Introduction:
Cellular-level simulation

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Ron Dror
• The interior of the cell is crowded, and all the molecules jiggle about.
• Note that lots of molecules (e.g., water) aren’t even shown in this movie.
Molecules jiggle about because other molecules keep bumping into them

https://www.youtube.com/watch?v=1jYabtziQZo
Diffusion

- This “jiggling about” by lots of molecules leads to diffusion
- Individual molecules follow a random walk, due to collisions with surrounding molecules
- Diffusion = many random walks by many molecules
  - Substance goes from region of high concentration to region of lower concentration
Reaction-diffusion simulation

• A common way to model how molecules move within the cell involves reaction-diffusion simulation

• Basic rules:
  – Molecules move around by diffusion
  – When two molecules come close together, they have some probability of reacting to combine or modify one another

• Several implementation strategies:
  – Particle-based
  – Continuum models
  – In some (limited) cases, one can solve the partial differential equations analytically
Particle-based approach

• Represent molecules by particles, and track the motion of each one
• Example software: ReaDDy (topic of one paper)
Continuum approach

- Divide space into finite “voxels”
- Instead of tracking positions of molecules, track concentrations of each type of molecule in each voxel
- At each time step, update concentrations based on reactions of molecules within a voxel, and diffusion between neighboring voxels based on concentration differences
- Example software: Simmune (topic of one paper), Virtual Cell (used by another paper, which also presents some analytical solutions)
Background information

• Review paper (Models at the single cell level, 2010)

• Slides from CS/CME/Biophys/BMI 279: