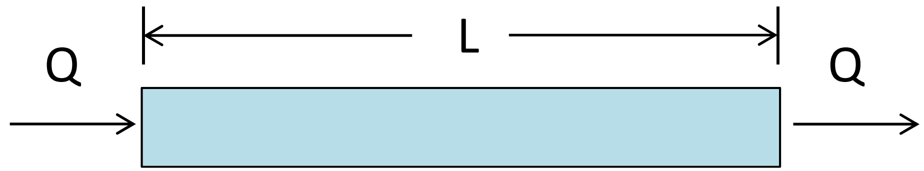
Reactors II

Today's lecture

- **Plug flow reactor**
  - Concept
  - PFR analysis for 1st order reaction
  - PFR analysis for Monod kinetics

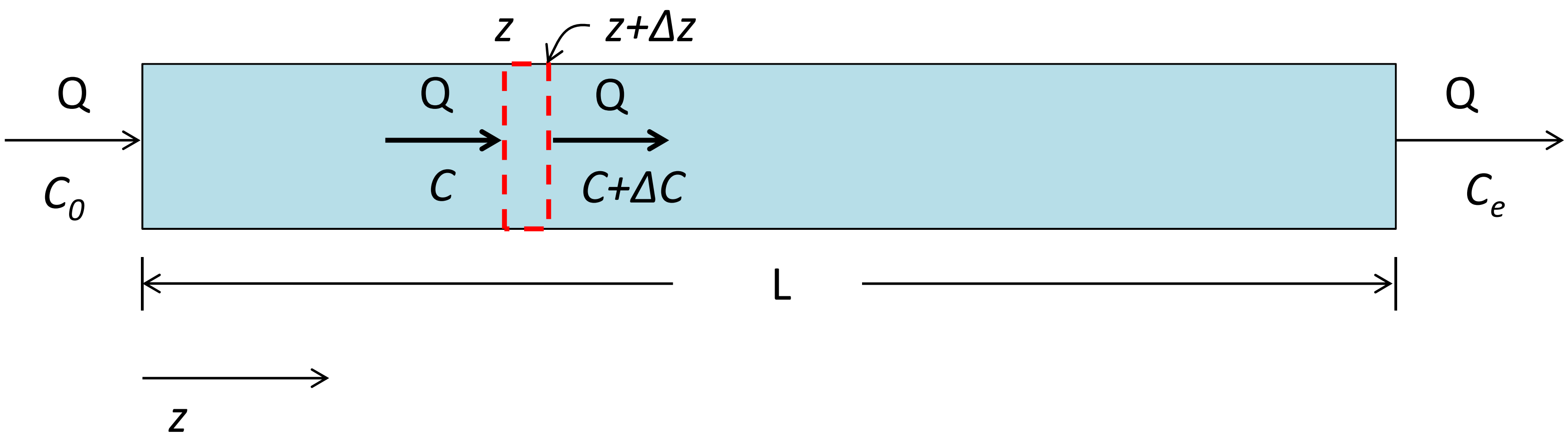
- **Continuous-stirred tank reactor**
  - CSTR analysis for 1st order reaction
  - PFR vs. CSTR
  - CSTR analysis for Monod kinetics

