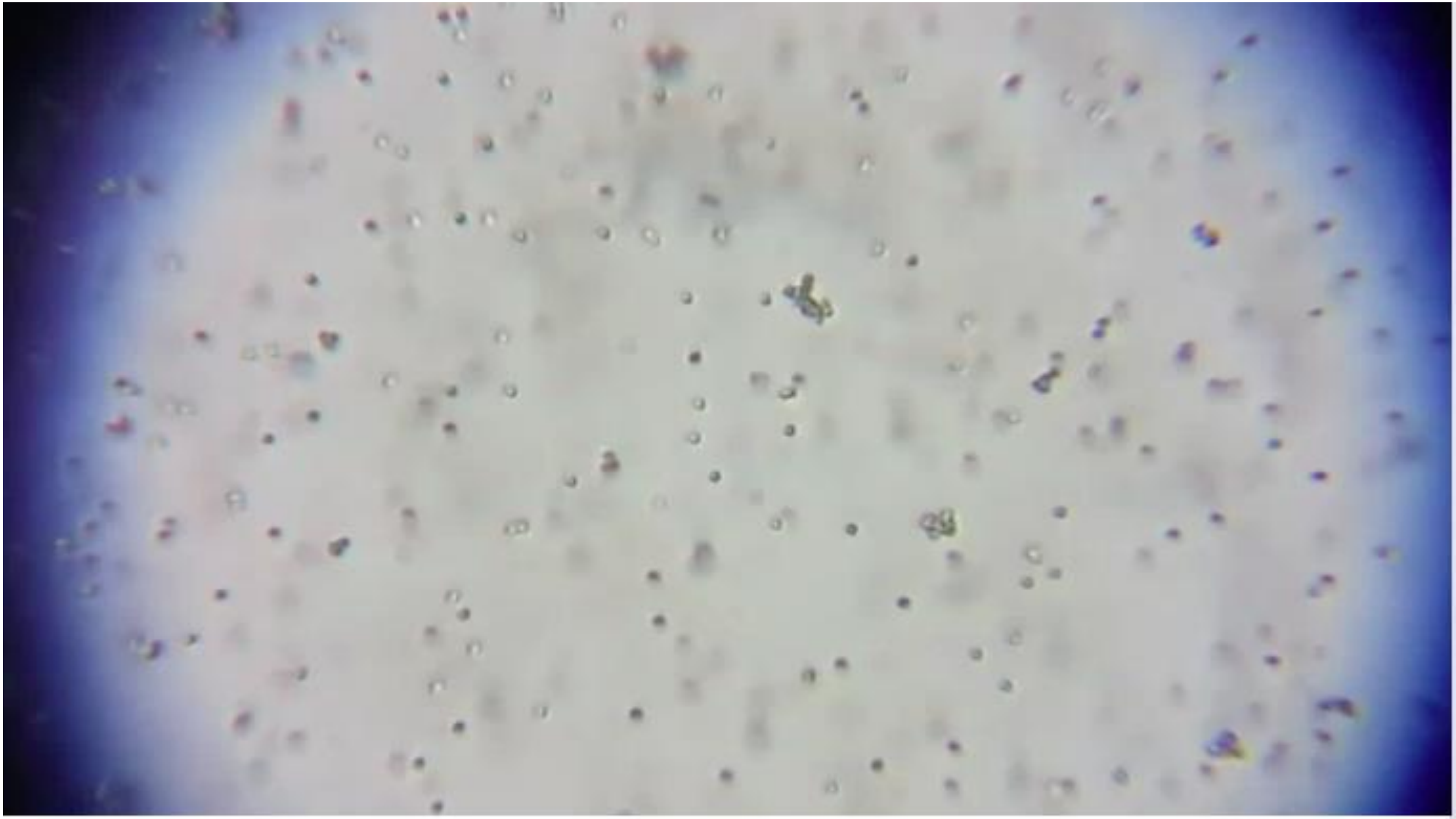
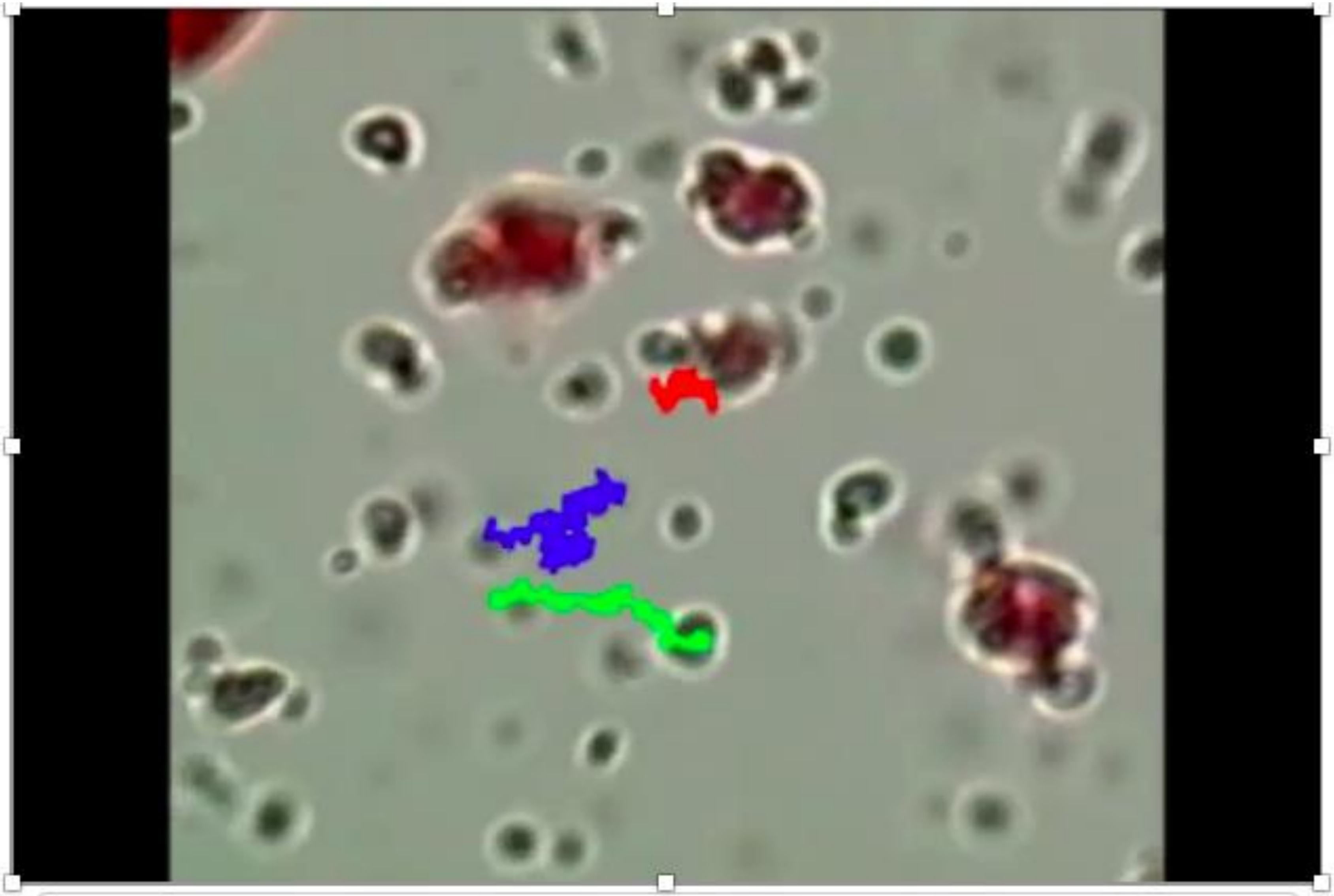
LS2102
Diffusion in Biology

