New Perspectives in Science Education
International Conference
NEW PERSPECTIVES in SCIENCE EDUCATION

Brownian motion: an interdisciplinary teaching proposal

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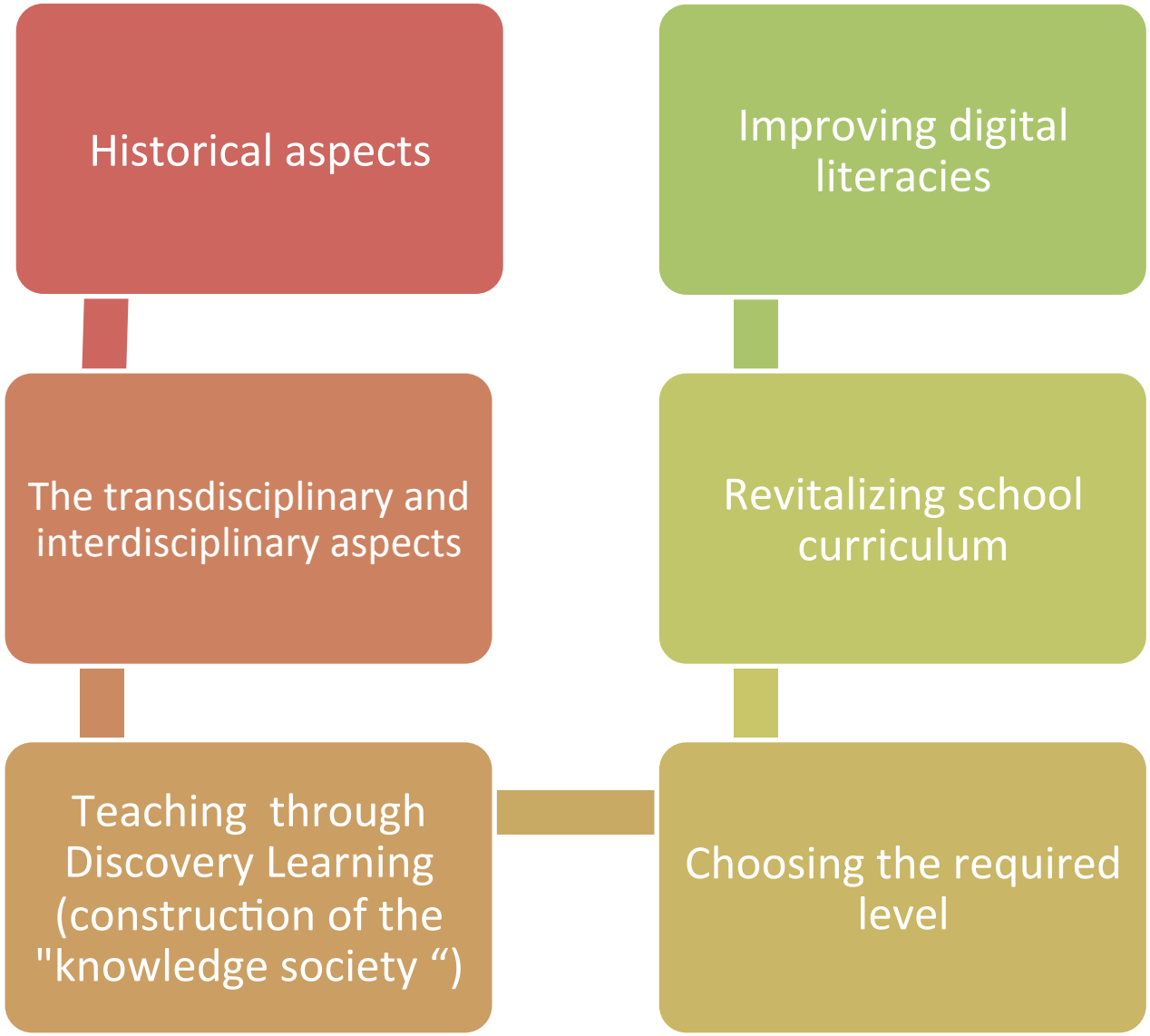
An educational proposal



An educational LAB proposal

Alongside the Brown's historical experience and some other classical experiments, real or virtual

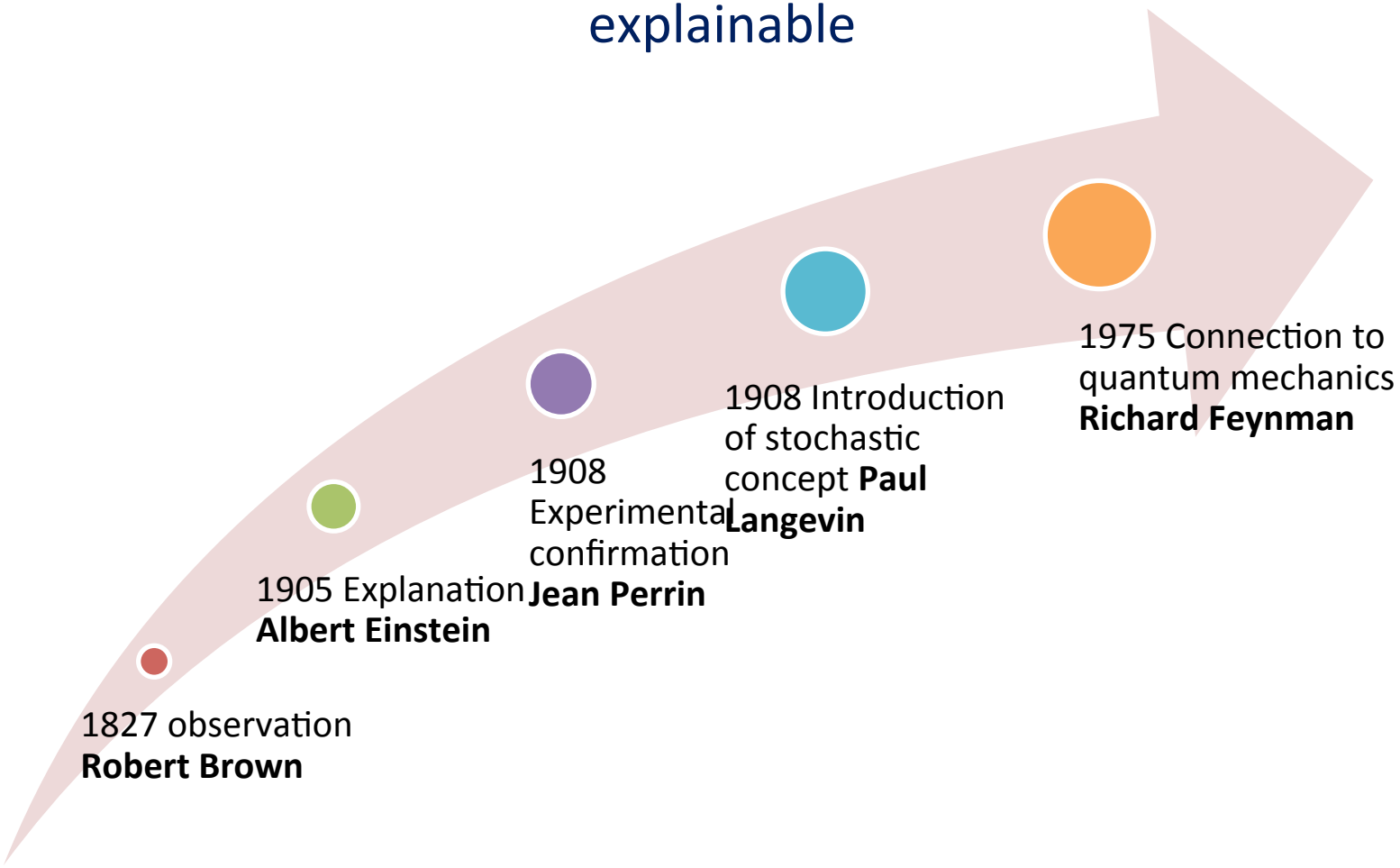
We propose

- a "random walk" simulation made using the software "Geogebra"
- a simple macroscopic model of chaotic motion

