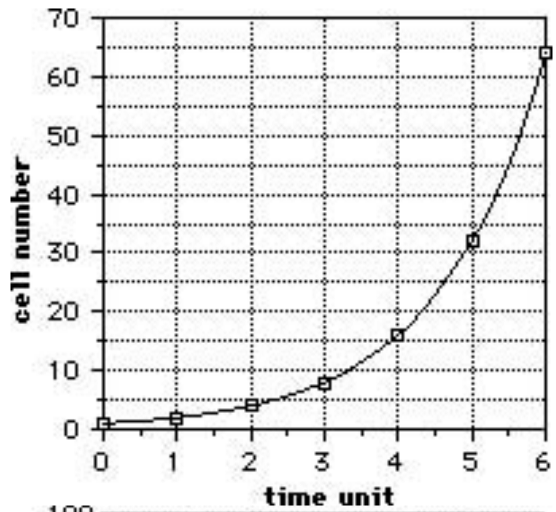
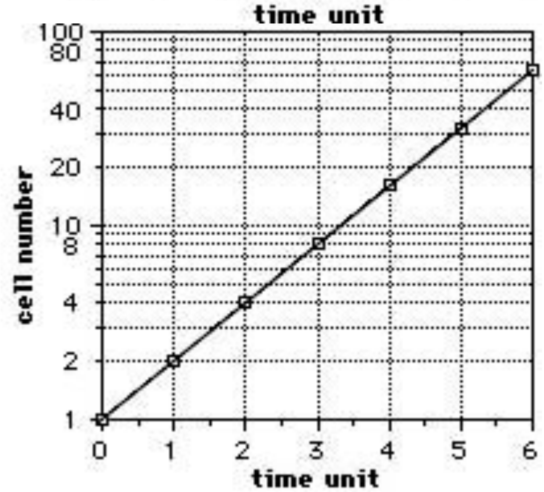
THE BACTERIAL GROWTH CURVE

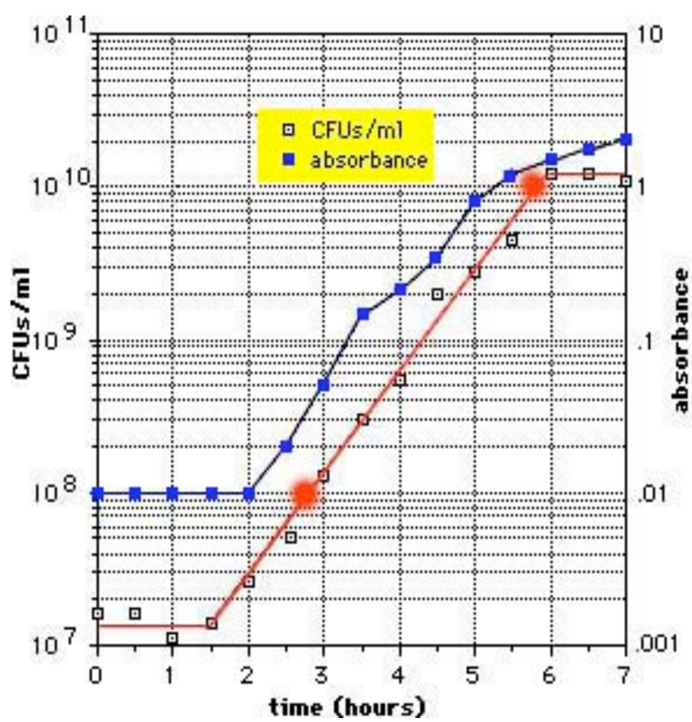


By definition, bacterial growth is cell replication – that is, increase in the population of the cells in the culture. Most species of bacteria replicate by **binary fission**, where one cell divides into 2 cells, the 2 cells into 4, the 4 into 8, etc. If this cell division occurs at a steady rate – such as when the cells have adequate nutrients and compatible growing conditions – we can plot numbers of cells vs. time such as on the graph at right. Before too long, we will need to extend the paper vertically as the population continues to double. For a culture where cells divide every 20 minutes, one cell can result in 16,777,216 (i.e., 2^{24}) cells after just 8 hours – barring nutrient depletion or other growth-altering conditions.



If we were to convert our vertical axis to a logarithmic scale – as on the graph on the right – we will not need as many sheets of graph paper, and we will find that a **steady rate of growth is reflected as a straight line**. (On the vertical axis, the same distance on the paper is covered with each doubling.) This type of graph paper is called **semilogarithmic graph paper** on which we can plot our class results. The numbers we plot will fall on the graph at the same place the logarithms of these numbers would fall when plotted on conventional graph paper.

The bottom example shows the type of graph we may get from our class data. **<u>NOTE</u>**: As absorbance is already a logarithmic value, it would be technically incorrect to plot it on the same sheet of semi-log paper as CFU/ml. But one may do so to simply demonstrate the **general upward trend** of both graphs, although there is no way that growth rate and generation time can be determined by an absorbance graph so posted. With the use of **linear paper** one can note a real correlation between the log of CFUs/ml vs. time and absorbance vs. time.



Rather than "connecting the dots," we draw the **best straight line** among our CFU/ml plots to represent the phases of growth – lag, exponential, and the start of the maximum stationary phase.

For the growth rate formula we are about to use, we need to **choose two points <u>on</u> the straight line** drawn through the exponential phase, also making note of the time interval between them. (For example, the log of $1X10^9$ is simply **9**.)

- Higher CFU/ml = $\mathbf{X_t}$ = $1X10^{10}$ (at 5.75 hours)
- Lower CFU/ml = $\mathbf{X_0}$ = $1X10^8$ (at 2.75 hours)
- Time interval (in hours) between the 2 points = **t** = 3

Using our first formula, we find the **growth rate** (**k**) which is the number of generations (doublings) per hour:

$$\mathbf{k} = \frac{\log_{10}[\mathbf{X_t}] - \log_{10}[\mathbf{X_0}]}{0.301 \text{ X } \mathbf{t}} = \frac{10 - 8}{0.301 \text{ X } 3} = \mathbf{2.21 \text{ gen/hr}}$$

With the second formula, we find the **generation time** ($\mathbf{t_{gen}}$)which is the time it takes for the population to double:

$$\mathbf{t_{gen}} = \frac{1}{\mathbf{k}} = \frac{1}{2.21} = \mathbf{0.45 \text{ hr/gen}} \text{ or } \mathbf{27 \text{ min/gen}}$$

When we graph the CFUs/ml and absorbance on the same graph, we would hope to see an upward trend for both. Sometimes the absorbance continues to rise after the CFUs/ml level off into the maximum stationary phase. What would be the cause of that?

With a clear graph, one should be able to determine the generation time without the use of formulas. **Simply look for a <u>doubling</u> of the population and the time it takes for that to happen**. For example – in the above graph – the time it takes to go from 3 X 10^9 to 6 X 10^9 appears to be approximately 30 minutes, which is close to the generation time determined by our formulas above.