Very small plastic particles in water:



Pond water under the microscope:



Ink droplet in cold, normal and hot water:

Density (ink) > Density (water)

Quantitative Explanation

Robert Brown

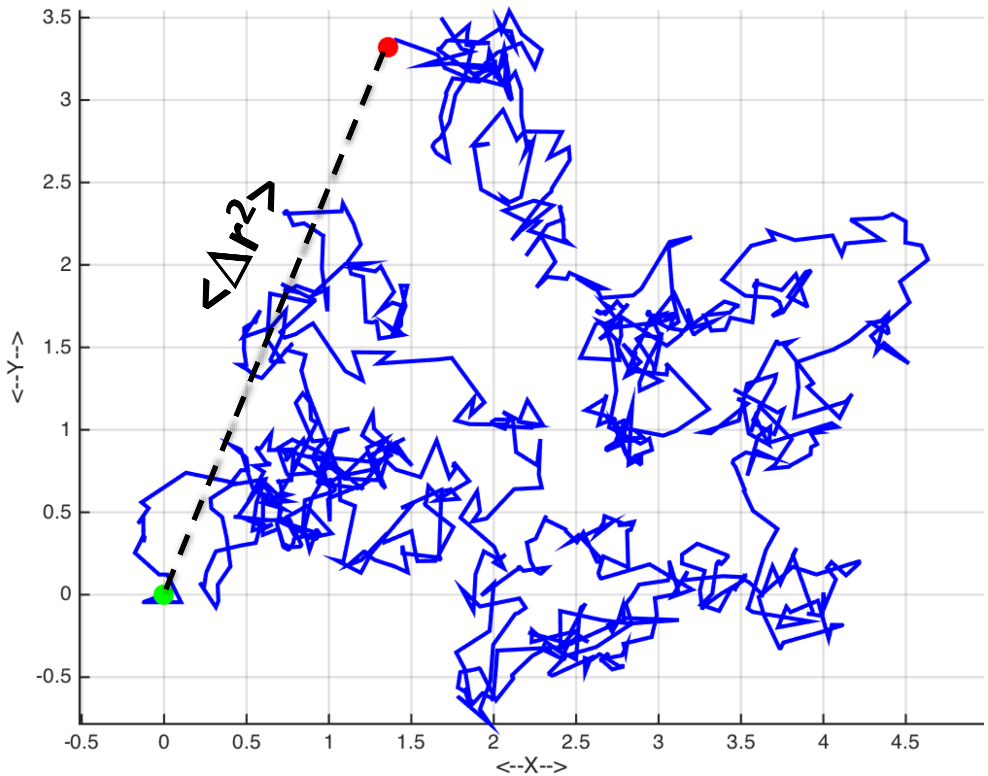
Brownian motion was discovered by **Robert Brown** in **1827**

