Modeling Exponential Growth

Introduction:

The cells in a culture reproduce by splitting in half forming two new daughter cells in a process called fission. As the population of cells grows more cells will be available to divide. Provided there are no barriers to cell division such as limited nutrients or space the rate of growth of cells will increase in directly proportion to the number of cells present. If N is the number of cells and t is the time then the rate of change in N is

$$\frac{\Delta N}{\Delta t} = k N$$

where the proportionality constant k is called the growth constant or the intrinsic growth rate of the cell culture. To see that this corresponds to exponential growth we can manipulate this expression to be

$$\frac{\Delta N}{N} = k \Delta t$$

which shows that the percentage change is constant over any fixed time interval. Since the cells are dividing continuously and there is a constant growth rate the number of cells present as a function of time can be described by the exponential function

$$N = N_0 e^{k t}$$

where N_0 is the initial number of cells.

The time it takes for the population to double is called the generation time g or the doubling time. The generation time g is related to the intrinsic growth rate k by the following relation

$$2 = e^{k g} \quad \text{which means} \quad g = \frac{ln2}{k}$$

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Eventually the nutrient supply will be exhausted and the cell culture will no longer grow at an exponential rate. The time period during which the cell culture grows exponentially is called the exponential phase or log phase by biologists. In this lab we will model cell growth using Hershey's Kisses. Do not eat the Kisses unless instructed to do so.

Procedure:

Get into groups of four or five. Each group should get one bag of Hershey's Kisses. Distribute one Kiss to each member and record the initial number of Kisses in a table in your book. These Kisses represent cells. Each person should then toss their Kiss. If a Kiss is pointing up it undergoes fission and become two cells instead of one. If it is on it's side it is still waiting. Give each person with a Kiss pointing up another Kiss. Record the total number of Kisses in the group. Once cycle is now complete. Now everyone should toss their Kisses again. Give each member of the group one Kiss for each Kiss they have that is pointing up. (If a member of the group has two Kisses pointing up they get two more Kisses). Again record the number of Kisses in the group. Repeat this procedure until the supply of new Kisses is exhausted. When the supply is exhausted change the rule so that any cells pointing up that do not get a chance to undergo fission due to lack of resources die and are removed from that member's pile. (Dead cells may be eaten, returned to the bag or offered as resources for other members to allow their Kisses to undergo fusion -- which method you use is up to the group, but be consistent and make which method you are using in a text box in your Excel file). Continue until all the cells are gone or you reach equilibrium or you have completed 20 cycles.

Plot the number of Kisses in the group vs number of reproduction cycles in a well labeled scatter plot. Find the interval during which the data demonstrates exponential growth and for these values of the data plot a new scatter plot for *ln(N) vs t.* This should lead to a linear graph from which you should be able to determine the parameters of the exponential function N_0 and k. Determine these values along with the generation number g, and the time period that the cells are in the log phase and write your answers in a text box in your spreadsheet. Copy your file to the Drop box using the naming convention Lastname_Firstname_Lab_5.xls