ME 517: Micro- and Nanoscale Processes

Lecture 16: Microfluidics - Introduction I

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Spring 2014

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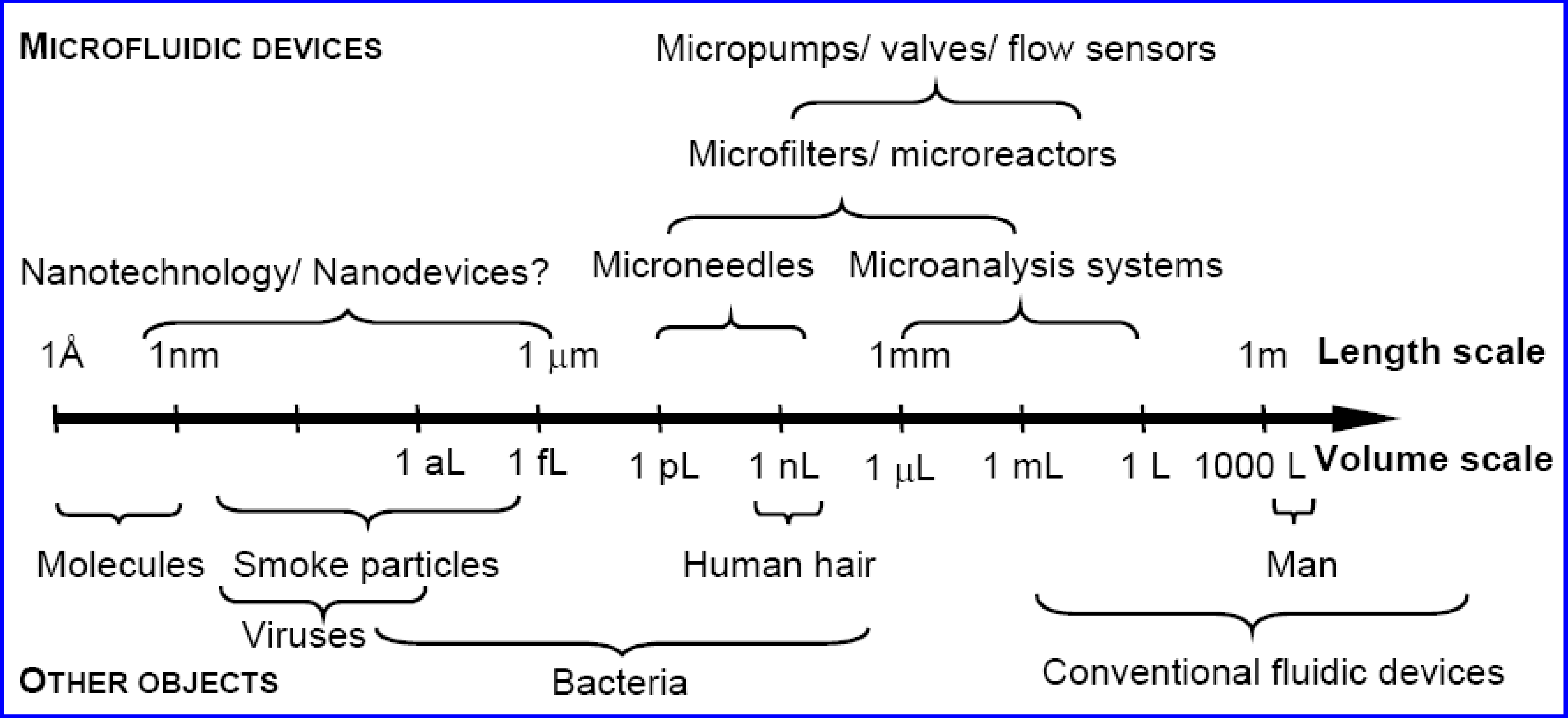
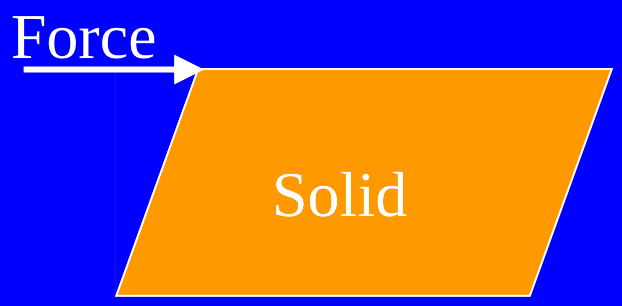
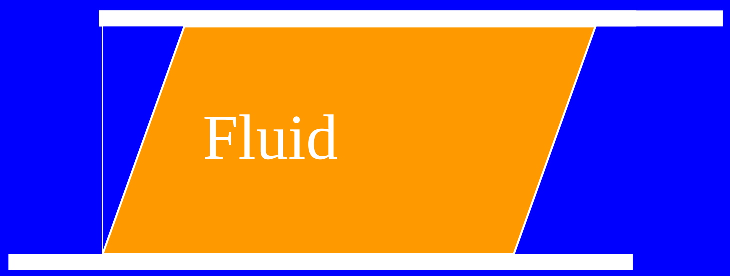
Microfluidics Length Scales/Applications



Fundamentals of Fluids

- **Definition**:
  A fluid is a substance that deforms continuously under the application of a shear (tangential) stress no matter how small the shear stress may be.
- Liquids and gases are very different animals
  – Liquids become *less* viscous as T increases
  – Gases become *more* viscous at T increases





Macroscale Fluids

- Used to carry heat around a circuit
  - forced air heating, refrigeration
- Used to transmit forces
  - Hydraulic lines,
- Used to create forces
  - Jet engines, paper handling systems
- Used to transport materials
  - Leaf blowers, paints