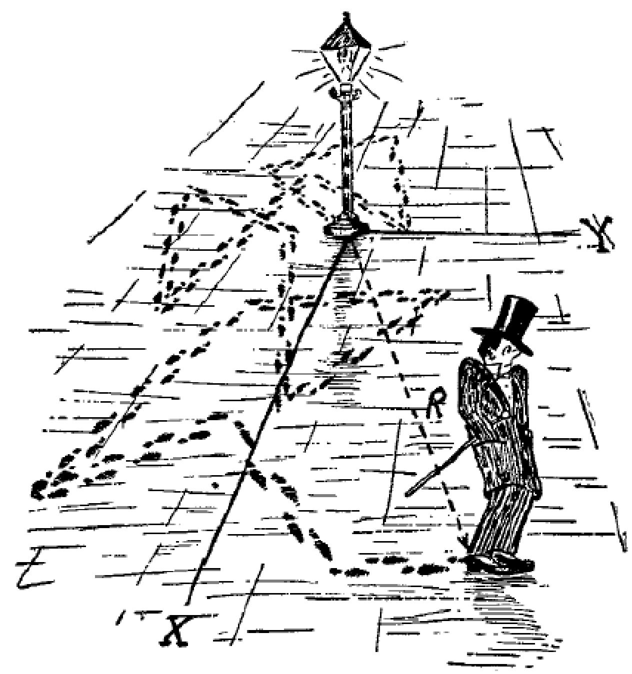
(before the Laws of Thermodynamics were put forward)

5. *Über die von der molekularkinetischen Theorie der Wärme geforderte Bewegung von in ruhenden Flüssigkeiten suspendierten Teilchen;*
von A. Einstein.

The explanation was formulated by **A. Einstein** in **1905**

Diffusion: movement of particles in unbiased random walks in any dimension

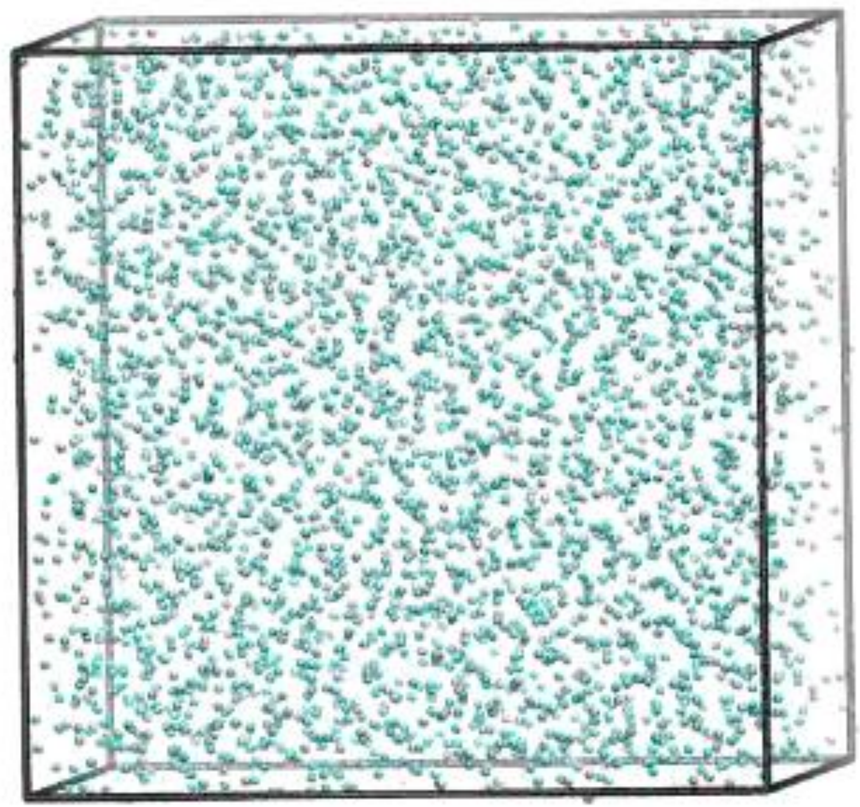




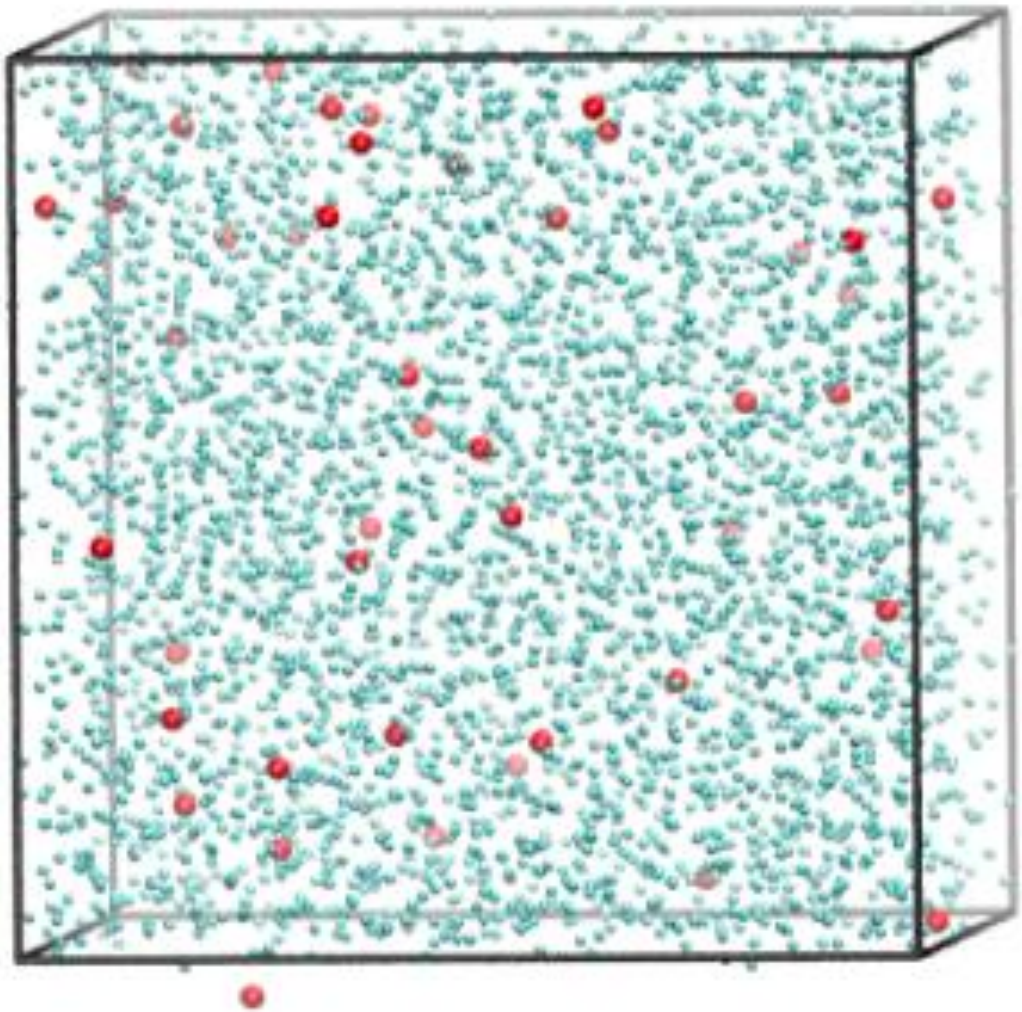
General Relationship:

