Brownian motion

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Brownian motion

Small objects move around "randomly"

Every object is constantly bombarded by water molecules, which bounce off it, knocking it back.

These collisions produce forces that are
- random magnitude
- random direction ← only this is required to produce Brownian motion
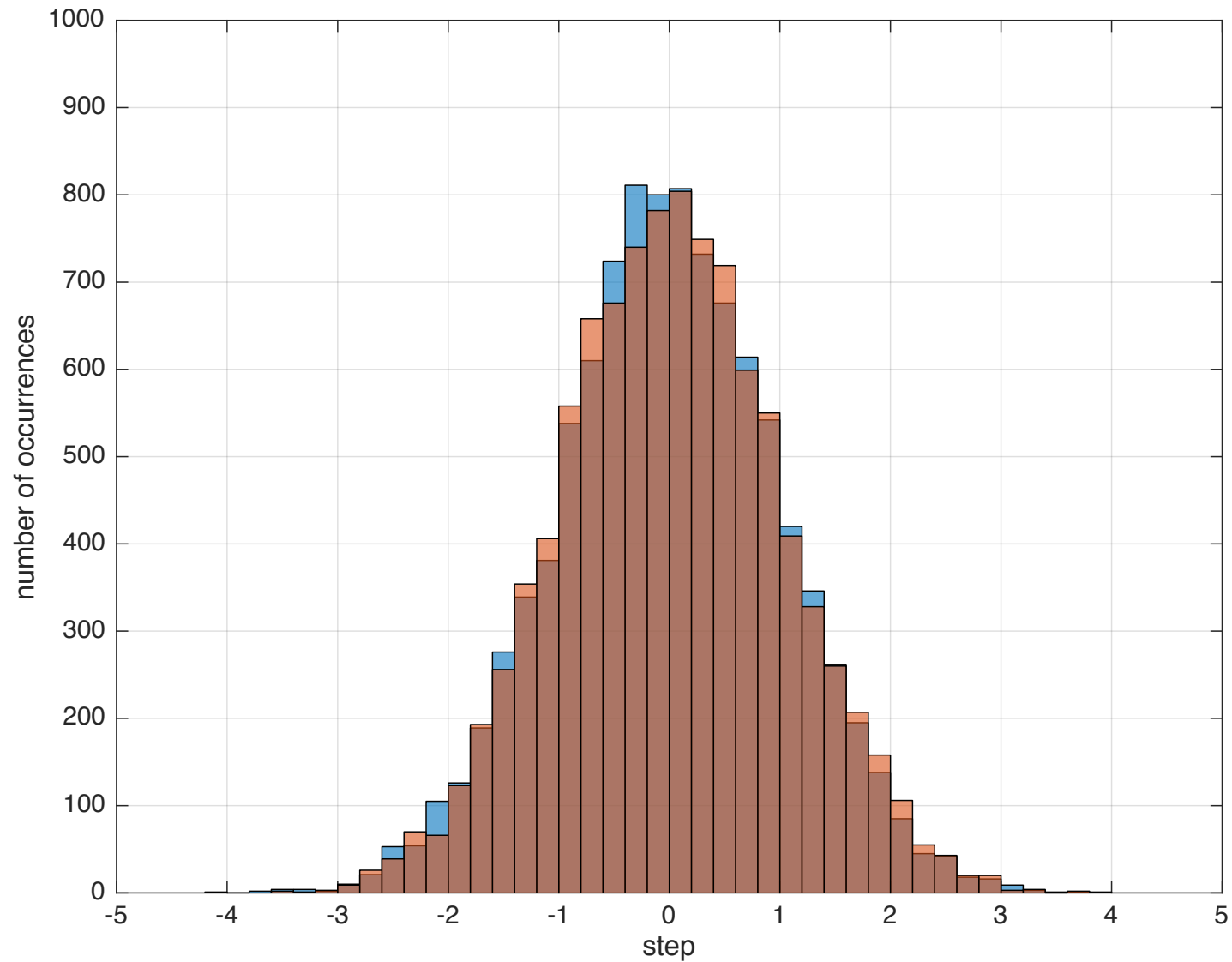- random timing

The motion of a single object is impossible to predict, but the *average* can be calculated
We can calculate the population average or the average of one particle over a long time. They are the same.

