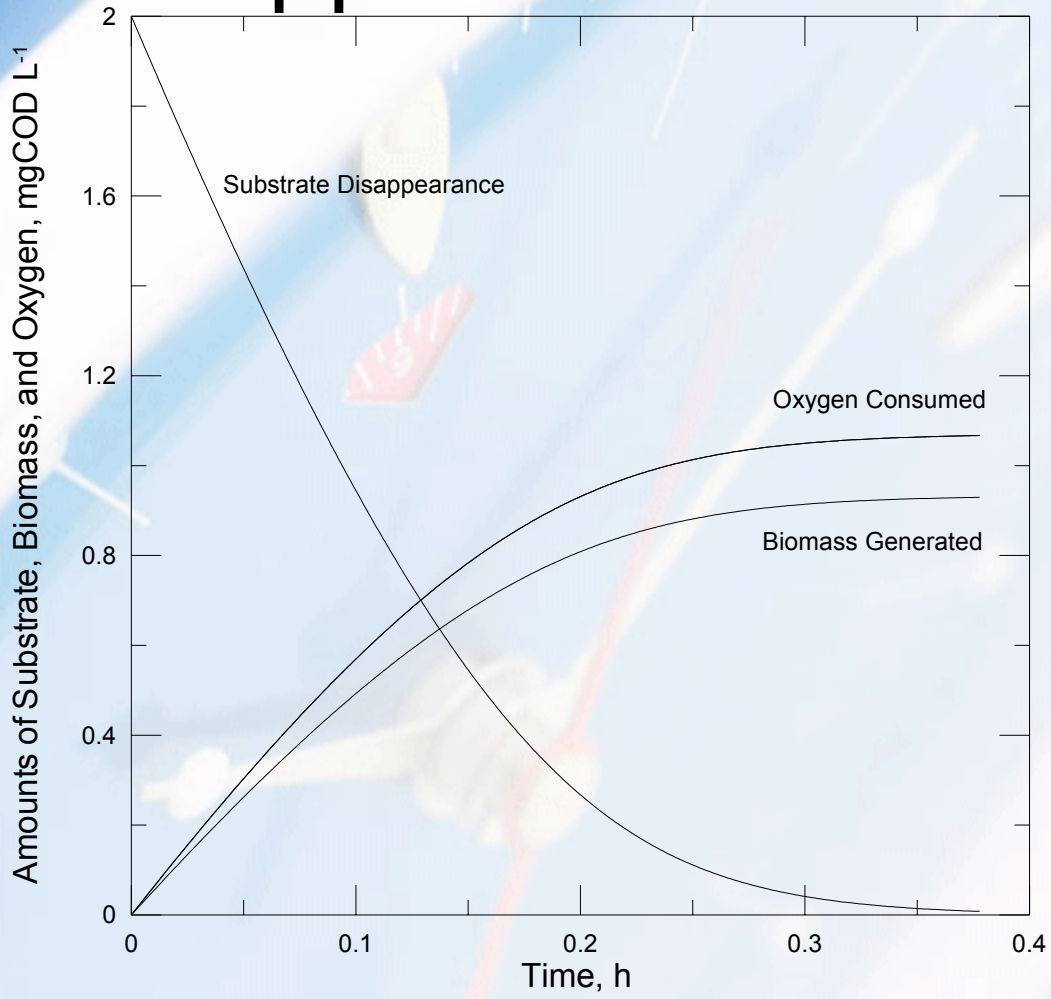
Quantifying Microorganisms and Their Activity

CE 421/521 Environmental Biotechnology
Lecture for September 19, 2006
Vaccari et al., Chapter 10