$$\boxed{\langle \boldsymbol{r}_N^{\,2} \rangle = (2d)Dt}$$

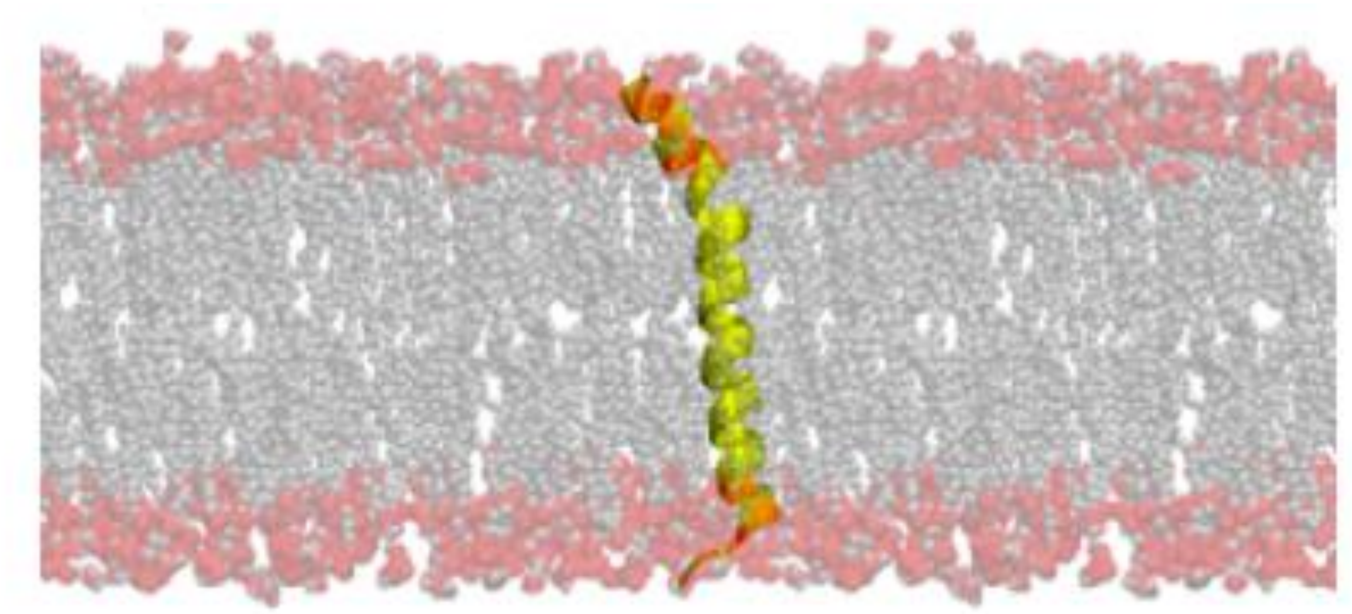
1A. Bulk Liquid - pure (Computer Simulation data)



1B. Bulk Liquid – mixture (Computer Simulation data)