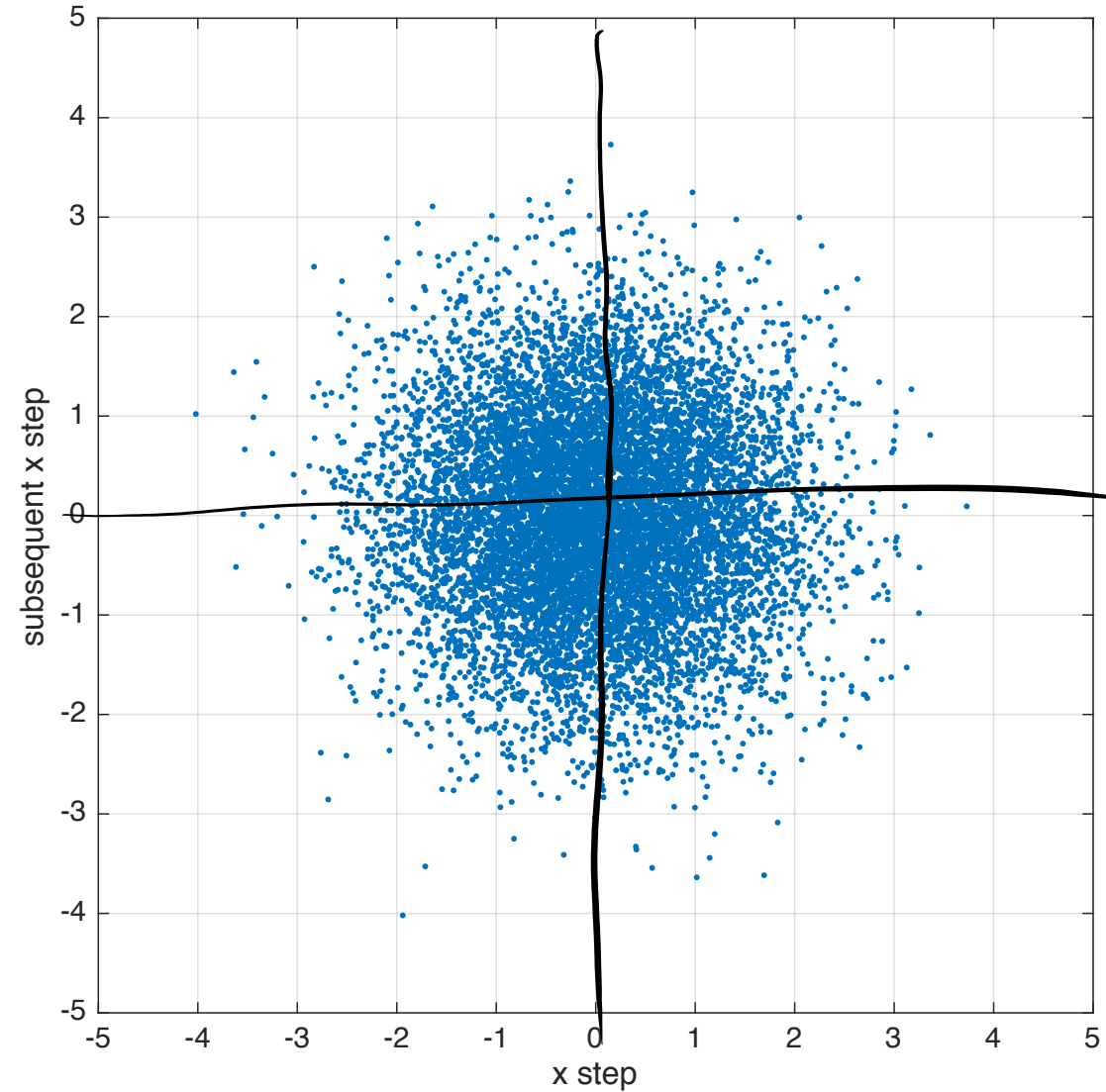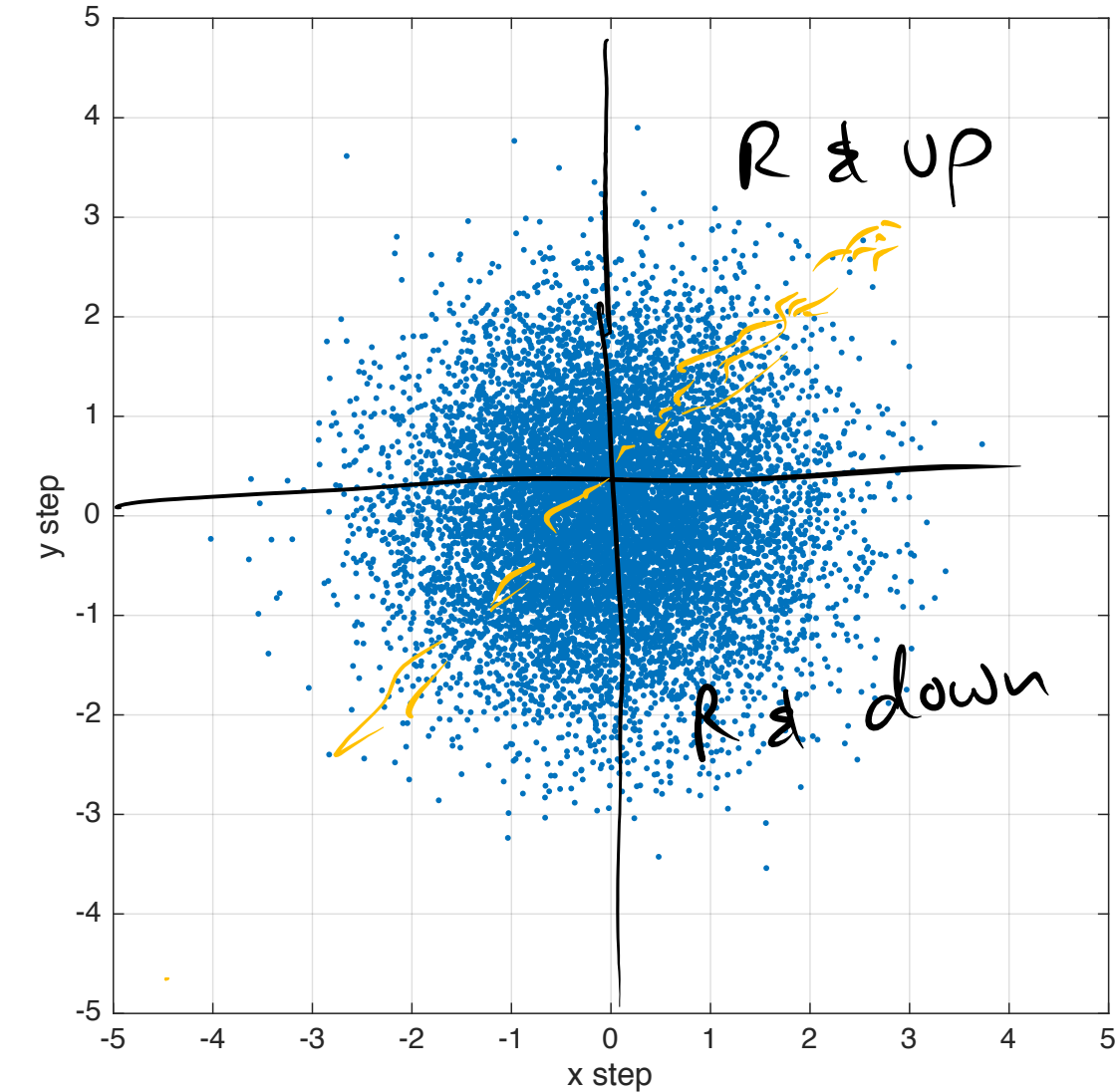## Large objects do Brownian motion too, but we tend not to notice.

