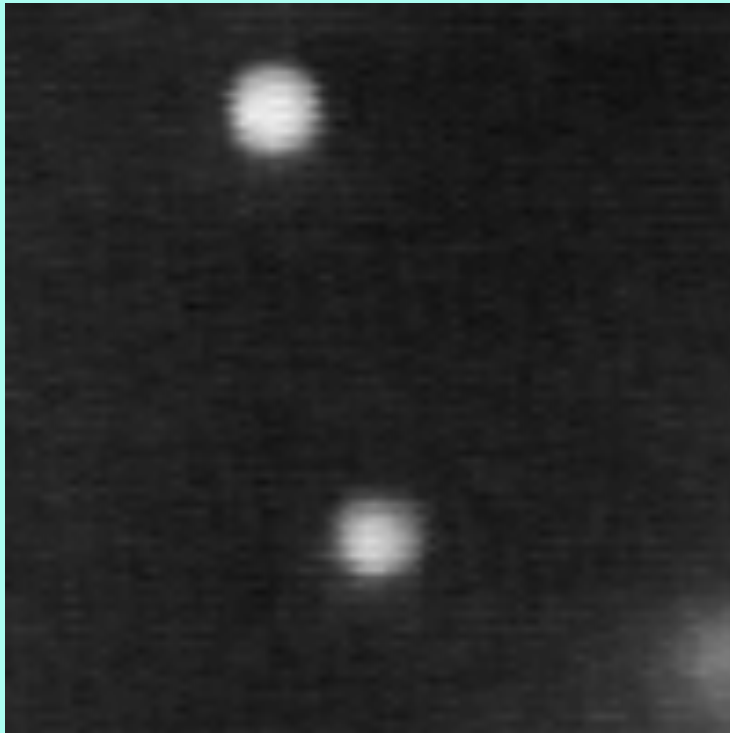
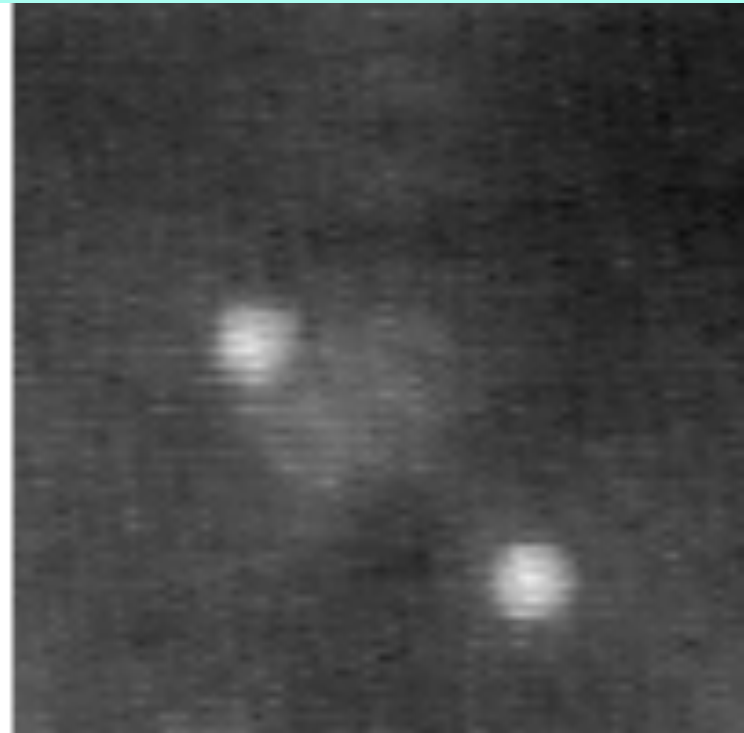


Brownian Motion

In 1828 Robert Brown, investigating pollen in water through a microscope, observed particles moving irregularly.



2 micron spheres
in water



2 micron spheres
in goo (DNA solution)

(Movies from Eric Weeks)

Theories of Brownian Motion

- Wrong theories proposed (irregular heating by incident light; electrical forces)
- In 1877 Delsaux proposed Brownian motion due to impacts of liquid molecules on the observed particles. (Right idea)
- Between 1905 and 1908, Einstein published papers laying out the theory of Brownian motion.

Simulation of Brownian Motion

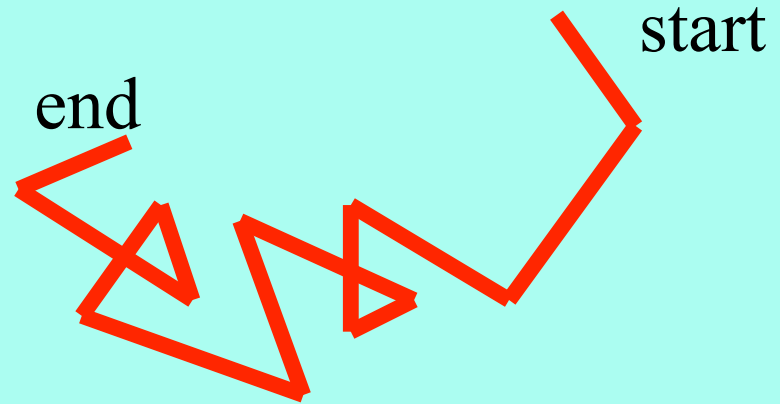
[brownianSimulation.html](#)

Einstein's Theory of Brownian Motion



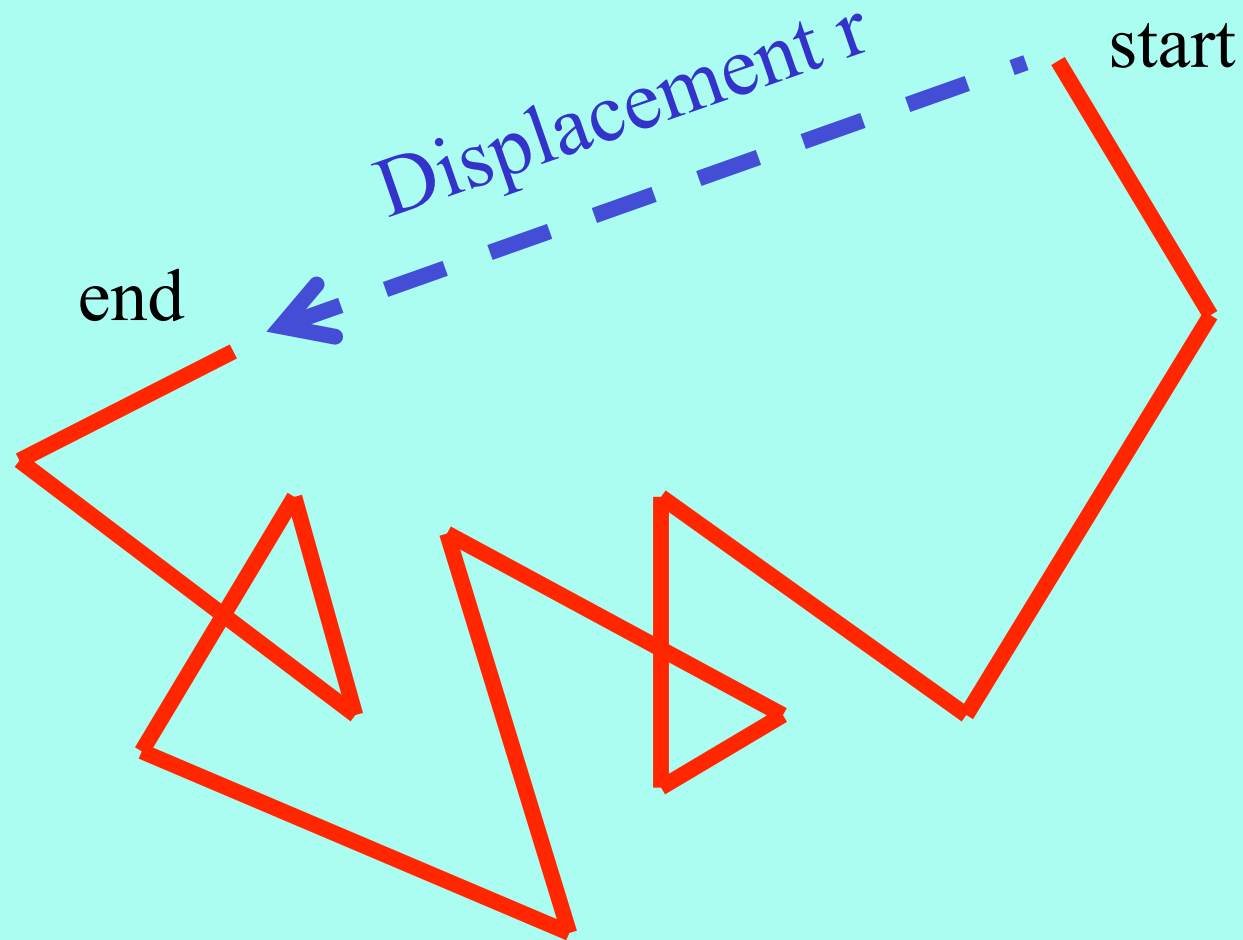
- Smaller particles move faster.
- Particles move faster at higher temperature.
- Larger particles move less than smaller particles.
- Particles move less in high viscosity solutions.
- Particles diffuse rather than move ballistically.