Both experiences are easily implementable in a classroom activity

A brief history of Brownian Motion

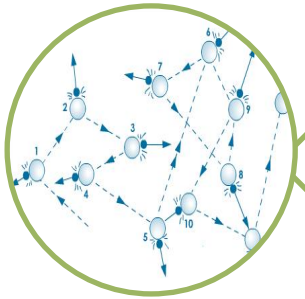
Interesting phenomenon, easily observable but not so simply explainable



A brief history of Brownian Motion

Robert Brown

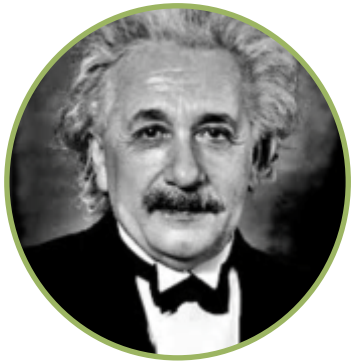
Any minute particle suspended in a fluid moves chaotically under the action of collisions with surrounding molecules.



The intensity of this chaotic motion is increased with a rise in temperature.

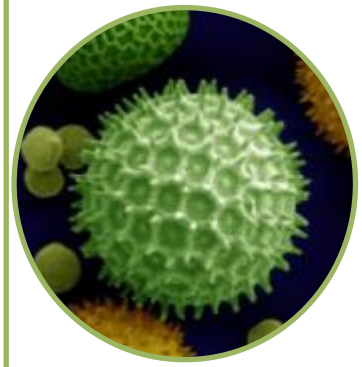
This experimental fact was highlighted by the British biologist R. Brown in 1827.

Relation between the macroscopic world and the atomic properties of matter

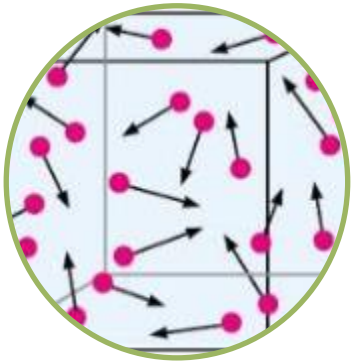


relation between the **macroscopic diffusion constant** D **and the atomic properties of matter.**

$D=kT/6\pi\eta a$

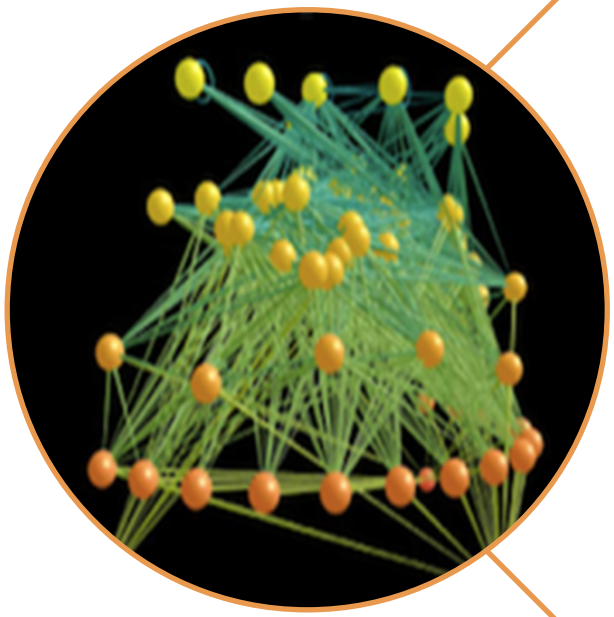


the average of particle displacement in the space during time



$\langle x(t)^2 \rangle \cong 6Dt$

Random walk



Explain Brownian motion using a probabilistic model:

- if the kinetic energy of fluids was adequate, its molecules moved with “random walk”.
- The “random bombardment” by the molecules of the fluid would cause a sufficiently small particle to move exactly as Brown observed and described.

The stochastic concept

The theory of Brownian motion has been extended to situations where the fluctuating object is not a real particle at all, but instead some collective property of a macroscopic system.

