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Brownian Motion and its Mathematical Applications in Medicine

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Brownian motion is small particles suspended in a liquid tend to move in pseudorandom or stochastic paths through the liquid, even if the liquid in question is inert. By Einstein's theories for Brownian motion referring to the 1905 works, equilibrium relations and viscous friction, osmotic pressure reaching the diffusion coefficient of Brownian particles. In the fluid medium, we will address the deviation (diffusion equation and basically the relationship between the mean square deviation of the particle position and the fluid temperature, the higher the temperature, the greater the mean square deviation, that is, directly proportional to the constant of the diffusion). The importance of this study is the movement of particles and molecules in the fluid medium, whether these molecules are lipids, proteins, we know that viruses and bacteria are having a certain movement in the organism and its systems, we will tend to study their movement within vessels and between fluids body, with two densities and particular conditions, knowing the likely displacement, we will know therapeutic interventions that are probably more effective. The aim of this work is to demonstrate through mathematical applications the Brownian motion.

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1. INTRODUCTION

Therapeutics is the application of Brownian motion in an anatomical motion, where particles displace within atoms and substance fluids. We will address possible uses and applications of these calculus on protein displacements (virus, bacteria, etc.) on the living tissue and organism.

Live organism is the one that manages to respond to the environment with other organisms and respond to stimuli, so I stand by the classification that viruses are living organisms, a study of scientists such as Einstein of the Brownian motion. Some basis for studies such as Smoluchowski, in 1912. Polish physicist Marian Smoluchowski had an unusual idea: to build a nanoscale engine to convert Brownian motion into work, these non-equilibrium physical systems, from the microscopic level, as observed in the diffusion of particles in a solvent, to scales of astronomical order, as seen in star systems, a black hole (BH) at the center of a dense star system [1-4].

Theoretically, when its mass is very large, a BH can acquire a motion that is similar to that of a particle suspended in a liquid or a gas. These examples guide us to apply this universal motion of the micro and macrocosm in Medicine, in its possible medical and therapeutic applications, and in exams with detailed displacement [5]. Theoretical work on the sedimentation of an aggregate of particles began with Brinkman (1947); Ooms, Mjinlieff and Beckers (1970), among other researchers, use the Navier-Stokes equation for the external flow to the aggregate, and use the Darcy or Brinkman equations for the internal flow.

According to Marco Vanni (1999), we are also interested in that we briefly and dynamically observe particle aggregates so that bacteria mainly tend to aggregate, the adhesion of different strains of bacteria is also influenced by the physicochemical properties and thermodynamics of the substrate involved [6,11]. Vander Waals forces govern interactions involving a variety of molecules and are responsible for the stability of intermolecular complexes and absorption of different elements on the surface, how these and other forces influence Brownian motion, how these adhesion forces in bacteria are influenced by Brownian motion.

Between two bodies, it is the result of the combined action between the attractive forces of Lifshitz-van der Waals and the electric double layer forces, obviously in a Brownian motion process, exerts a significant force in these processes and in the diagnostics area, so these studies overlap on the Brownian motion, such as diagnostic X-rays, magnetic resonance, computed tomography, the displacement of particles allowed us to bring to light events that before could only be observed with observational surgical incisions [7,8].

A simplified model to describe the behavior of a particle subjected to a random force *f* (t), resulting from constant collisions with the liquid molecules e, which result in a completely random trajectory, is known as a random path. The variables that describe the probability distributions are mean shift and root mean square shift [9-11].

To describe the model, random path in the case of X-rays, until today we have not been able to have adequate control of the particles, most of them in examinations are lost in unforeseen trajectories, even the most modern devices still have great difficulties to predict, its clear displacement, its trajectory to correct it as necessary, in magnetic resonance, diffusion measures the Brownian motion of water molecules and is especially sensitive to initial ischemic changes [5].

