

## The Process of Growth

- Metabolism required for growth, both anabolic and catabolic; ~2000 reactions!
- Usual Definition: **Increase in cell numbers**  
Other definitions possible – spores, UMC's, respiration, viable but nonculturable, morphology changes (life cycle)
- Divide via Binary Fission: 3 mechanisms involved!  
Cell Elongation – cell wall  
DNA Replication – rate limiting step  
Cell Division – septum formation

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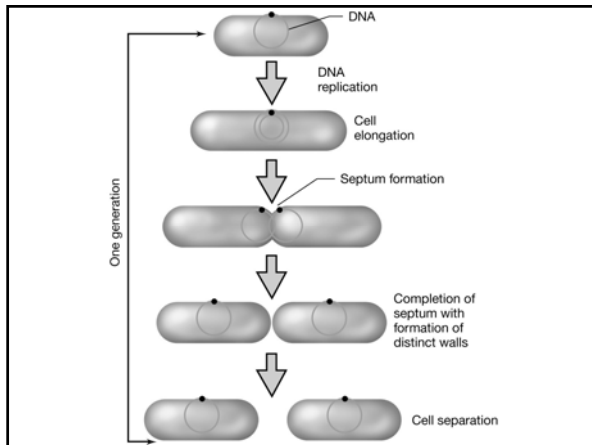
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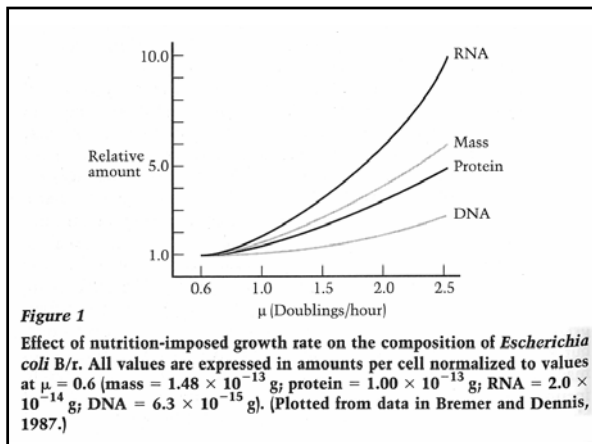
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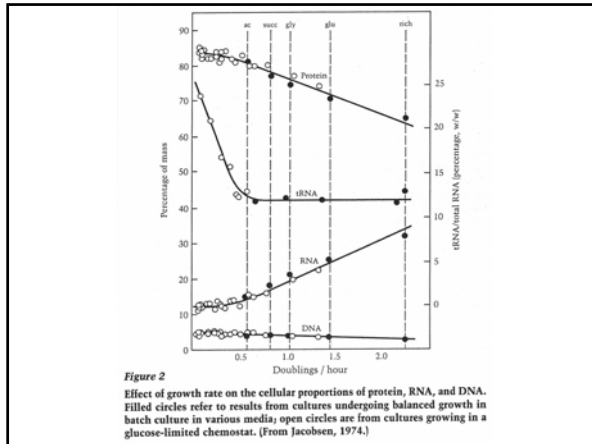
