Exercise 4

1. Cell population with infinite nutrients

What you have been told:
• There is a huge flask with a great amount of nutrients.
• Now it is 9:00, and we just put 6 healthy yeast cells into this flask. They are identical, and will be healthy for many days.
• Every 100 minutes, each cell divides into two (they actually bud, but it does not matter).

What is your task (of course, do not go to the lab to do experiment, but write code in Python)?
(1) Predict the total population of cells at 17:20.
(2) Show a figure about how cell population is supposed to change over time, till 17:20.

2. Logistic growth

Cell's exponential growth is for an ideal situation where the nutrient is infinite, the space for cells is infinite etc. So, in reality, cell's growth is not described by $dN(t)/dt = \mu \cdot N(t)$, instead, it is better described by the following logistic growth ODE:

$$\frac{dN(t)}{dt} = \mu \cdot N(t) \cdot (1 - \frac{N(t)}{K})$$

where $N(t)$ is the total number of cells at time t, μ is the specific growth rate, and K is the carrying capacity.
If you are told the value of μ, K and the initial number of cells N_0, namely $N(t=0)$, you should be able to solve the differential equation and obtain a curve of population vs. time.

Let $N_0 = 100$, $\mu = \frac{3}{5} \cdot \ln 2 \approx 0.41589$, and $K = 10,000$. Draw the figure about how the population changes over time, till $t = 24$.

3. Advanced: cell population with finite nutrients

You have been told that:
• There is a flask with 0.1 $mmol$ glucose which is yeast cell's food ($1\ mmol = 1 \times 10^{-3}\ mol$). Inside the flask, there are a great amount of other nutrients that yeast cells need.
• Now it is 9:00, and we just put $1,000,000$ healthy yeast cells into this flask. They are identical, and will be healthy for many days.
• Each of these cells divides into two every 100 minutes.
• Each cell consumes $1 \times 10^{-6}\ mmol$ glucose during its one-to-two division process.

What your task is:
(1) Predict the total population of cells, and the total amount of glucose at 17:20.
(2) Show a figure about how cell population is supposed to change over time, till 17:20.
(3) Show a figure about how the total amount of glucose changes over time, till 17:20.

NB: In Python, 1×10^{-6} is written as 1e-6, and 3.2×10^{5} is written as 3.2e5, and so on.