In 1908, Langevin introduced stochastic concept into the explanation of Brownian motion, founding an equation containing both frictional forces and random forces.

Works on Brownian Motion have

indirectly confirmed

atomic theory

kinetic theory

the origin of stochastic processes' study

And BM is still relevant in today's physics

Why introduce Brownian Motion into the students' curriculum?

Large educational potential into STEM *education*

It links the microscopic world and the macroscopic world

It integrates many disciplines

Adaptability to different didactic levels

Methodology

The implementation of research methodology.

The implementation of “laboratory teaching”.

The topics are proposed emphasizing their historical importance.

Students are placed in the core of the whole process of teaching and learning.

“Lab" as cognitive context

“Lab” is not necessarily a physical space

The laboratory is a place for discovery, observation and action-research around cultural facts

Educational Activities

The main educational power of the chosen argument is its adaptability to different didactic levels

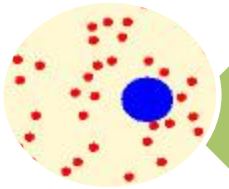
The teaching content covers a variety of topics in mathematics, probability and statistics, classical and modern physics

Experimental practice is necessary alongside theoretical activities

Web Resources

Videos of lectures and experiments on Brownian motion.

Videos of experiments and lessons on fluids' diffusion.

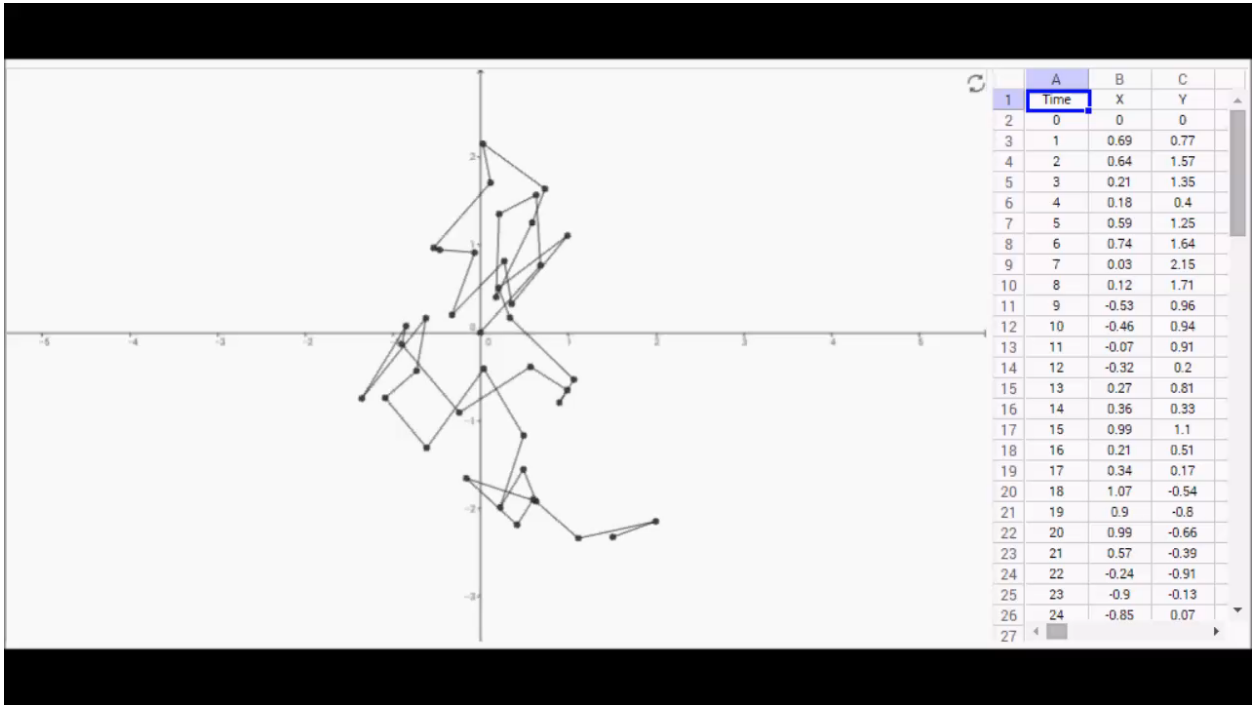


Use of applets on Brownian motion

Software –TRAKER- to describe and quantify Brownian motion.