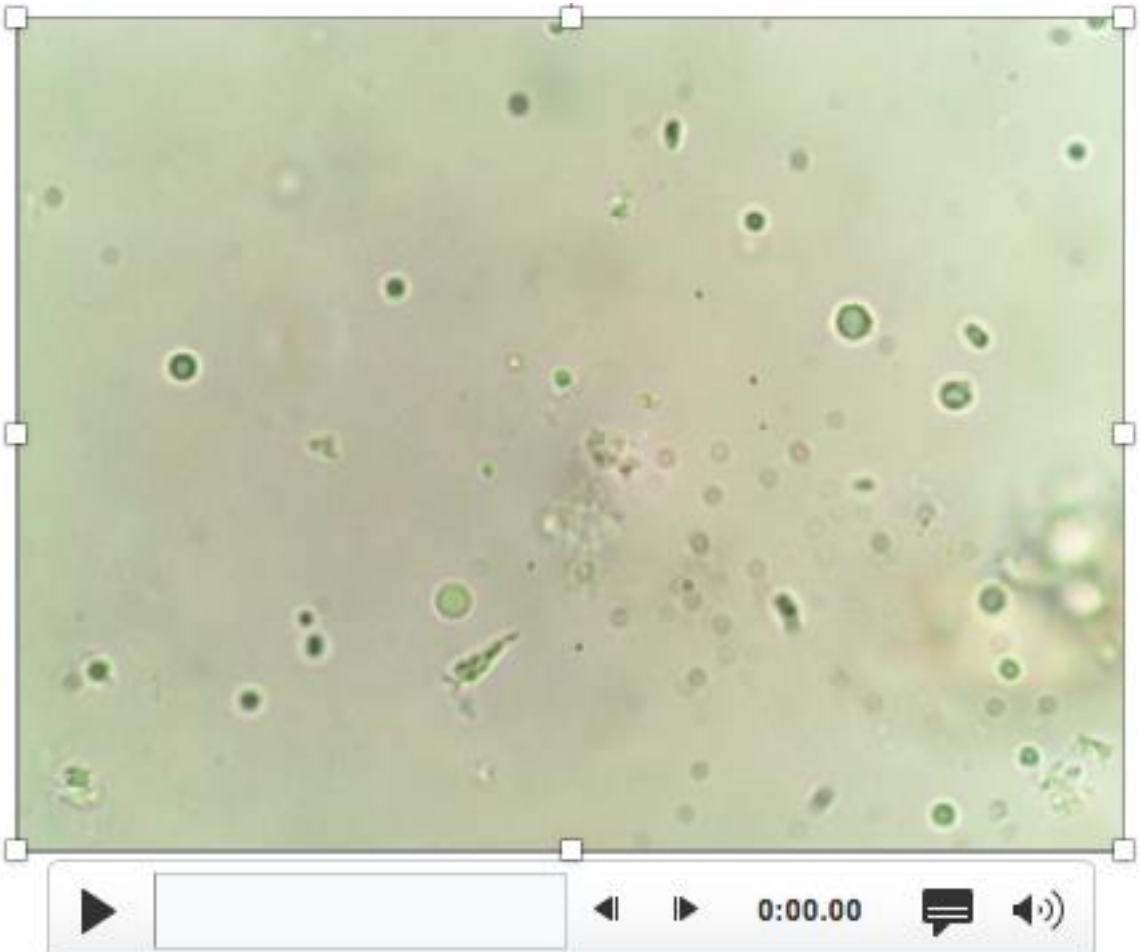


2. Protein fragment within a DPPC Bilayer (Computer simulation data)



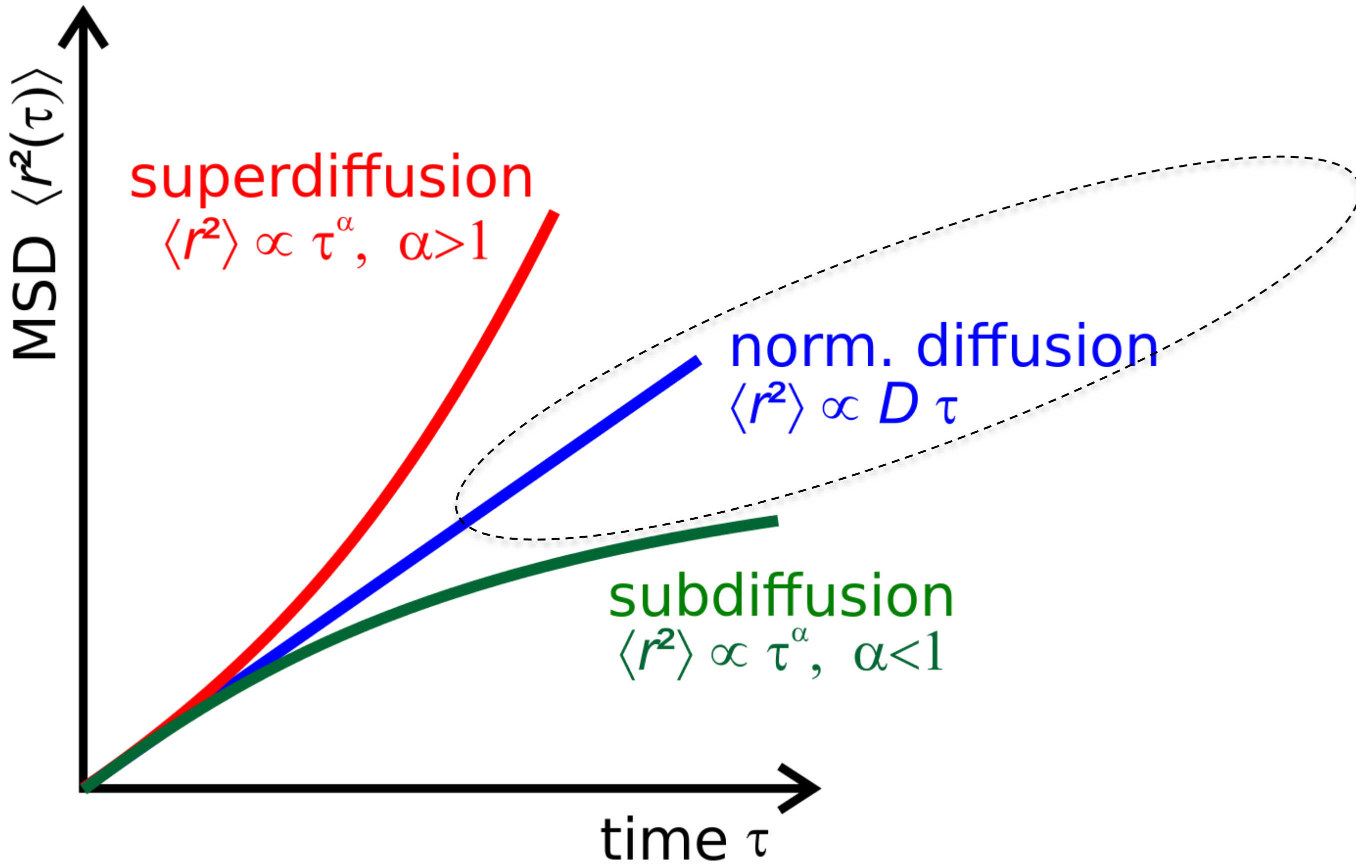
Frames spaced by Δt = 10 picoseonds

3. Pollen grain in water (Experimental data - Light microscopy)



Frames spaced by $\Delta t = 0.1$ seconds

Deviations from linearity:



Linear fits may still be done to extract and compare ‘D’

Deviations from linearity:

1. Poor statistics

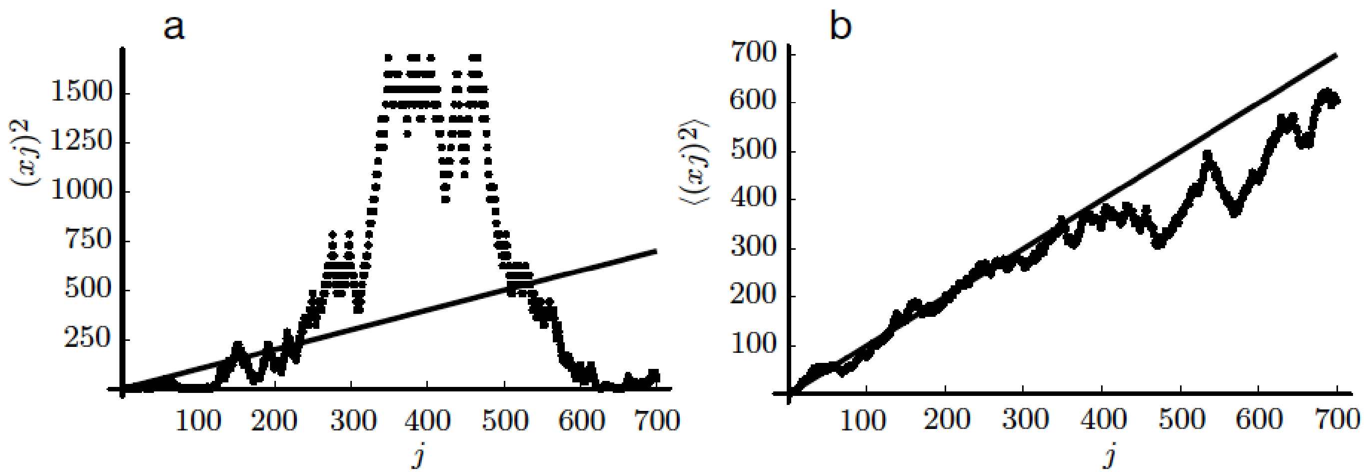