Reactor analysis: PFR



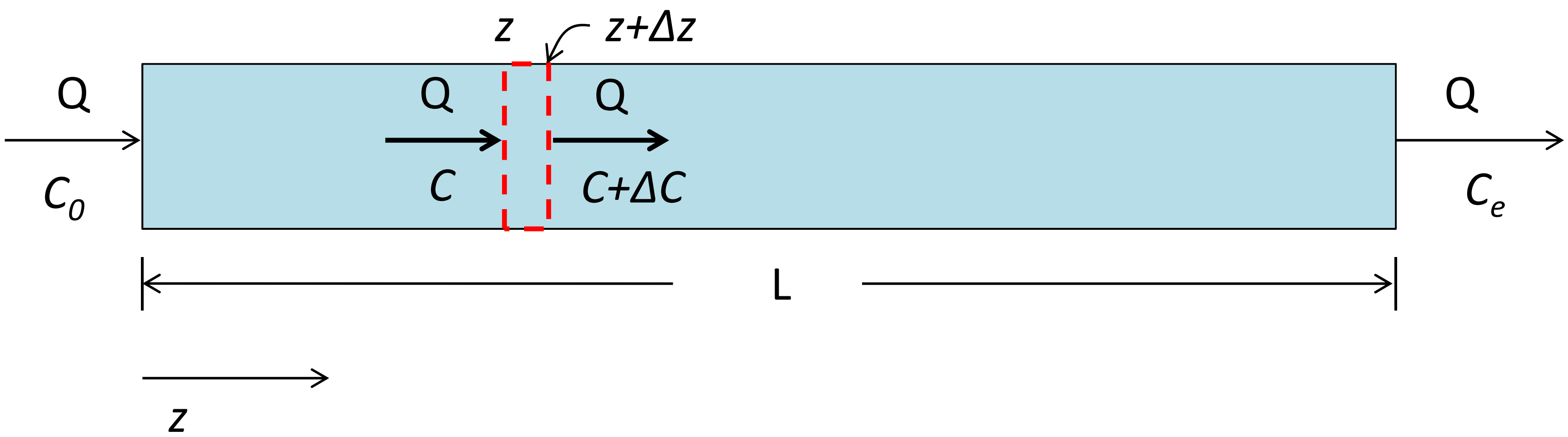
- Plug flow reactor (PFR)
  - assumption: no mixing in the direction of flow & completely mixed in the direction perpendicular to the flow
  - reactors get close to PFR as the length gets longer than the width and depth (e.g., rivers)

PFR, first-order reaction



- Take control volume as a thin plate perpendicular to the flow at $z=z$ with a dimension of Δz in z dir.

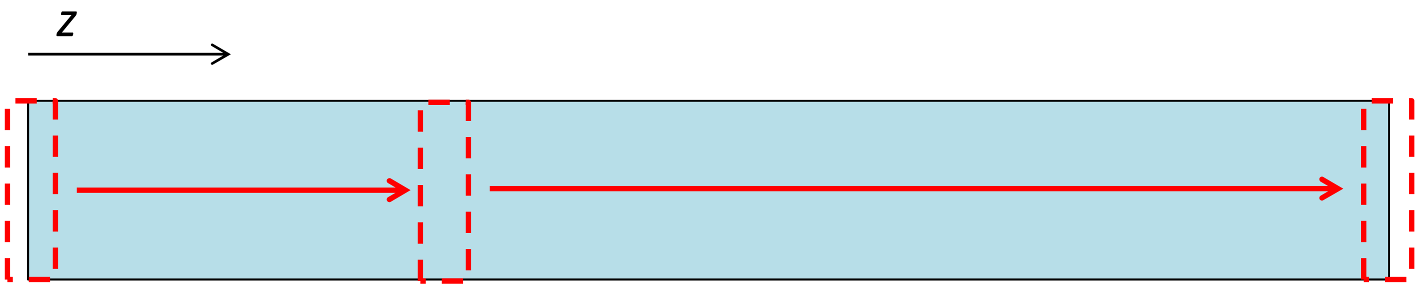
PFR, first-order reaction



$$C/C_0 = e^{-k\theta}$$

Same form as the batch reactor (why??)