Random walk Simulation by Geogebra

An example of a two-dimensional Brownian motion simulation created using Geogebra software

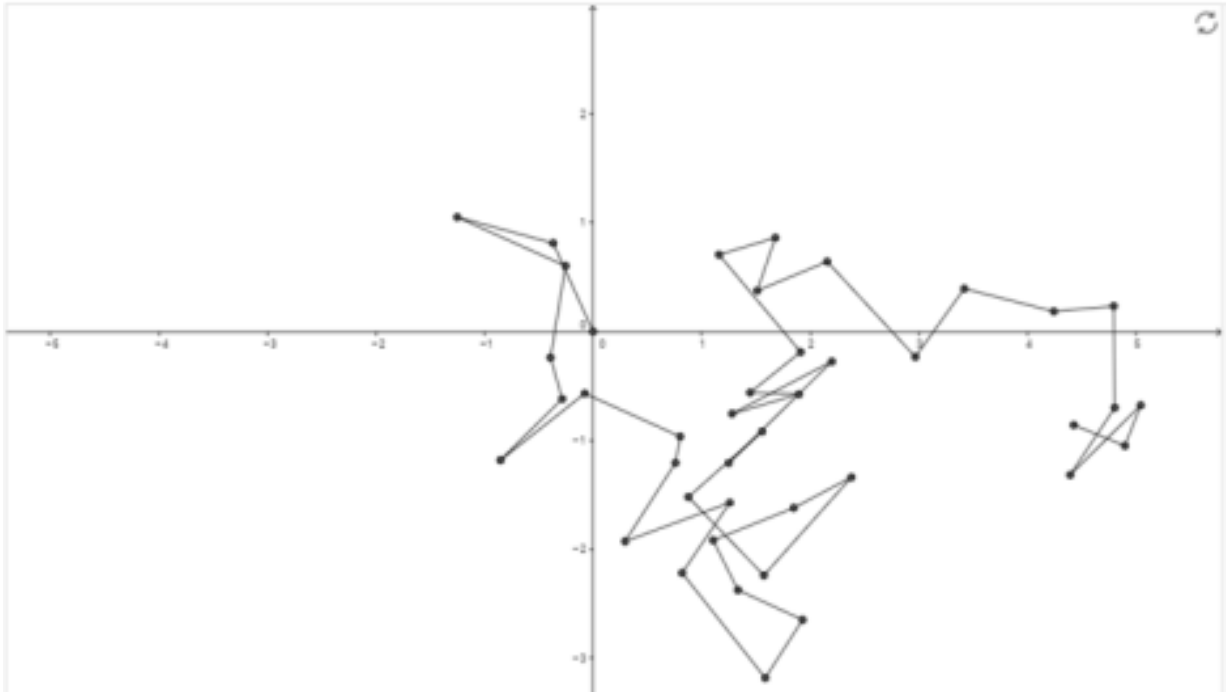


	A	B	C
1	Time	X	Y
2	0	0	0
3	1	0.69	0.77
4	2	0.64	1.57
5	3	0.21	1.35
6	4	0.18	0.4
7	5	0.59	1.25
8	6	0.74	1.64
9	7	0.03	2.15
10	8	0.12	1.71
11	9	-0.53	0.96
12	10	-0.46	0.94
13	11	-0.07	0.91
14	12	-0.32	0.2
15	13	0.27	0.81
16	14	0.36	0.33
17	15	0.99	1.1
18	16	0.21	0.51
19	17	0.34	0.17
20	18	1.07	-0.54
21	19	0.9	-0.8
22	20	0.99	-0.66
23	21	0.57	-0.39
24	22	-0.24	-0.91
25	23	-0.9	-0.13
26	24	-0.85	0.07
27			

In the second and the third column there are the X and Y particles coordinates.

