Midterm review I

Basics of microbiology

- Genetic molecules: DNA & RNA

	DNA (deoxyribonucleic acid)	**RNA (ribonucleic acid)**
Sugar	deoxyribose	ribose
Strand	double-stranded	single-stranded
Base	adenine (A), thymine (T), guanine (G), cytosine (C)	adenine (A), uracil (U), guanine (G), cytosine (C)
Function	Long-term storage and transmission of genetic information	Transfer the genetic code from DNA to ribosomes to make proteins

Basics of microbiology

- Classification of bacteria
  - Gram positive vs. negative
  - Phototrophs vs. chemotrophs
  - Organotrophs vs. lithotrophs
  - Autotrophs vs. heterotrophs
  - Aerobes vs. anaerobes
    - Obligate anaerobes
    - Aerotolerant anaerobes
    - Obligate aerobes
    - Facultative aerobes

Basics of microbiology

- Enzyme reactivity: Michaelis-Menten eq.
  - Based on theoretical analysis of enzyme reactivity
  - Enzyme reaction as two steps:

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES$$

$$ES \xrightarrow{k_2} E + P$$

  - Assumption: the enzyme complex (ES) does not change with time

$$k_1[S][E] = k_{-1}[ES] + k_2[ES]$$

$$[E]_{total} = [E] + [ES]$$

$$\Rightarrow \quad v = \frac{v_m[S]}{K_M + [S]}$$

$$v_m = k_2[E]_{total}$$

$$K_M = \frac{k_{-1} + k_2}{k_1}$$

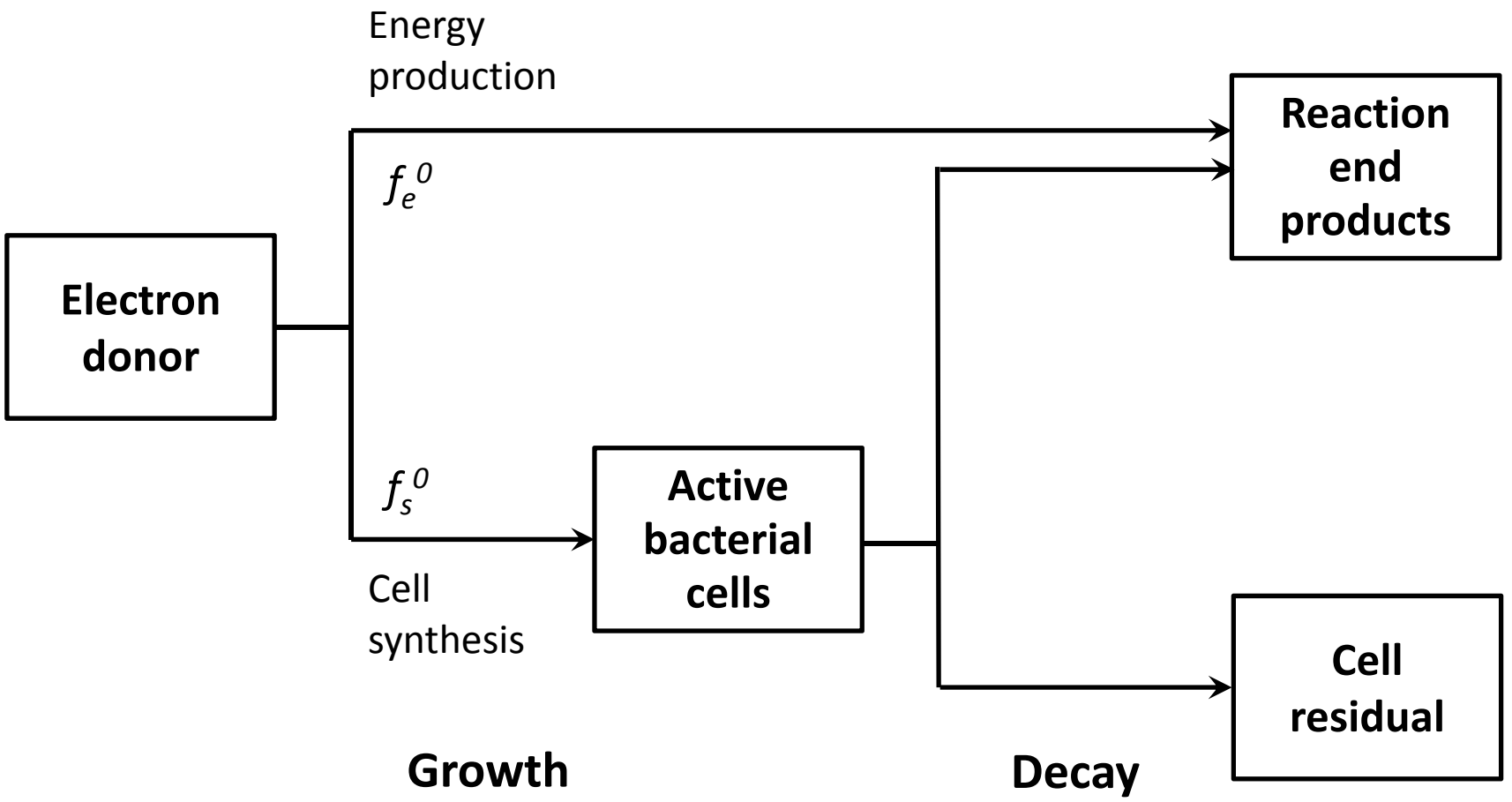
Basics of microbiology

- Inhibitions
  - Reversible vs. irreversible
  - Reversible inhibitions
    - Competitive inhibition: $E + I = EI$
    - Noncompetitive inhibition
      - Uncompetitive inhibition: $ES + I = ESI$
      - Mixed noncompetitive inhibition: $ES + I = ESI$ and $E + I = EI$

Basics of microbiology

Q: Another type of reversible inhibition, occurring less frequently, is the product inhibition where the product (*P*) combines with the enzyme-substrate complex (*ES*) to form enzyme-substrate-product complex (*ESP*). Assuming that the ESP concentration does not change with time, analyze the enzyme reactivity under product inhibition and effect of the inhibition on Michaelis-Menten parameters.

Stoichiometry



Stoichiometry

- Writing half reactions

Step 1 Write oxidized form on the left and reduced form on the right

Step 2 Add other species involved in the reaction

Step 3 Balance the reaction for all elements except for oxygen and hydrogen