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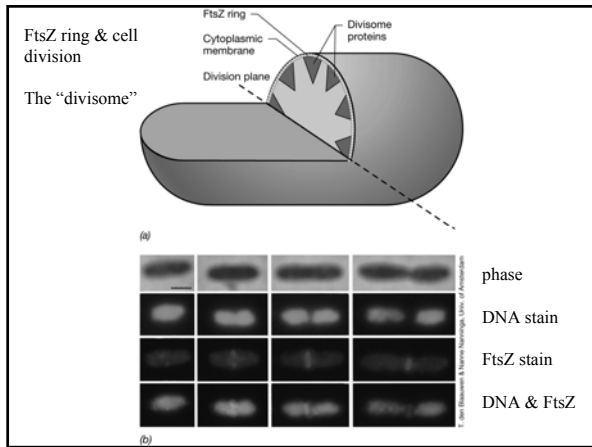
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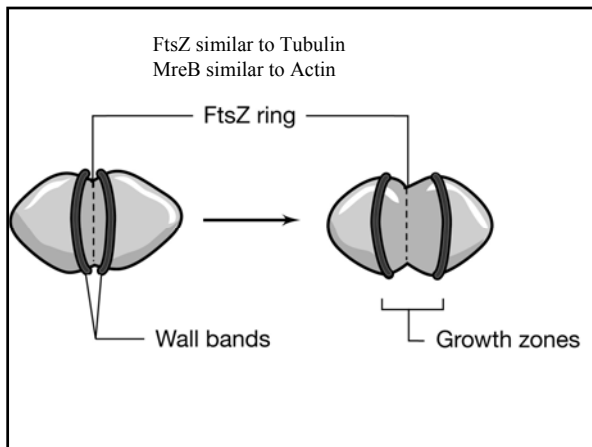
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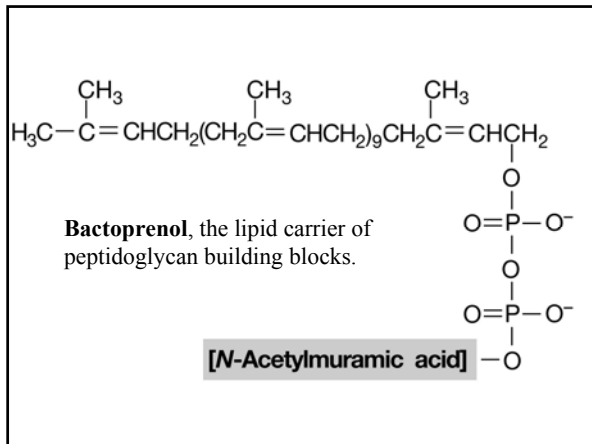
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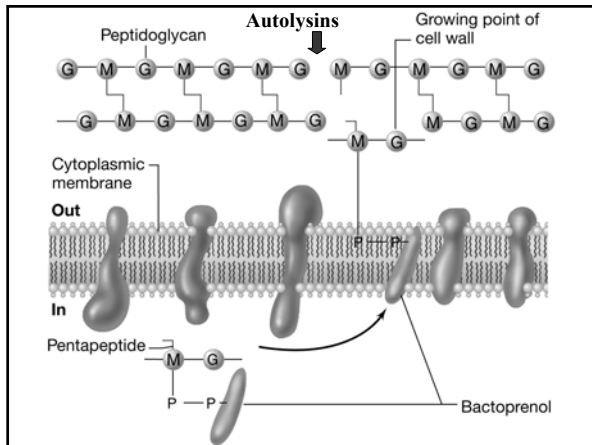
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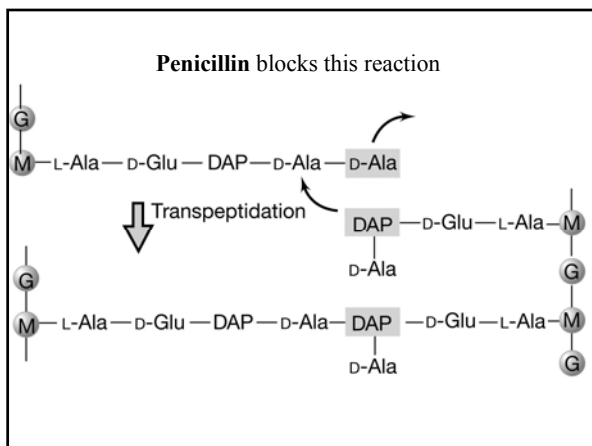
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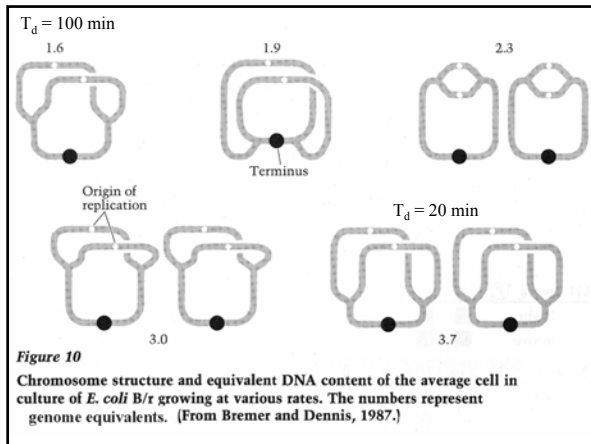
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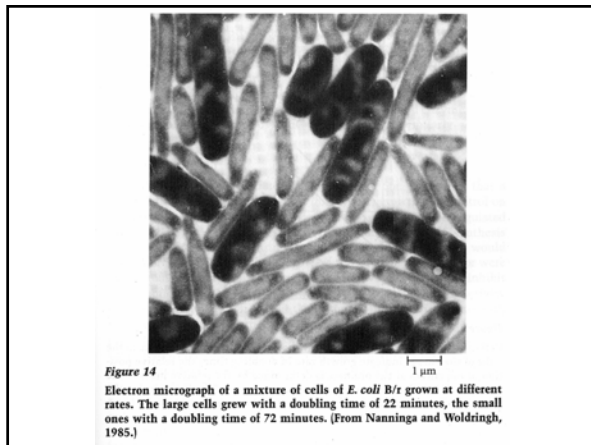
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**The Process of Growth**