Diffusion is a matter transport process, in which a solute is transported from a region of high concentration to a region of lower concentration, due to the random thermal motion (Brownian motion) of all particles at temperatures above absolute zero (-273°C), it is clearly seen how important these universal motions in the area of health and Medicine are to us, which enable us to anticipate, predict events and diagnose with greater precision the spatial location and also predict the future displacement of certain diseases as in cases of metastases and/or schematic processes and onset and ending evolutions, such as a myocardial infarction, the possibility and probability of displacement and obstruction of a thrombus in a certain coronary artery and its possible effects allowing us to have a more accurate view of a more or less favorable post-

diagnosis, which allows for a more effective and less aggressive treatment for the patient.

It is of paramount importance to study how viruses and bacteria move between atoms of the organism, between bodily fluids, between cell layers, what is the tendency of displacement and what is the consequence of these displacements.

O objetivo do presente trabalho é demosntrar atraves das aplicações matematicas o movimento Browniano.

2. METHODS

Considering the objective of this study, a descriptive qualitative, exploratory and bibliographic approach was adopted. According to Triviños [12], descriptive research intends to describe the facts and phenomena of a given reality. For Mattar [13] an exploratory research aims to propose greater knowledge about the theme or research problem.

As for the approach to the problem, this research can be characterized as qualitative, as: It considers that there is a dynamic relationship between the real world and the subject, that is, an inseparable link between the objective world and the subjectivity of the subject that cannot be translated into numbers. The interpretation of phenomena and the attribution of meanings are basic in the qualitative research process. This does not require the use of statistical methods and techniques [14].

According to Triviños [12], exploratory studies allow investigators to increase their experience around a given problem. At other times, it aims to delimit or handle with greater certainty a theory whose enunciation is too broad for the objectives of the research he has in mind to carry out.

According to the author, bibliographic research is expensive and requires intense work and a critical attitude from the researcher regarding the material collected. Furthermore, it is necessary, as demonstrated, that the review is part of the work as a whole and not as an isolated step as a way of elucidating and validating the material covered [15].

3. RESULTS AND DISCUSSION

We will start our studies with the theoretical bases of sustainability, which are the epitome support of some theorists mentioned above, as mathematical formulas for such conclusions and hypotheses. Einstein, based on the similarity and behavior of diluted solutions and suspensions in the relation of diffusion coefficient and viscosity, probabilistic reasoning. Einstein arrives at the expression of the mean quadratic path of Brownian motion:

$$\langle x^2 \rangle = 2Dt = \frac{RT}{3\pi N_A a \eta} t, \qquad (4)$$

Fig. 1. Square path of the Brownian motion
Source: Adapted from ICMC, 2020.

Continuing the studies and citing the work of Einstein and Smoluchowski, Langevin publishes a demonstration of the motion of a suspended particle, including the Stokes force. The kinematic viscosity coefficient of a liquid can be obtained by expressing the Stokes drag force FD:

$$\mu = \frac{2r^2}{9v_{esf}} (\gamma_{esf} - \gamma_{fluido})$$

Fig. 2. Stokes drag force FD
Source: Adapted from ICMC, 2020.

Stokes' law is generally applied to the flow of a viscous, incomprehensible fluid around a sphere for Reynolds number less than 1.

Viscosity can be seen as the internal friction of liquids, that is, the friction that the various layers of a liquid encounter when flowing over each other; "to maintain the agitation of the particle, and in whose absence the viscous friction force would eventually lead to rest".

The displacement probabilities of a particle, let's say it can be two-dimensional, three-dimensional, XY axis or XYZ axis, in a given time interval $tp(\Delta)d\Delta$ the probability of the particle moving between Δ and $\Delta + d\Delta$ in the interval of time τ. The probability density must be symmetric, $p(\Delta) = p(-\Delta)$ developing the idea and transforming it into possible numbers to arrive at displacement probabilities, Einstein concludes that the mean squared deviation of energy depends on the number of microscopic particles; in the case of a fluid, the relative deviation becomes absurdly small, with no chance of being observed.