https://tube.geogebra.org/material/simple/id/2294315

Random walk Simulation by Geogebra



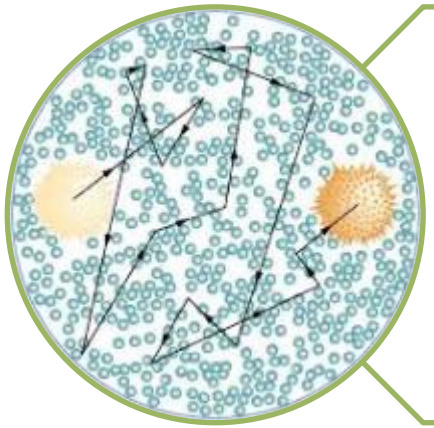
	A	B	C
1	Time	X	Y
2	0	0	0
3	1	-0.37	0.81
4	2	-1.25	1.05
5	3	-0.25	0.6
6	4	-0.39	-0.24
7	5	-0.28	-0.62
8	6	-0.85	-1.18
9	7	-0.08	-0.57
10	8	0.8	-0.97
11	9	0.76	-1.21
12	10	0.3	-1.93
13	11	1.26	-1.57
14	12	0.82	-2.22
15	13	1.59	-3.19
16	14	1.93	-2.65
17	15	1.34	-2.38
18	16	1.11	-1.92
19	17	1.85	-1.62
20	18	2.38	-1.34
21	19	1.57	-2.24
22	20	0.88	-1.52
23	21	1.56	-0.92
24	22	1.25	-1.21

This Geogebra construction allows students to observe graphically a random motion and so, to create a Brownian's motion simulation.

The creation of computer application allows students to work out skills that are the bases for "digital literacy".

Physics laboratory

A simple but incisive experiment allows students to observe macroscopic chaotic motion of particles in a fluid, with no apparent explanation



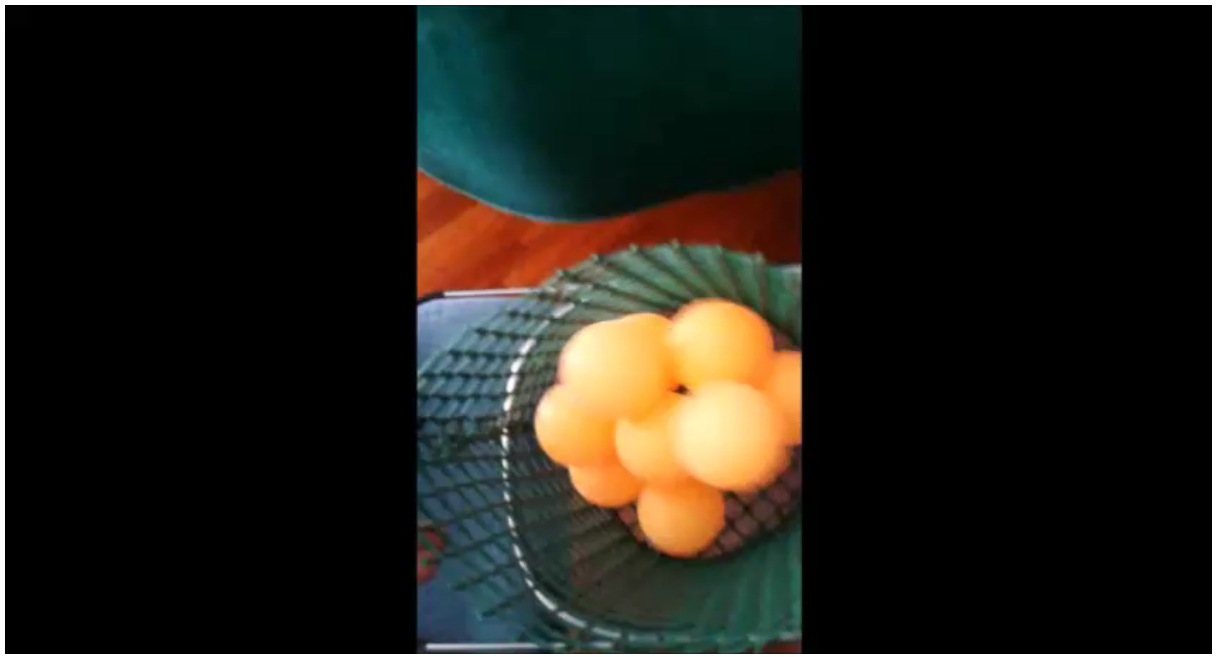
Reproduction of Brown's historical experiment (pollen grains' motion in water).