PFR, first-order reaction



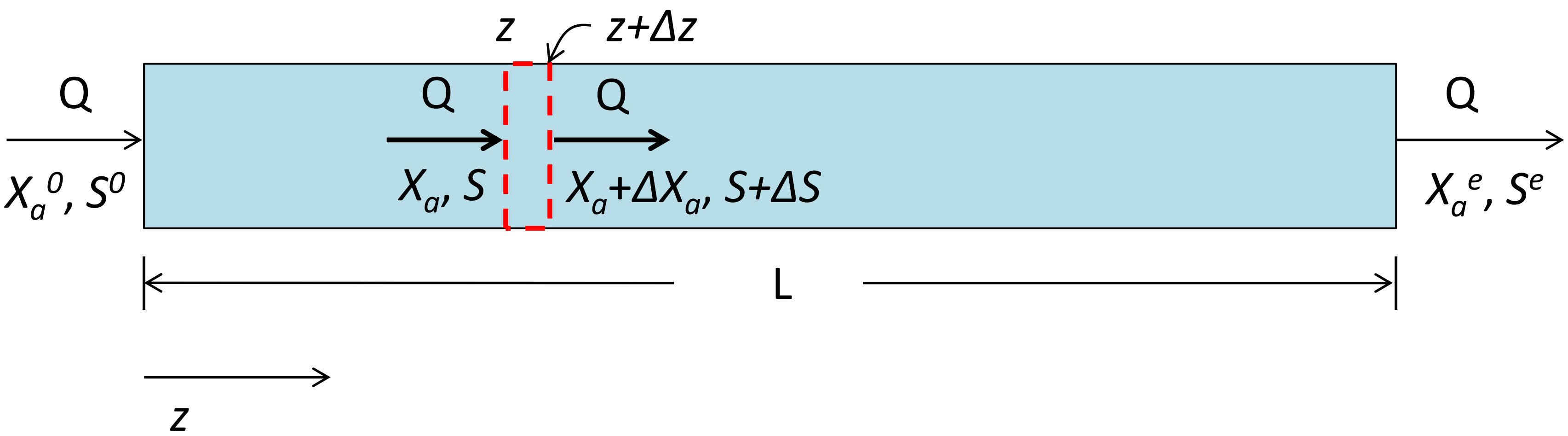
distance=0, time=0, $C=C_0$

distance=z, time=t, $C=C_0e^{-kt}$ $=C_0e^{-kz/u}$

distance=L, time=Θ, $C=C_0e^{-k\Theta}$ $=C_0e^{-kL/u}$

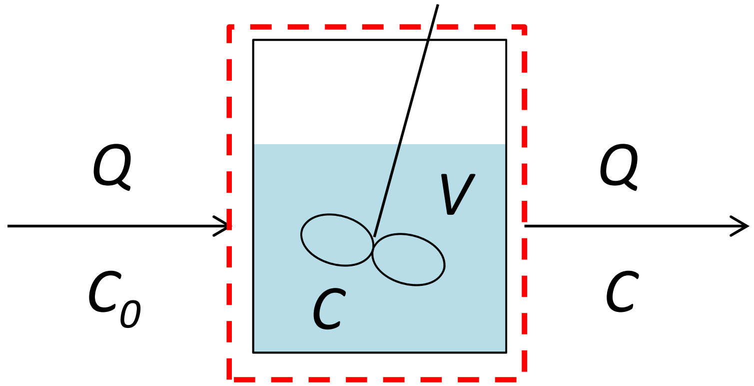
- We model plug flow reactor as a movement of a “plug”
- The plug has a cross sectional area same as the reactor dimension and an infinitesimal dimension in z-dir (a thin plate)
- Complete mixing within the plug → batch reactor moving in the direction of flow