Entering again into the context of examinations, diagnostic imaging, magnetic resonance imaging, diffusion-weighted magnetic resonance imaging (DWI), it concerns random motion, also known as “Brownian” motion [5]. Isotropic diffusion, that is, there is no predetermined direction for displacement, and it can move in any special direction, that is, XYZ, this form of diffusion when aligned and structured by magnetic fields, can form images by diffusion, where they are called Diffusion-weighted images, the greater the final signal, ie, the less diffusion there is in the measured sample, the clearer the element voxel of a volume of images. The possibilities of atomic alignment are rooted in the knowledge of Brownian motion, this knowledge brought to light the microscopic world and joined this microscopic world to the macroscopic world [5].

In the presence of auto magnetic gradients, the Brownian motion causes an attenuation in the signal, it serves as a filter, basically highlighting here the importance of the Brownian motion. In the case of using contrast to observe anatomical anomalies and pathologies, for example, an aneurysm in arteries, say femoral arteries, even the contrast that makes it possible to see these deformations in organ structures, the theory of Browian motion should also be applied, if we understand how these particles behave in the fluid medium, what is their quadratic probability of displacement, without a doubt it takes away the light, very important issues in the diagnosis of lesions such as disfigurement or metaplasia of certain organs or certain systems, in an image also in the case magnetic resonance imaging, citing Larmor effect. Joseph Larmor (1857-1942), the effect of a magnetic field on charged particles describing circular orbits known as the Larmor frequency.

Magnetic resonance imaging is a very good method for soft tissues with less difference in density and even with little difference in density allows us to have a high quality image, facilitating the diagnosis of the image, obviously, it is linked to the quality of the generated image, in the case of organs by images, the knowledge of the quadratic displacement of a certain particle in the atomic environment influences the quality of these images, the deepening of the issue of special atomic behavior and its displacements and predictability in these displacements, we will be thus making the images have a greater demonstration of the reality of a certain structure.

The number of Avogadro also had this premise of being born from the idea of the Brownian motion and its studies by Carlo Avogadro (1776-1856) in his work, equal volumes of all gases at the same temperature and pressure contain the same number of molecules, the number of Avogadro and, consequently, one mole is equal to about 6.022×10^{23}, that is, about 600 trillion billion. This is, by definition, equivalent to the number of atoms of 12 grams of carbon-12 in this environment of trillions of atoms, a particle moves randomly, there are gigantic possibilities of collisions, clashes with these atomic structures.

Using the knowledge of Brownian motion, we can predict, in a situation of probability, the propagation of certain particles such as bacteria and viruses in the act of sneezing an individual and how these particles propagated in a mixture of gases and under the effect of an atmosphere by example.

Having these pre-knowledges, even if they are based on probability, are valuable for controlling the propagation of pathogens between beings and valuable in the sense of studies of time and space and also of their suspension based on the quadratic area of the Brownian motion.

The probability, for example, of a given virus being suspended in an atmosphere in a given environment, taking into account the likely amount of shocks and whether or not these atomic shocks could interfere with its protein capsule and what average time for this virus to arrive to the ground. Obviously when it reaches the ground its transmission capacity decreases a lot and its inactivation probability increases considerably.

4. CONCLUSION

The study of Brownian motion made it possible to verify the alignments of atoms brought us enormous possibilities for advances in several areas, including in the health area, contributing to the non-invasive advance of diagnoses, a very important fact, as they cause little or no sequel in obtaining diagnostic images by means of excitation of atoms that promote alignment with the magnetic field of excitatory in the mapping of certain evolutions such as metaplasia and in the displacement called metastasis of certain anomalous cells of the organism. The study of these displacements that follow the orders of energy and magnetic fields make it possible to predict and create images as in magnetic resonance Magnetic Resonance

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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