]. At the present time, re-examination of spectroscopic data/observations is warranted.

2.2 The Golden Ratio of the erythrocyte

The Golden Ratio is an irrational number, a function of phi, φ, and has been considered the most beautiful mathematical ratio in art, architecture, and nature for centuries [28–30]. The erythrocyte can be seen to display this Golden Ratio when one examines the size, shape, proportions, and curvature of this unique cell (**Figure 3**) [3].

The average diameter of the human red blood cell is 6.2–8.2 μm with the thickest point measuring 2–2.5 μm ($\sqrt{5}$) and the minimum thickness at the center of the toroid measures 0.8–1 μm divided by 2 for the two equal and opposing sides of the proportion to achieve 1.6803339887 (Golden Ratio of the red blood cell) (Eq. (3)).

$$\boldsymbol{\varphi} = \frac{\left(1+\sqrt{5}\right)}{2} = \mathbf{1.6180339887\ldots} \tag{3}$$

The measurement of the center depth of the torus to the thickest point of the torus divided represents a measurable relative radial proportion of the Golden Ratio in the human erythrocyte. The normal and measurable range for the Golden Ratio would then be set into normal range values for the RBC (i.e., 1.4–1.75). It should be said that this ratio could be a notable biomarker that would require a lensless sensor imaging for point-of-care testing in order to disrupt the red blood cell's microenvironment as little as possible.

The microenvironment where this cell resides and maintains its multiferroic and field-driven component is critical to its function and for the maintenance of this Golden Ratio. Just as a snowflake is a water molecule that has frozen into its geometric proportions (Golden Ratio) falling/spinning through a specific microenvironment (freezing temperatures) within the field of the earth and must be examined before it is removed from these critical factors of formation, the red blood cell must be examined as close to its natural state (non-hemolyzed, non-anticoagulated, non-centrifuged etc.) in order to visualize its innate and natural state/physiology.

The maintenance of this Golden Ratio may have been underestimated since this living geometry of the red blood cell may be critical for efficient oxygen/carbon dioxide exchange as well as acid/base balance in the body [3]. The erythrocyte morphology and what guides this unique shape has been one of the least understood in the human body and it appears that biological shape and geometric changes are significant and can be linked to degenerative changes, embryogenesis, and even cancer [31].

2.3 Dielectrophoretic electromagnetic field flow fractionation in the Golden Ratio proportions of the erythrocyte

Since the geometric proportions of the Golden Ratio appear in nature, one must contemplate the significance of this geometry and why it occurs throughout nature.