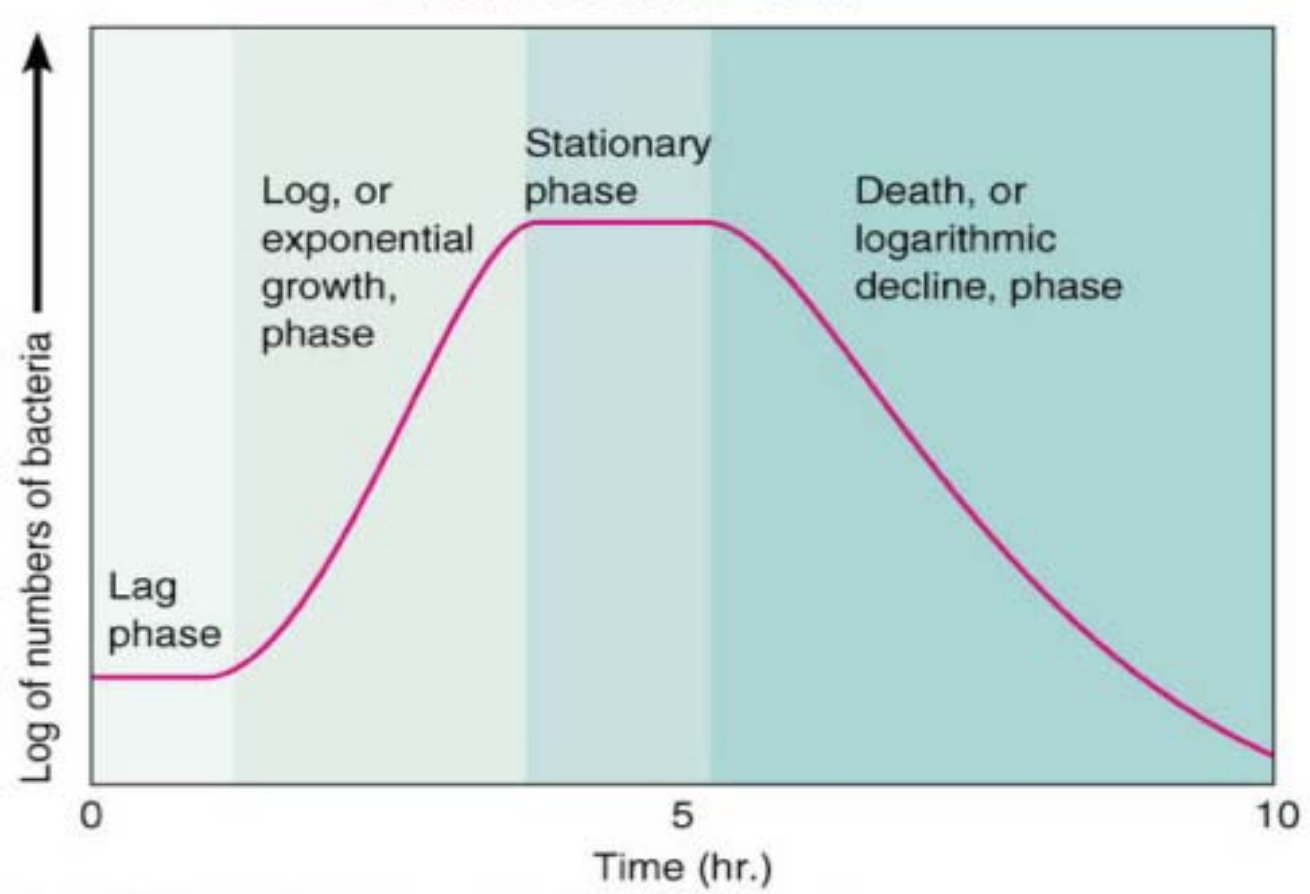
Two Events

- Microbial Growth (dX/dt)
- Substrate Disappearance (dS/dt)
- During balanced growth can use a surrogate measure of growth
  - Oxygen consumption
  - Carbon dioxide production
  - Methane production (anaerobic systems)