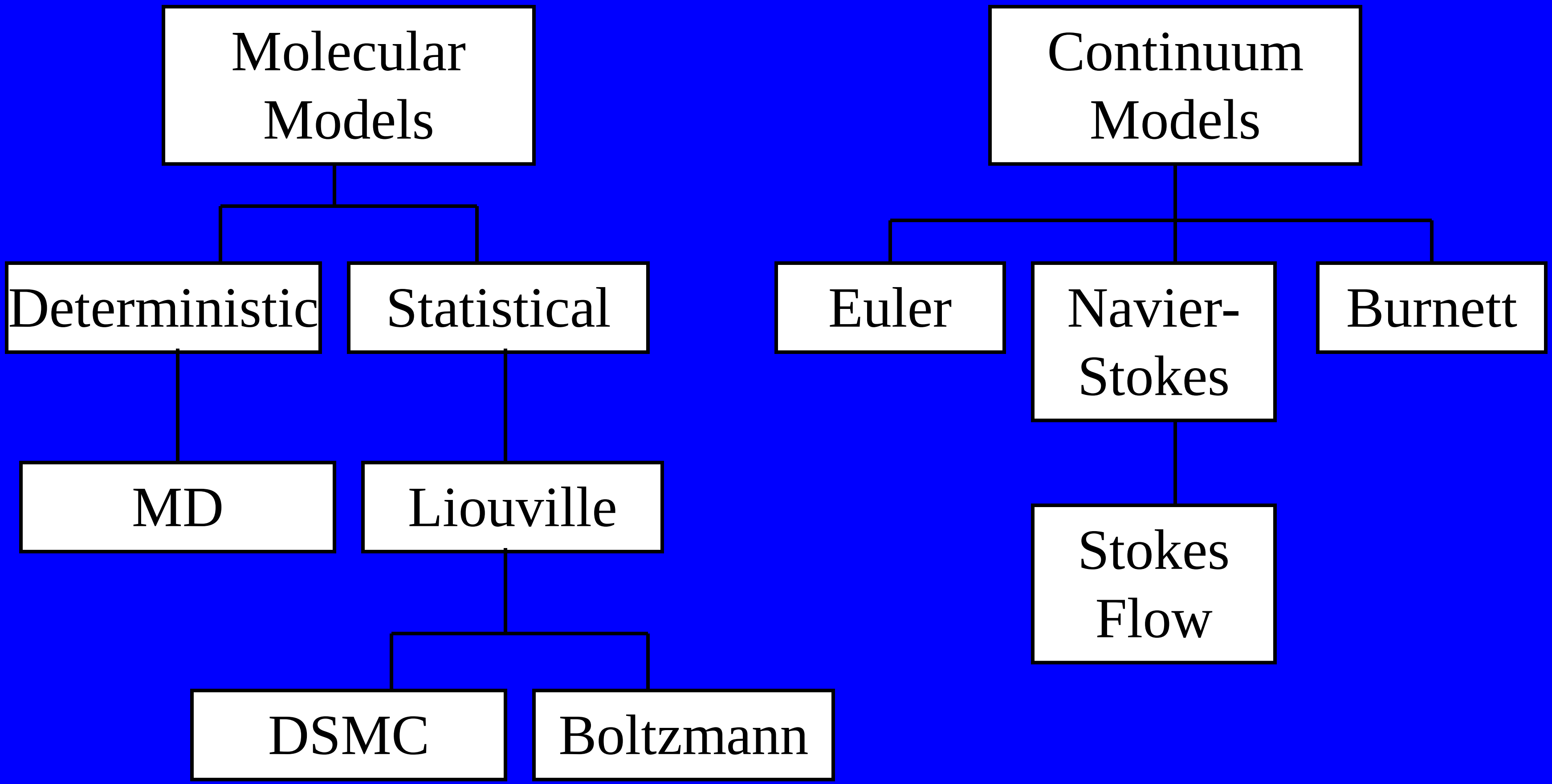
Microscale Fluids

- Used to carry heat around a circuit
  - on-chip IC cooling, micro heat pipes
- Used to transmit forces
  - PDMS phase change pumps
- Used to create forces
  - micro thrusters
- Used to transport materials
  - distribute cells, molecules to sensors

Fundamental Macro Assumptions

- Fluid behaves as a continuum
- Fluid ‘sticks’ to surfaces (no-slip condition)
- Fairly high Reynolds number (Re)
  Re=inertial forces/viscous forces
  implies inertia relatively important

Fluid Modeling Family Tree



Two Approaches for Modeling Fluids

- Continuum models
  - works when point quantities can be large enough to contain many molecules but still small compared to the scale of the flow
- Molecular Models
  - must be used when these conditions are not met
- Can be complicated to figure out which domain you're in
  - Almost always requires at least some knowledge of the molecular nature of the fluid

Molecular Interaction Forces: Lennard-Jones 6-12 Potential

$$V_{ij}(r) = 4\varepsilon\left[c_{ij}\left(\frac{r}{\sigma}\right)^{-12} - d_{ij}\left(\frac{r}{\sigma}\right)^{-6}\right]$$

$$F_{ij}(r) = -\frac{\partial V_{ij}}{\partial r} = \frac{48\varepsilon}{\sigma}\left[c_{ij}\left(\frac{r}{\sigma}\right)^{-13} - \frac{d_{ij}}{2}\left(\frac{r}{\sigma}\right)^{-7}\right]$$

V_{ij}=potential energy between t
molecules i and j

F_{ij}=force between two molecul
i and j

c_{ij} and d_{ij} are parameters for chosen molecules

ε,σ are characteristic energy ar
length scales respectively

r is the separation distance