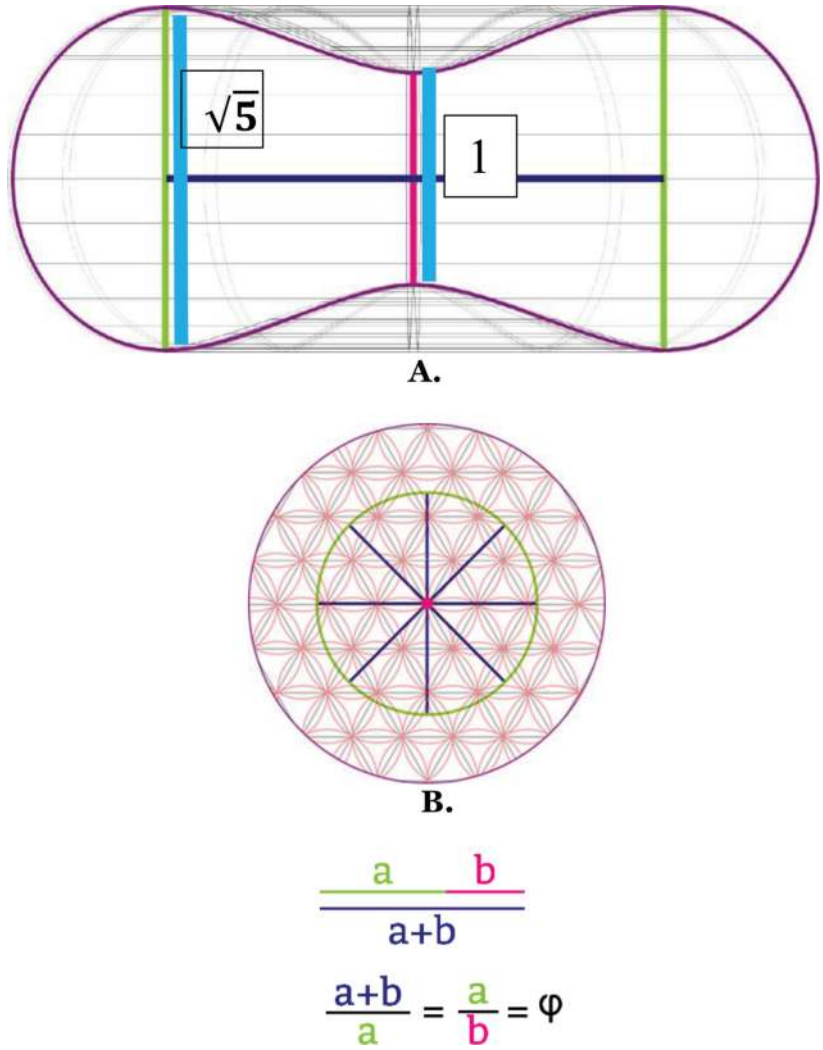

Figure 3.
The Golden Ratio geometrical proportions of the erythrocyte. Upon cross-sectional analysis (A.), the sum of the quantities of the larger quantity (a + b) is equal to the ratio of the larger quantity (a) to the smaller one (b) and represents the entire Golden Ratio area of the erythrocyte or a measure of one representative radius (or measurable relative radial proportion) as denoted in Eq. 3. (B) The entire Golden Ratio area shown from top view of the Erythrocyte. The measurable relative radial proportion could be mathematically set into normal range values for the RBC Golden Ratio (i.e., 1.40-1.75) (Purnell, Butawan & Ramsey, 2018).

The Golden Ratio and its mathematically defined proportions of the erythrocyte may actually house a dielectrophoretic electromagnetic field (DEP EMF), and these proportions may be critical for the proper physiological function of this unique cell. Recently, dielectrophoresis has been a topic of study due to its potential to manipulate microparticles and nanoparticles within and around cells [32]. Dielectrophoresis is seen to occur when a polarizable particle becomes suspended in a non-uniform alternating current (AC) or direct current (DC) electric field. This electric field polarizes the particle and if the particle moves in the direction of increasing electric field, then the behavior is positive dielectrophoretic (pDEP), and if the particle moves away from the high field regions, it is known as negative dielectrophoretic (nDEP).

According to the Maxwell-Wagner-Sillars polarization, this separation response occurs in conjunction with a necessary dielectric regulator or a field separator [33]. The concept of field separation through dielectric media has been well defined and understood in solid state electronics. It now appears the metal-organic applications in living organisms strongly speak to the need to apply and understand the field separation that may be necessary for membrane function in living things.

Dr. Bruce Lipton first offered the novel concept that the cell membrane is the cell's "brain" [34]. The membrane is a separator in the sense that it differentiates the cell from the outside world. There are mechanisms that control the membranes that have remained elusive to date. There appears to be a wisdom within cells and their membrane functionality that governs their behavior and physiology. The chloride anion may play a unique role in the gating of membranes through its dielectric properties and ferroelectric polarity changes it exhibits in and around cell membranes present in all cell types including the erythrocytes.

Just as the chloride anion is known to gate and modulate Band 3/AE1 on the surface of the erythrocyte torus, it may also play a role within the torus and especially within the area of the Golden Ratio that may serve as a dielectrophoretic electromagnetic field flow fractionation (DEP EMFFF) mechanism to process serum CO_2 (a cell respiration by-product within living organisms). We should note that water is a necessary component that is critical to both shield and amplify different charged species, serve as a high dielectric constant (ε), and is the known matrix of all living organisms [35, 36]. It is also known that water clusters may be able to transmit electromagnetic signals [37]. Therefore, water and CO_2 as H_2CO_3 (carbonic acid) are thought to enter the red blood cell from the plasma and can be seen as entering into a recycling arena within this unique cell. To date, carbonic anhydrase has been thought to be the enzymatic catalyst that separates H_2CO_3 into H^+ and HCO_3^- and is currently a topic of research across the globe [38–40].

We hypothesize that the negatively charged diamagnetic chloride anions and the static current they induce in and around the negative surface membrane charge and the Stern layer in the plasma (to drive zeta potential) may also drive the DEP EMFFF in the Golden Ratio of the proportions where the chloride anion continues to act as a field separator. This field separator action of the chloride anion and its ferroelectric changes in polarity within the magnetic field that resides within the Golden Ratio of the erythrocyte may fuel the DEP EMFFF in conjunction with the

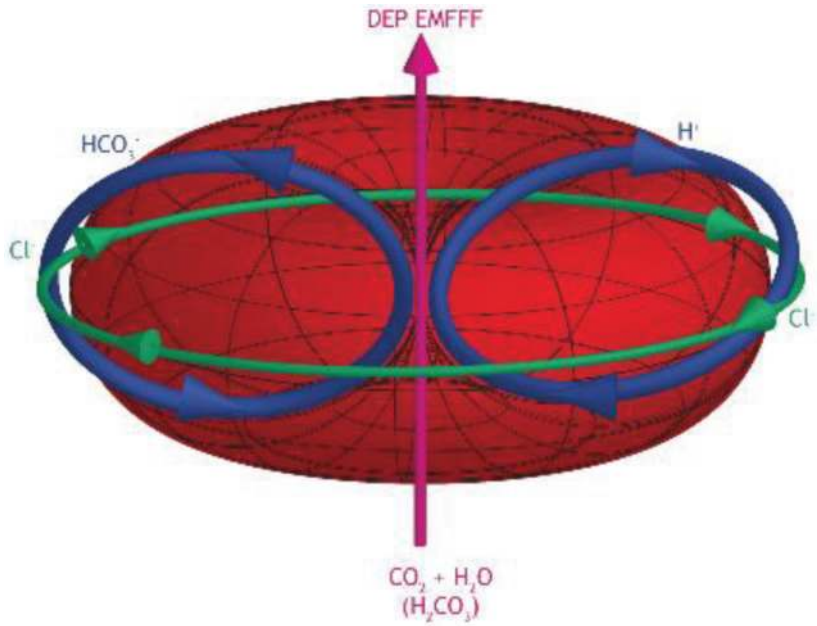

Figure 4.
Dielectrophoretic electromagnetic field flow fractionation of the erythrocyte. This DEP EMFFF, with the assistance of hydrodynamic (water) and dielectric chloride anion (Cl^-) influences, separates H_2CO_3 into positively charged H^+ (pDEP), which flows to the membrane surface (Hgb) to facilitate oxygen delivery and the negatively charged HCO_3^- (nDEP) exits into the plasma through Band 3/AE1 for acid/base homeostasis (Purnell et al. [3]).

hydrodynamic (dielectric influence of water) influences. The water and the chloride anion may induce a DEP separation of the positively charged H^+ (pDEP) which flows to the erythrocyte membrane surface to be used for hemoglobin function as the negatively charged HCO_3^- (nDEP) exits the cell into the plasma through the anion channel Band 3/AE1 for acid-base control in the body (**Figure 4**).

The chloride anion may again function as the separator of charge/flow at the red blood cell plasma membrane as the HCO_3^- (nDEP) is eluted from the cell and the chloride enters the cell to continue to its function within the cell. Parabolic velocity of the flow of these charged ions causes the HCO_3^- (nDEP) to move further away from the cell membrane in order to be eluted from the cell into the plasma as opposed to the H^+ (pDEP) that remains in the membrane for hemoglobin function [41]. The erythrocyte ideally recycles 70–75% of the serum CO_2 in the body (to H^+ and HCO_3^-) and generally only 20–25% of the serum CO_2 needs to remain available in the plasma for use by the lungs for regulation of acid/base homeostasis. The maintenance of the zeta potential and the Golden Ratio proportions may be a new area of future research for medicine and science [42].

3. Conclusion

The Golden Ratio proportions (possibly driven by the zeta potential) of the erythrocyte appear to offer clues to this cell's unique shape and function. Since biological shape and geometric changes can be linked to degenerative changes, it is important that we take notice of why and how these geometric shapes are important [43–55]. When there is a disruption in the zeta potential (toroidal surface) on the erythrocyte, this may lead to a loss of the Golden Ratio proportions (DEP EMFFF), geometric shape distortions, and decreased efficiency of CO_2 recycling as well as O_2 delivery with this most abundant and unique cell in our bodies [56].

Miniaturized lensless sensor imaging for microscopic visualization at point-of-care delivery is currently a research focus across the globe [57–59]. Due to the quantum microenvironmental factors that are critical to this possibly field-driven cell, it is important to examine these proportions with as little disruption to these factors as possible in order to quantify the Newtonian fluidics as well as calculations such as the Reynolds number. Future lensless imaging and examination of a newly drawn drop of blood may be the most valuable and accurate tool to evaluate the Golden Ratio along with the red blood cell's efficiency [47, 54, 57].

Conflict of interest

Marcy C. Purnell is the holder of "Biochloride Generation and Methods" International Application Number PCT/US18/14238.

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