Step 4 Balance oxygen using water

Step 5 Balance hydrogen using H^+

Step 6 Balance charge using e^-

Step 7 Convert the equation to the e^--equivalent form

Stoichiometry

- Writing overall reactions

Step 1 Obtain half-reactions for an electron donor (R_d), electron acceptor (R_e), and cell formation (R_c)

Step 2 Obtain f_s and f_e

Step 3 Calculate overall reaction by $R = f_e R_a + f_s R_c - R_d$

Stoichiometry

Q: Write the overall reaction for acetogenesis using hydrogen as an electron donor. Assume f_s = 0.10.

Microbial kinetics

- True yield, Y

  Y = (g cells produced) / (g substrate utilized)

- Net yield, Y_n (term generally used for a batch reactor)

  Y_n = (g net cell growth) / (g substrate utilized)

- Observed yield, Y_{obs} (term used for any reactor)

  Y_{obs} = (g cell growth observed in a reactor) /
  (g substrate utilized used in a reactor)

Microbial kinetics

- Basic concept: $\frac{dX_a}{dt} = Y\left(\frac{-dS}{dt}\right) - bX_a$

- Monod equation
  - In the form of microbial growth

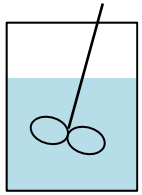
$$\mu_{syn} = \left(\frac{1}{X_a}\frac{dX_a}{dt}\right)_{syn} = \hat{\mu}\frac{S}{K+S}$$

  - In the form of substrate utilization

$$r_{ut} = \frac{dS}{dt} = -\frac{\hat{q}S}{K+S}X_a$$

Microbial kinetics in reactors

- **Batch reactor**



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

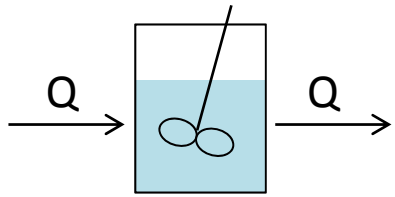
- **Plug flow reactor (PFR)**

  - No longitudinal mixing, complete transverse mixing
  - Batch reactor moving in the direction of flow

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

Microbial kinetics in reactors

- **Continuous-stirred tank reactor (CSTR)**
  - Complete mixing with constant flow



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

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

Microbial kinetics in reactors

Q: Calculate the effluent substrate and active biomass concentration of a bioreactor operated as a CSTR when the influent substrate concentration is 100, 1000, and 10000 mg BOD_L/L. The reactor volume is 1000 m^3 and the flow rate is 250 m^3/hr. Use typical values of Y=0.42 g VSS/g BOD_L, $\hat{q}$=20 g BOD_L/g VSS-d, K=100 mg BOD_L/L and b=0.15 d^{-1} for aerobic degradation of typical organic matter.