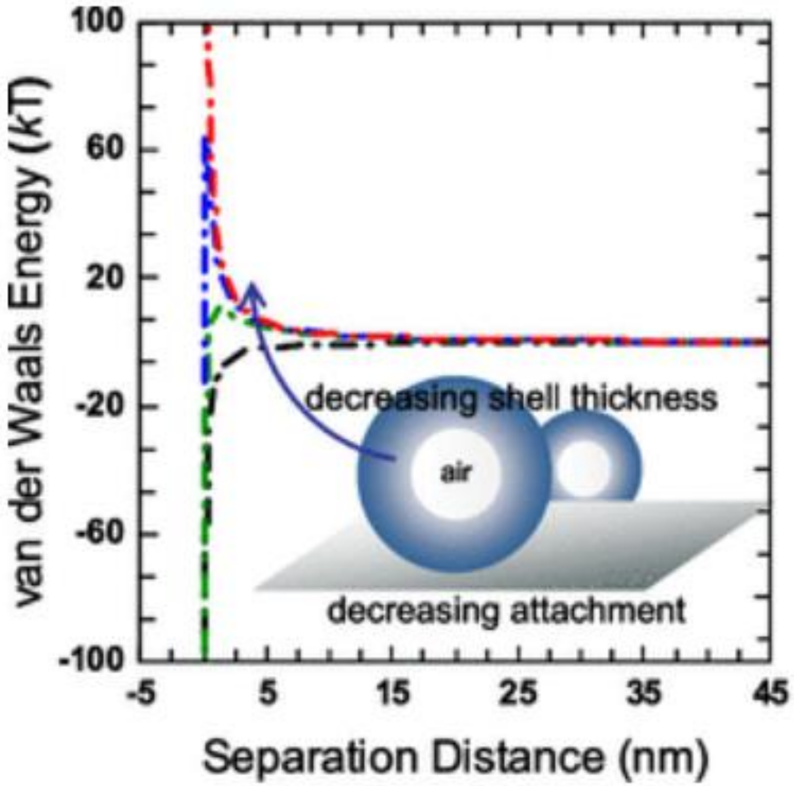
Figure 4.5: (Mathematical functions.) (a) Squared deviation $(x_j)^2$ for a single, one-dimensional random walk of 700 steps. Each step is one unit long. The solid line shows j itself; the graph shows that $(x_j)^2$ is not at all the same as j. (b) As (a), but this time the dots represent the *average* $\langle (x_j)^2 \rangle$ over thirty such walks. Again the solid line shows j. This time $\langle (x_j)^2 \rangle$ does resemble the idealized diffusion law (Equation 4.4).

Nelson, *Biological Physics*, Ch. 4

Deviations from linearity:

2. Particle-Particle Interaction

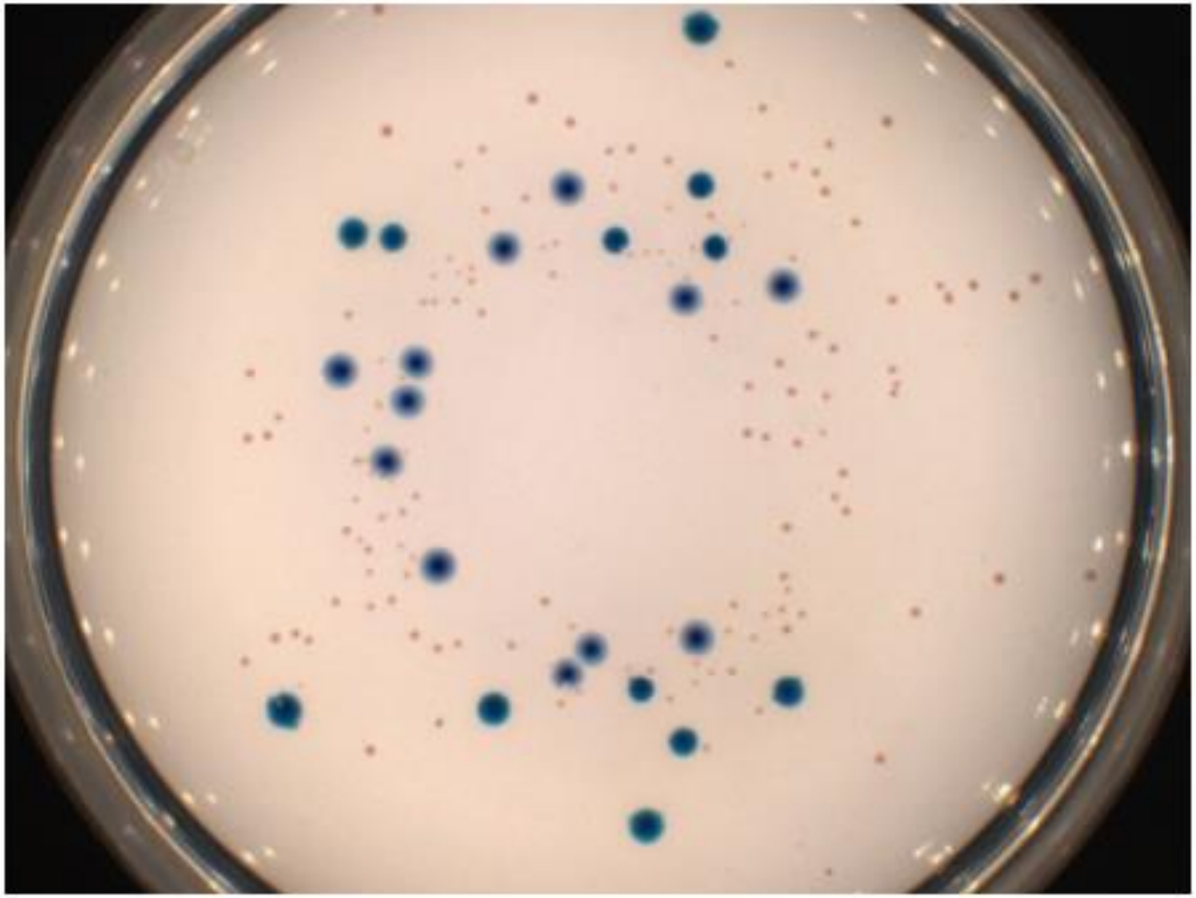
- Movement is not truly 'random'



Deviations from linearity:

3. Finite Diffusion Volume

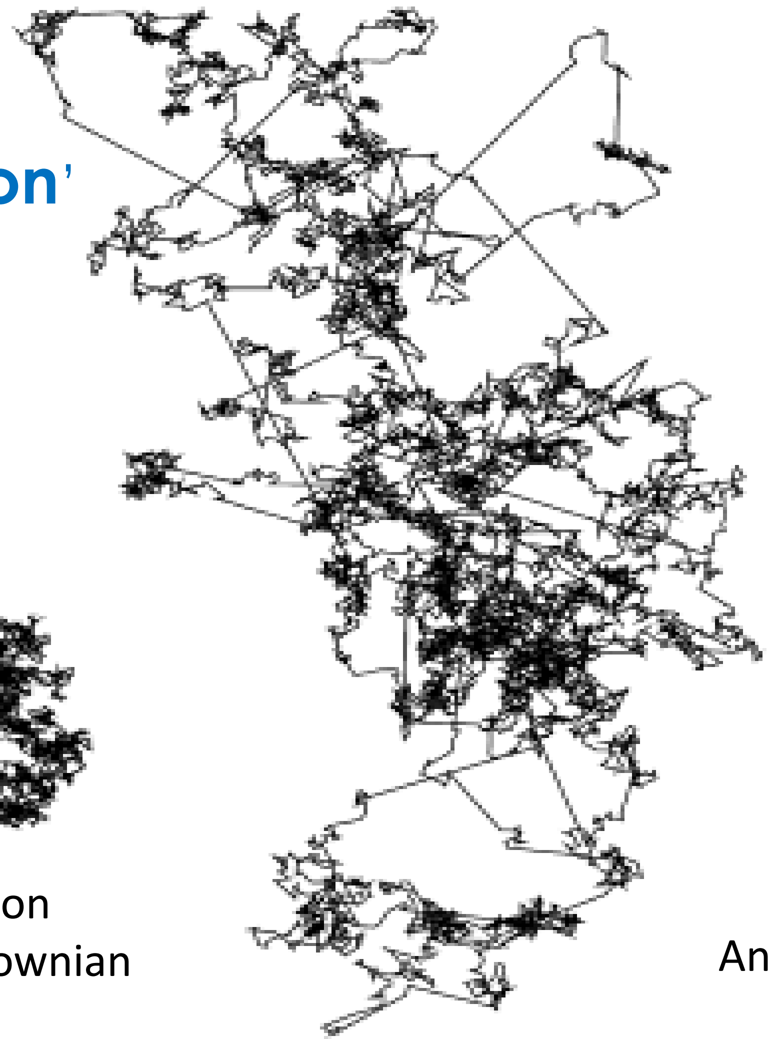
- Spatial restriction and interaction with boundaries (walls)