Brownian motion

Displacement (aka *steps*) is random in x and y:
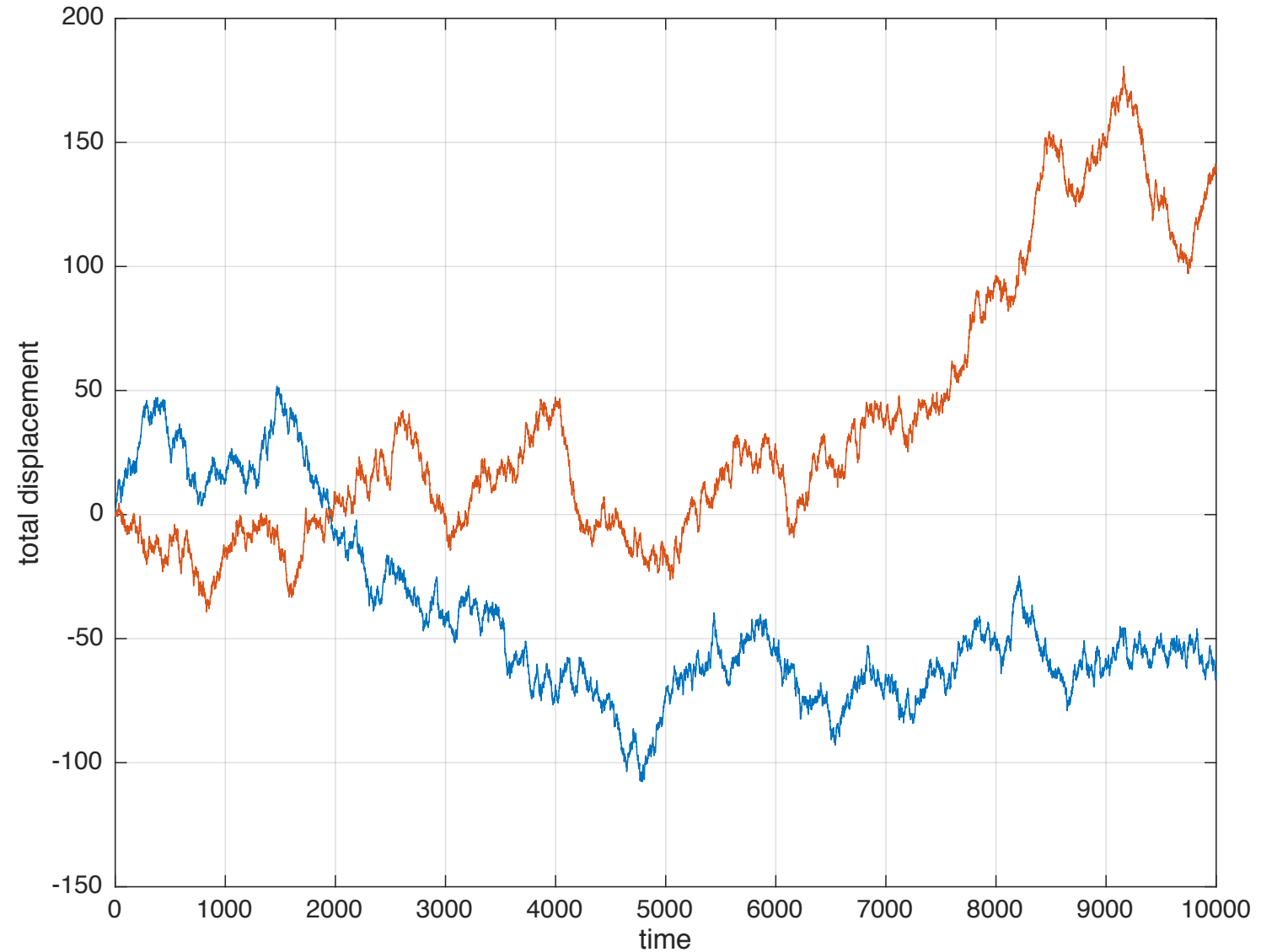
Brownian motion

Steps in x and y are uncorrelated:

Brownian motion

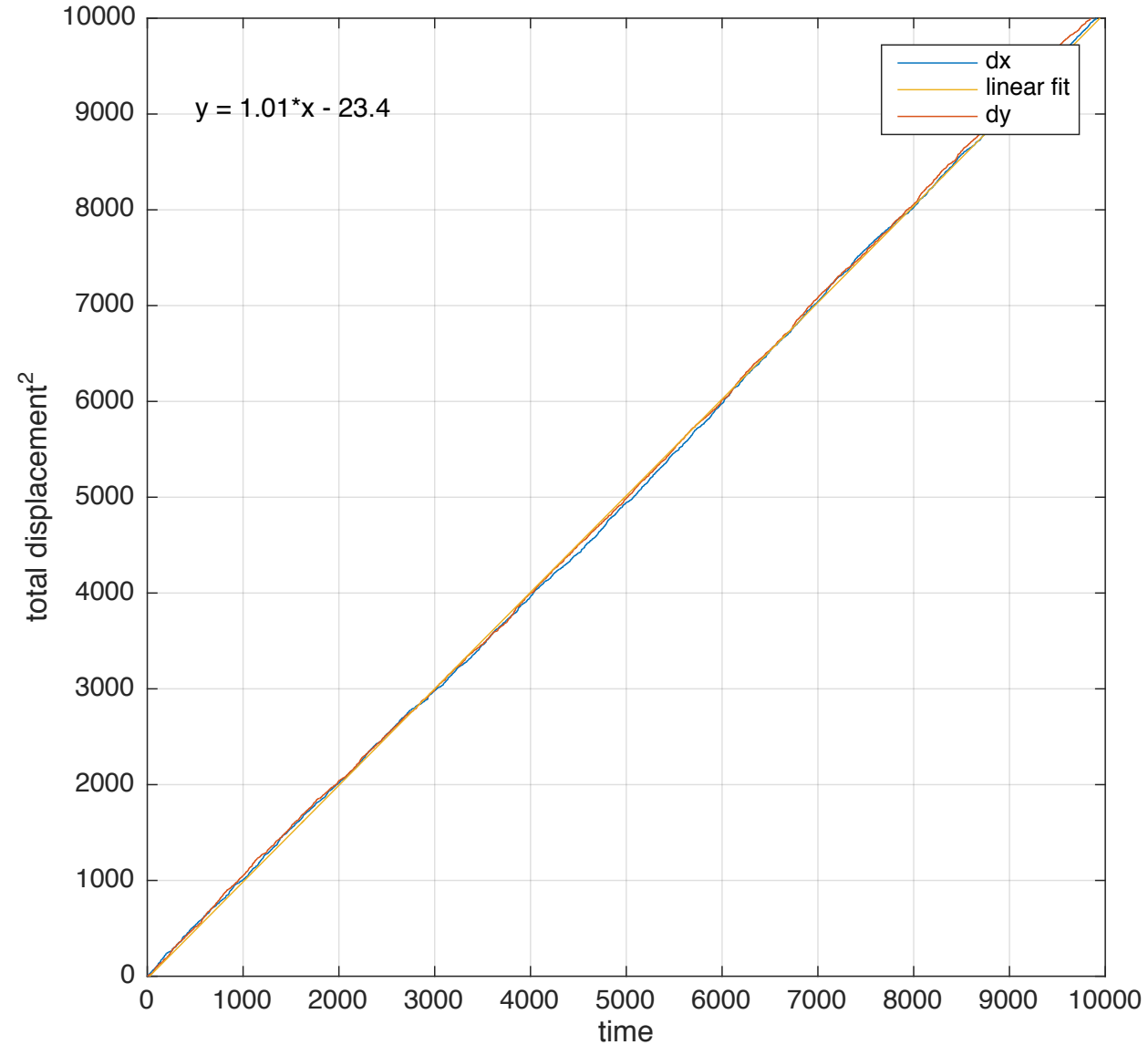Over time, the average displacement is zero in x and y

$$\langle x(t) \rangle = \langle y(t) \rangle = 0$$

Brownian motion

Over time, the average displacement^2 is NOT zero:

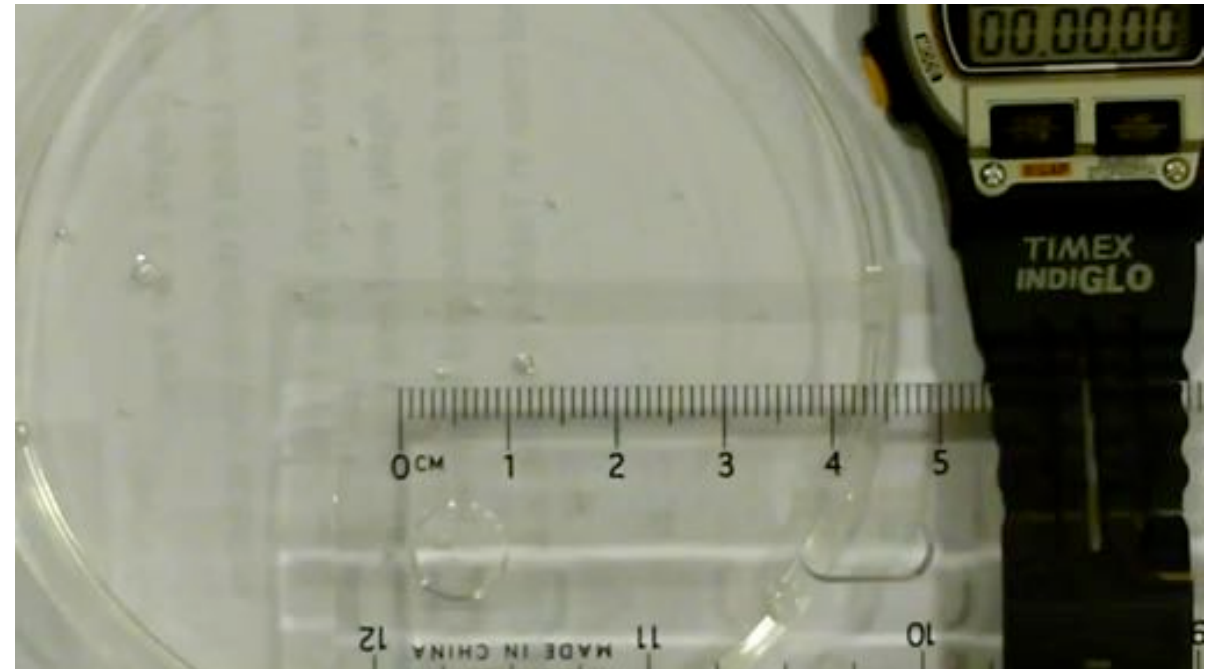$$\langle x^2(t) \rangle = \langle y^2(t) \rangle = 2Dt$$

Brownian motion

In 1D: $\langle x^2 \rangle = 2Dt$

In 2D: $\langle r^2 \rangle = \langle x^2 + y^2 \rangle = \langle x^2 \rangle + \langle y^2 \rangle = 4Dt$

In 3D: $\langle r^2 \rangle = \langle x^2 + y^2 + z^2 \rangle = 6Dt$

Brownian motion is the microscopic explanation of the macroscopic phenomenon of diffusion:

Brownian motion

Summary:

Brownian motion

Brownian motion in biology:

1. Bacterial chemotaxis.

2. Search patterns (horseshoe crabs).

3. Rates of molecular reactions.

Today's lab

1. Record at least 30 frames of microbeads suspended in water using the inverted microscope.
2. Track one bead by hand using ImageJ.
3. Plot x(t) and x^2(t) vs time: does this look like Brownian motion?
4. Turn in your plots and your two-sentence conclusion for next lab.

also $\Delta y(t)$

$\Delta y^2(t)$

$\Delta r^2 = \Delta x^2 + \Delta y^2$

Microscope hints

The slide must be upside down (cover slip *down*).
Start from low mag if you're having trouble finding the beads.

Illumination:

Don't bother using phase contrast.

Make sure some light is going to the camera.

The camera needs more light than your eye does.

Turn up the lamp when recording.

Recording video

Use the manufacturer's video grabbing software (AmScope)

Note the frame rate. In the future, record the spatial calibration.

Use wmv recording format with all default parameters.

Fiji can handle this with the ffmpeg importer

Move your video to a safe location before logging out. I use the prism drive.

Fiji

If Fiji is crashing when importing, update it twice, quit and restart.