Growth vs Substrate Disappearance



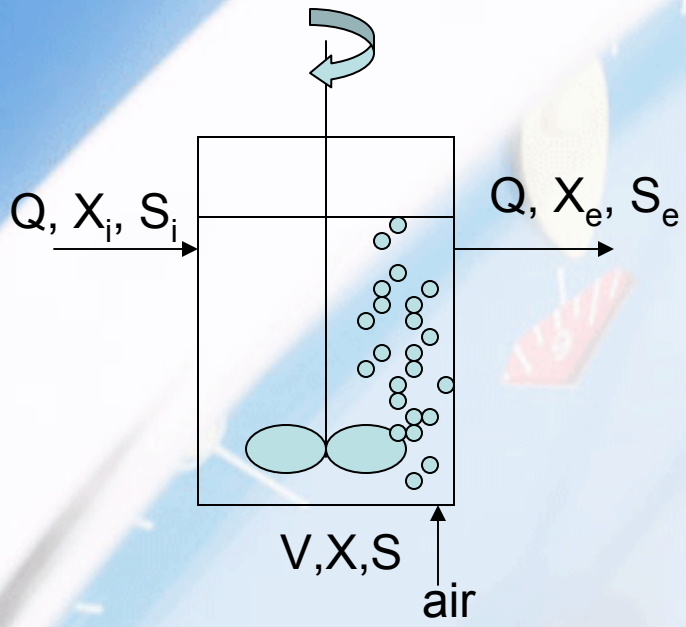
Batch Growth Curve



Exponential Growth

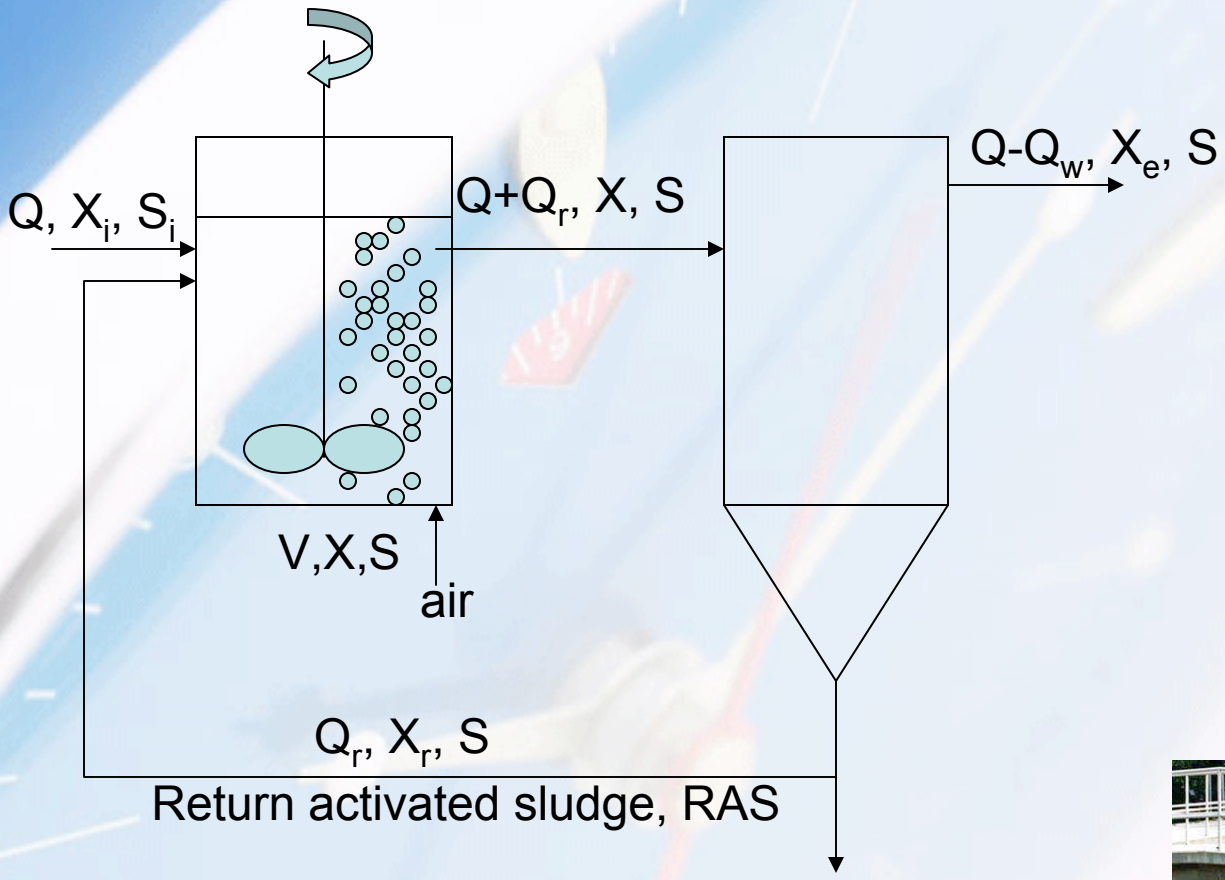
- Doubling (generation) time

CSTR or Chemostat



General mass balance;
in – out – generation = accumulation

CSTR with settling



CSTR mass balance equations

Biogeochemcial Cycles (C, N, P, & S)