PFR, Monod kinetics



$$u\frac{dS}{dz} = -\frac{\hat{q}S}{K+S}\left[X_a{}^0 + Y(S^0 - S)\right]$$

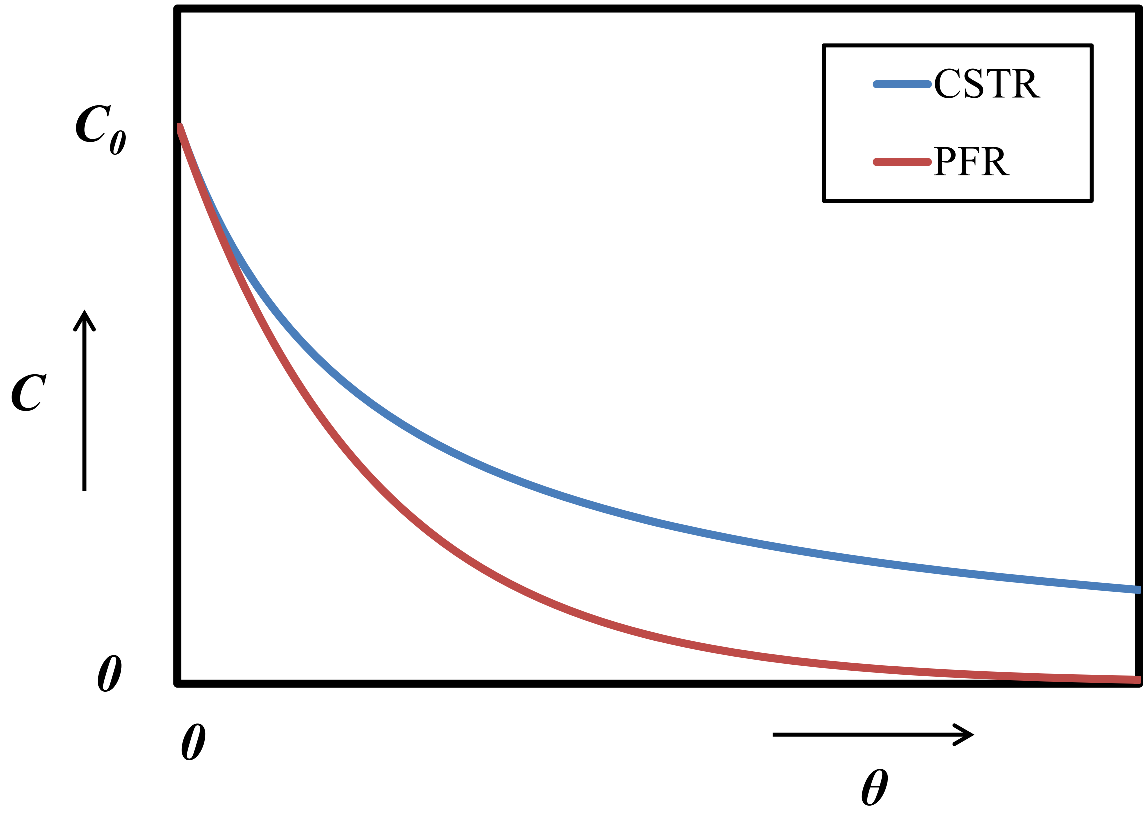
Reactor analysis: CSTR, 1st order



At steady state,

$$C = \frac{C_0}{1 + k\theta}$$

PFR vs. CSTR



For 1st order reaction,

CSTR:

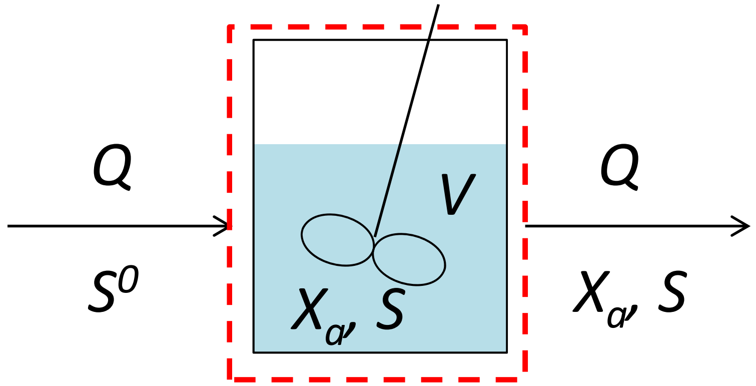
$$C = \frac{C_0}{1 + k\theta}$$

PFR:

$$C = C_0 e^{-k\theta}$$

PFR shows better performance esp. at high HRTs

Reactor analysis: CSTR, Monod kinetics



Assumption:

- Steady state
- X_a = 0 in the influent
  (negligible influent biomass)

$$S = K\frac{1 + b\theta}{Y\hat{q}\theta - (1 + b\theta)}$$

No S_0 or X_a in the equation!

$$X_a = Y\frac{S^0 - S}{1 + b\theta}$$