Random Walk



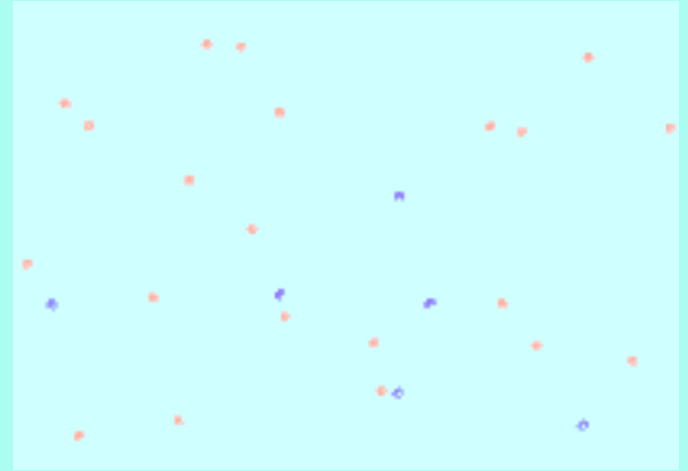
- The trajectory of the diffusing particle is a random walk. brownianSimulation.html
- Drunk starts from a lamp post and has equal probability of taking a step to the right or the left.
- Don't know where to go for dinner? Flip a coin at every intersection to decide whether to go right or left. Your route will be a random walk.

Displacement r is distance traveled
as the crow flies






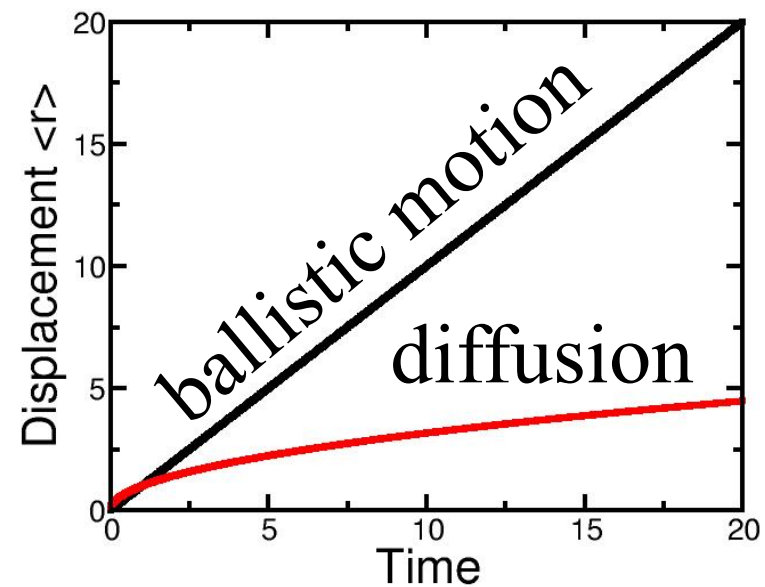
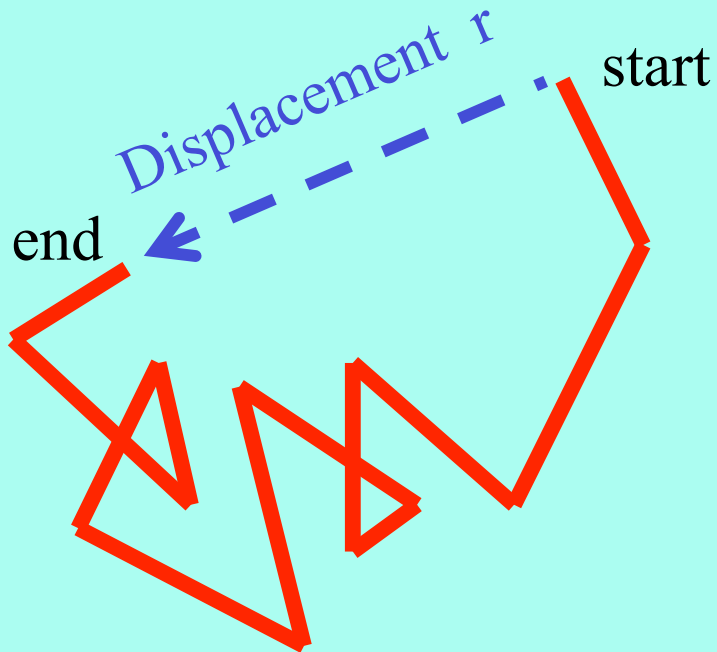
Diffusion



- Perfume particles diffuse through the air to your nose from an open perfume bottle
- Milk in coffee diffuses
- Drop of ink in water diffuses
- Particles undergo Brownian motion
- Particles perform random walk

Diffusion vs. Ballistic Motion

- Ballistic motion: Distance traveled increases linearly with time. 
- When particles diffuse, they don't go as far as when they move ballistically in a straight line in one direction.
- Average diffusive displacement $\langle r \rangle$ goes as $\sqrt{\text{time}}$



Einstein's Legacy

- Brownian motion, diffusion, random walks are still used today in science (physics, biology, chemistry, etc.), engineering and economics.