- composition of b_____ cell (molar formula: $C_5H_7O_2N$ with P 1/5 of the N requirement)

- limiting nutrients are _____ and _____

TABLE 14.1 Chemical Composition of an *E. coli* Cell

Elemental breakdown	% dry mass of an *E. coli* cell
Major elements	
Carbon	50
Oxygen	20
Hydrogen	8
Nitrogen	14
Sulfur	1
Phosphorus	3
Minor elements	
Potassium	2
Calcium	0.05
Magnesium	0.05
Chlorine	0.05
Iron	0.2
Trace elements	
Manganese	all trace elements combined comprise 0.3% of dry weight of cell
Molybdenum	
Cobalt	
Copper	
Zinc	

Adapted from Neidhardt *et al.* (1990).

Nitrogen

TABLE 14.10 Global Nitrogen Reservoirs

Nitrogen reservoir	Metric tons nitrogen	Actively cycled
Atmosphere		
N_2	3.9×10^{15}	No
Ocean		
Biomass	5.2×10^{8}	Yes
Dissolved and particulate organics	3.0×10^{11}	Yes
Soluble salts (NO_3^-, NO_2^-, NH_4^+)	6.9×10^{11}	Yes
Dissolved N_2	2.0×10^{13}	No
Land		
Biota	2.5×10^{10}	Yes
Organic matter	1.1×10^{11}	Slow
Earth's crust[a]	7.7×10^{14}	No

[a] This reservoir includes the entire lithosphere found in either terrestrial or ocean environments. (Adapted from Dobrovolsky, 1994.)

- Atmosphere is _____% nitrogen, yet nitrogen is considered a l_____ n_____
- required in p_____

Nitrogen Cycle

Organic nitrogen

NO_3^-

N_2

NH_4^+

NO_2^-

Fixation

- $2x10^8$ metric tons/y compared to $2.5x10^{10}$ metric tons C/y
- cyanobacteria & few others
  - non-symbiotic – *Clostridia*
  - symbiotic – *Rhizobium*
- .nitrogenase – requires Mg^{2+} & ATP (15 to 20 ATP/N_2)

Assimilation

- NH_3 (NH_4^+) preferred, will use NO_3^- but has to be reduced to NH_4^+
- C/N ratio is approximately
  - 10:1 for aerobes
  - 150:1 for anaerobes
  - 50:1 for anaerobes in highly loaded (high rate) system
- cell composition is characterized by the empirical formula: _____

  with the P requirement as 1/5 the N requirement (alternatively $C_{60}H_{87}O_{23}N_{12}P$)
- in general cell composition is
  - » 50% C
  - » 20% O
  - » 10-15% N
  - » 8-10% H
  - » 1-3% P
  - » 0.5-1.5

Ammonification

- Breakdown of organic N to NH_4^+
- Examples:
  - Urea
  - proteins

Nitrification

- Two step process:
- requires 4.57 mg O_2/mg NH_4^+-N converted to NO_3^- – N

Nitrification Kinetics

$$\mu = \frac{\mu_{\max} S_{NH4}}{K_S + S_{NH4}} \cdot \frac{S_{O2}}{K_O + S_{O2}}$$

where

μ_{max} = maximum specific growth rate, h-1

K_S = half saturation coefficient for ammonia, mg/L as NH_4-N

K_O = half saturation coefficient, mg/L as O2

Yield = mg biomass formed/mg ammonia utilized

Nitrification Kinetics

	Nitrosomonas		Nitrobacter	
parameter	range	typical (@ 20°C)	range	typical (@ 20°C)
μ_{max}	0.014 - 0.092	0.032	0.006 - 0.06	0.034
K_S	0.06 - 5.6	1.0	0.06 - 8.4	1.3
K_O	0.3 - 1.3	0.5	0.3 - 1.3	0.68
Yield	0.04 - 0.13	0.1	0.02 - 0.07	0.05

Optimum pH for nitrifiers is around 8.0, range 7.5 - 8.5 (higher than for most other biological processes).