- Growth Rate: Time it takes to reproduce  
 $t_{1/2} = \ln 2 / \mu = 0.693 / \mu = g$
- Phases of Growth in Batch culture  
 Lag, Log, Stationary, Death
- Measurement of Growth  
 Total cell counts  
 Viable cell counts  
 Turbidity

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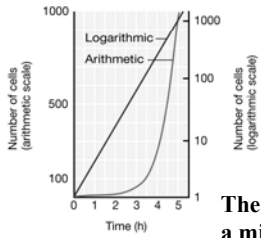
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Time (h)	Total number of cells	Time (h)	Total number of cells
0	1	4	256
0.5	2	4.5	512
1	4	5	1,024
1.5	8	5.5	2,048
2	16	6	4,096
2.5	32	.	.
3	64	.	.
3.5	128	10	1,048,576

(a)



The growth rate of a microbial culture

(b)

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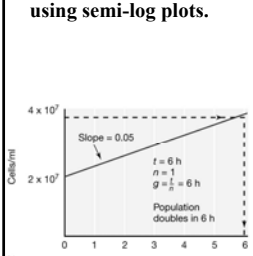
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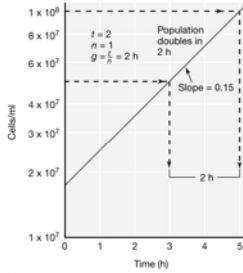
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How to estimate the generation times of an exponential microbial culture using semi-log plots.



(a)



(b)

t = time  
n = generations  
g = generation time

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**Table 6.1** Approximate generation times for several organisms growing in media optimal for growth

Species	Generation Time
<i>Escherichia coli</i>	20 min
<i>Bacillus subtilis</i>	28 min
<i>Staphylococcus aureus</i>	30 min
<i>Pseudomonas aeruginosa</i>	35 min
<i>Thermus aquaticus</i>	50 min
<i>Thermoproteus tenax</i>	1 hr 40 min
<i>Rhodobacter sphaeroides</i>	2 hr 20 min
<i>Sulfolobus acidocaldarius</i>	4 hr
<i>Thermoleophilum album</i>	6 hr
<i>Thermophilum pendens</i>	10 hr
<i>Mycobacterium tuberculosis</i>	13 hr 20 min