Diffusion experiments in fluids.

Exhibit hands -on

We propose building a simple macroscopic model achievable with basic materials.

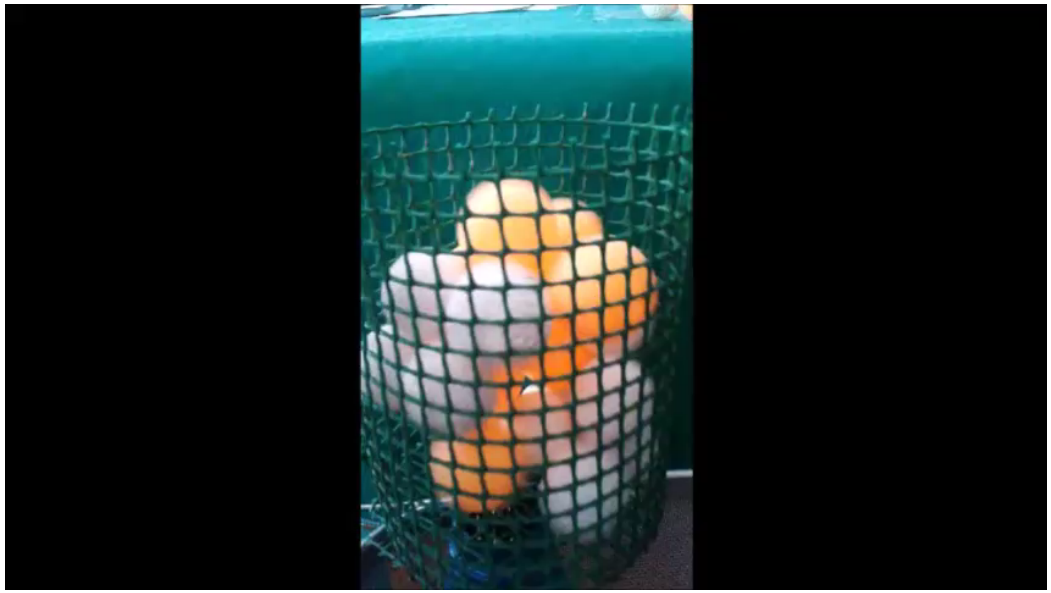
- *light balls "agitated" by air flow, are moving chaotically*



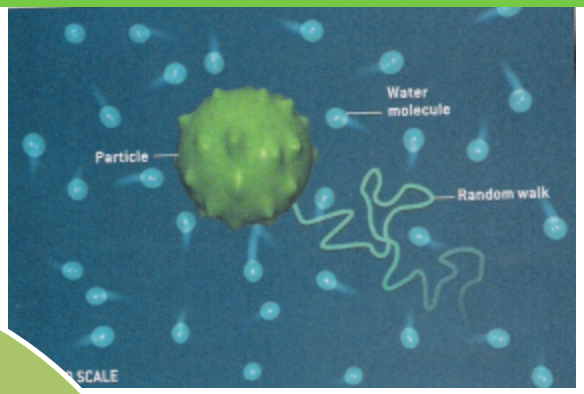
An «hands –on» Exhibit

light balls of different colors are separated by a grid.

when the internal grid is removed, the orange balls are diffused by air flow.
The motion obtained is not deterministic, but occurs due to the casual collision between balls.



Conclusion



The fascination of Brownian motion is:

- Its connection between macroscopic scale and microscopic world
- It facilitates the interdisciplinary teaching

History of Brownian motion after nearly 200 years remains pertinent today

Our proposal is

to introduce students to the microscopic world and some physical, mathematical, statistical theories

Through

simple experiments

software simulations

Alongside theoretical study

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