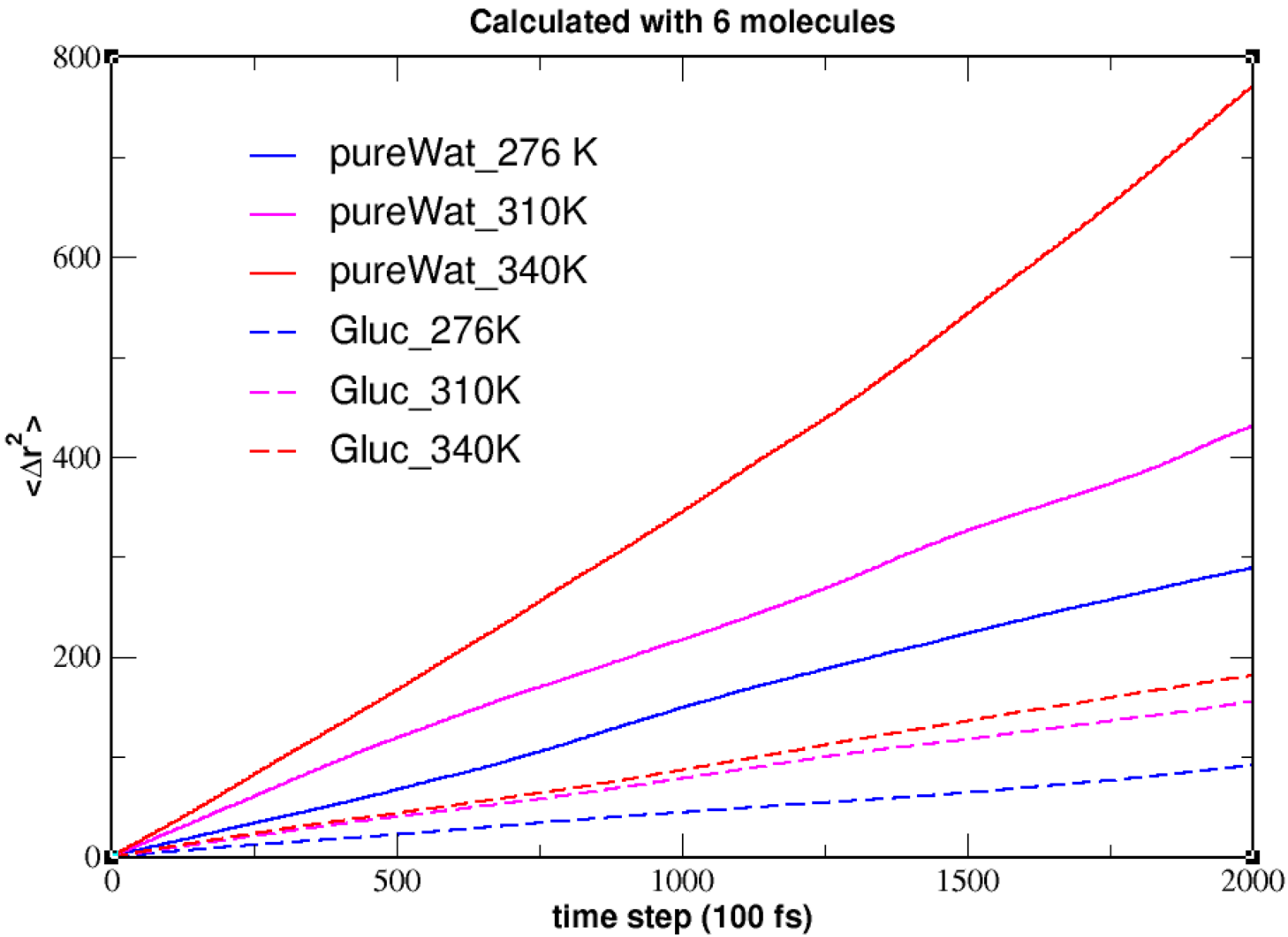
Deviations from linearity:

4. Anomalous Diffusion

Normal Diffusion
(Random walk/ Brownian motion)



Anomalous Diffusion
(Levy walk)


Calculated with 6 molecules
pureWat_276 K
pureWat_310K
pureWat_340K
Gluc_276K
Gluc_310K
Gluc_340K
<Δr^2>
0
200
400
600
800
0
500
1000
1500
2000
time step (100 fs)