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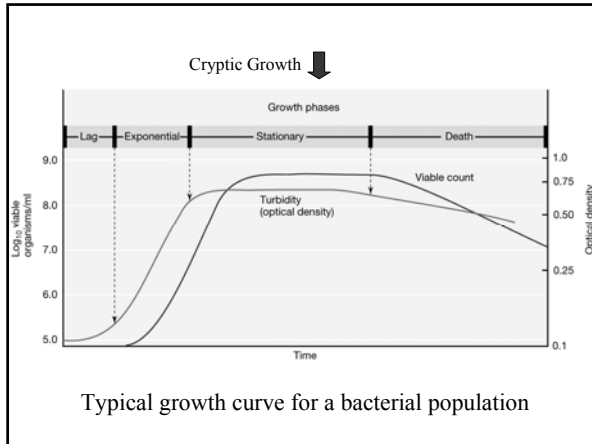
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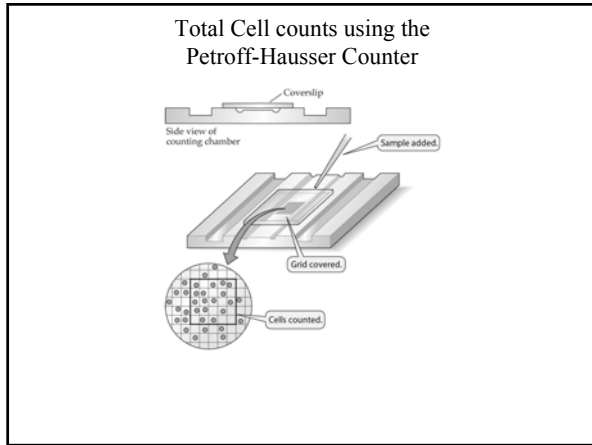
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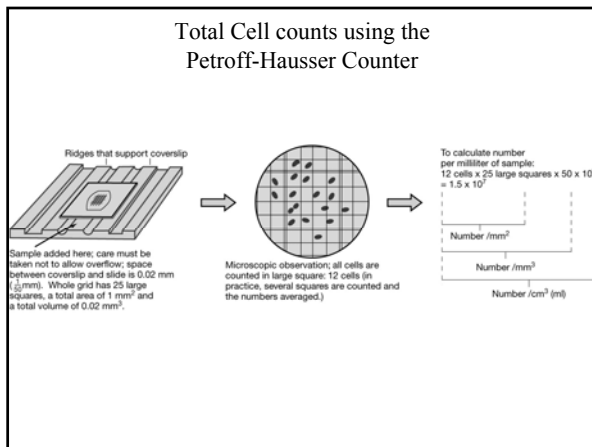
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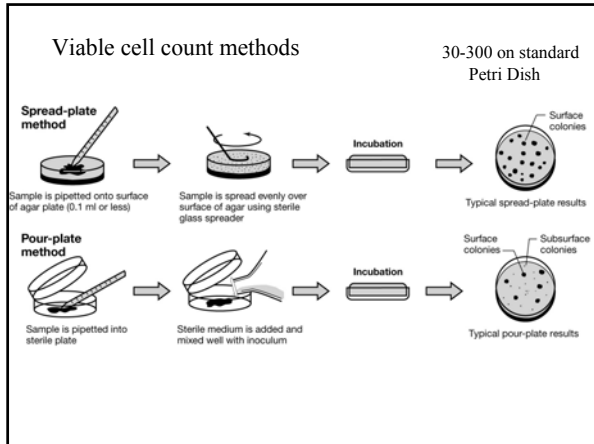
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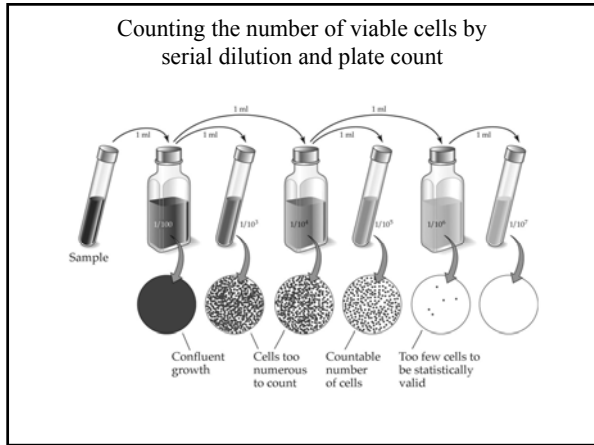
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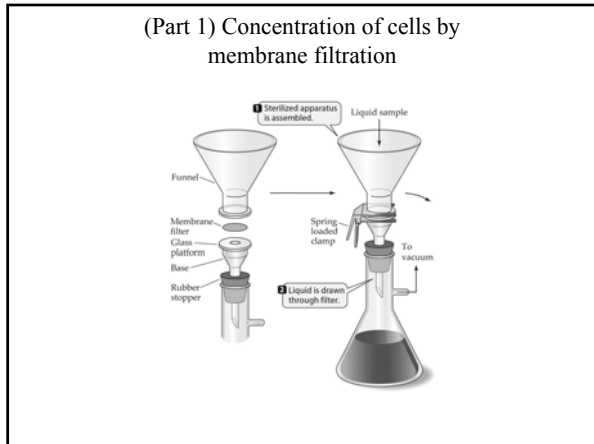
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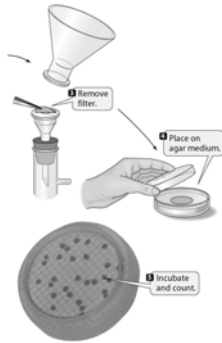
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(Part 2) Concentration of cells by membrane filtration




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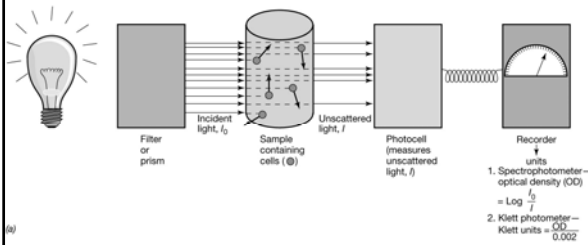
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Turbidity measurements of microbial growth




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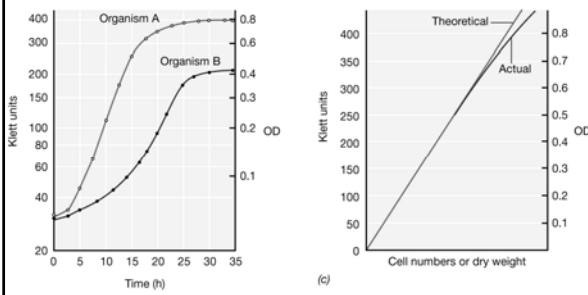
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Turbidity measurements of microbial growth




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## The Process of Growth

- Continuous Culture: The wonders of the Chemostat
  - Steady State
  - Reproducible Physiology
  - Fine control

Key parameters –  $K_s$ ,  $\mu_{max}$ , Yield

Closed systems vs. Open systems vs. Nature!  
 (Batch)            (Chemostat)

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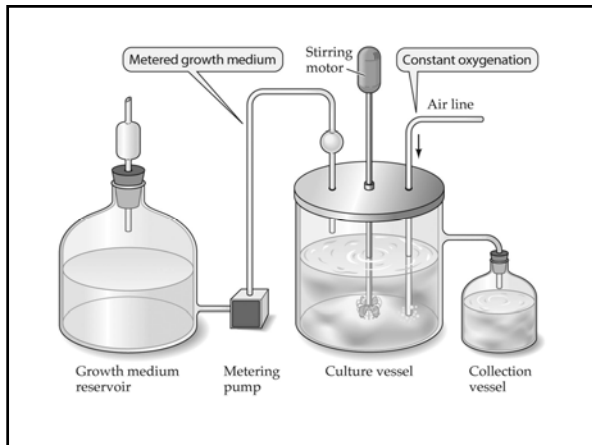
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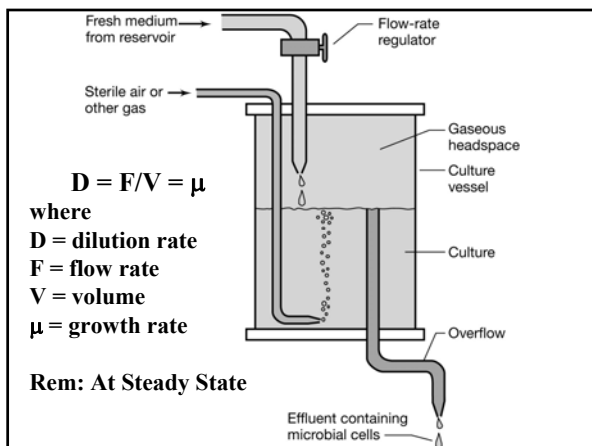
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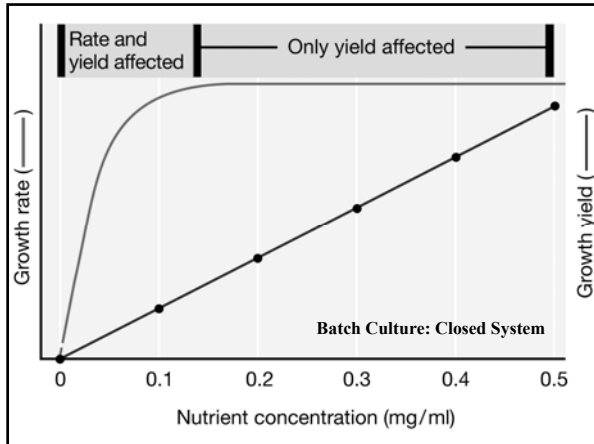
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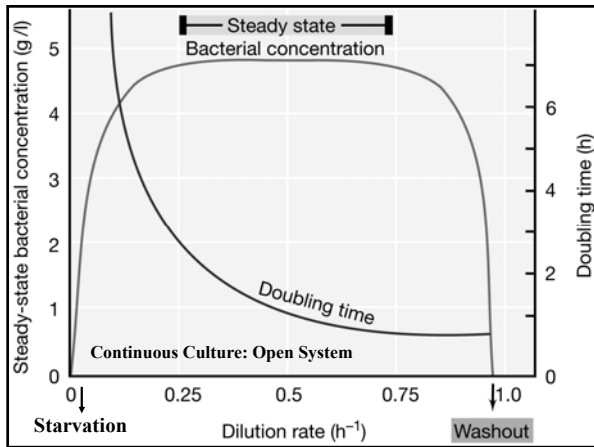
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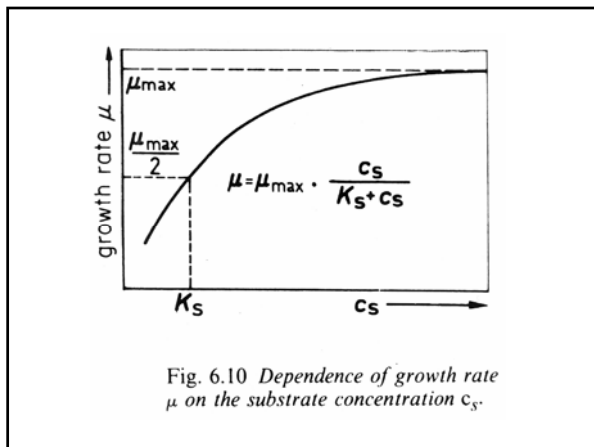


Fig. 6.10 Dependence of growth rate  $\mu$  on the substrate concentration  $c_s$ .

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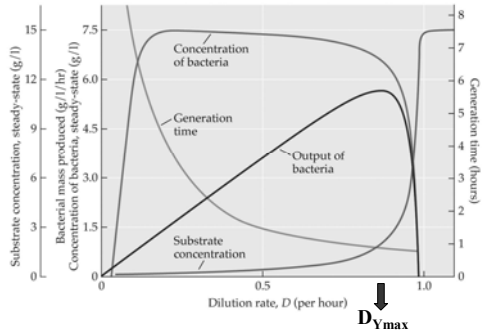
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Steady-state relationship between substrate concentration and output of bacterial mass




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**Table 6.2** Growth yields of anaerobic bacteria utilizing glucose as the energy source

	Mol ATP/Mol Glucose	$Y_{max}$ (g of cell/mol Glucose)	$Y_{ATP}$ (g of cell/mol ATP)
<i>Lactobacillus delbrueckii</i> <sup>a</sup>	2	21	10.5
<i>Enterococcus faecalis</i> <sup>a</sup>	2	20	10
<i>Zymomonas mobilis</i> <sup>b</sup>	1	9	9

<sup>a</sup>Homolactic fermentation, Embden–Meyerhof pathway (see Chapter 10).  
<sup>b</sup>Alcoholic fermentation, Entner–Doudoroff pathway (see Chapter 10).

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