data_analysis_corrected

March 5, 2018

1 Tumor growth modeling

This practical session is intended to explore tumor growth data and interpret it using mathematical models. It is divided into three parts: 1. Analysis of the data by basic plots 2. Fitting and comparing tumor growth models to the data in order to understand **tumor growth laws** 3. Using the model(s) to **predict** future tumor growth with only a limited number of initial data points

The data provided consists of measurements of tumor volumes from tumors implanted subcutaneously in the back of mice. The cells are from a murine lung cancer cell line (Lewis Lung Carcinoma). The volumes were computed from two one dimensional measures recorded using a caliper (the length L and width w) and using the formula $V = \frac{1}{2}L \times w^2$. Volumes are given in mm^3 as a function of days following injection of the cells (10^6 cells $\simeq 1\ \text{mm}^3$ injected on day 0.

Are you ready to start your exploration?

Good luck on your adventure! :)

2 1. Data analysis

2.0.1 Import modules

```
In [ ]: % matplotlib inline
```

```
In [2]: import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
```

Load the data file `data_table.xlsx` as a pandas Dataframe and display it

```
In [10]: df = pd.read_excel('data_table.xlsx')
         df
```

```
Out[10]:              1           2           3           4           5  \
         5          NaN   54.886377         NaN         NaN   68.809022
         6          NaN   59.408036   89.231295   55.348590   59.853289
         7    50.021795   85.662278  157.351502   56.175814   58.988502
         11  309.519493  261.572775  221.698580  103.330909  179.664759
         12  324.895878  412.265650  327.492254  155.320341  309.787647
         13  450.842120  488.450738  461.437963  167.958671  470.571322
         14  572.450814  618.854795  641.444986  219.378690  480.930314
```

15	664.336606	798.997212	746.868414	412.378378	488.777983
18	1151.693754	1218.721058	1359.458389	584.192211	1021.721046
19	1338.383299	1415.471856	1626.874371	762.074018	1278.530775
20	1522.807849	1410.149208	2063.912472	880.325721	1377.381845
21	1897.073737	1524.126579	NaN	1040.074430	1538.922047
22	NaN	1935.415344	NaN	1335.136464	1958.560253
24	NaN	NaN	NaN	1850.447333	NaN
25	NaN	NaN	NaN	2079.445167	NaN

	6	7	8	9	10
5	NaN	NaN	NaN	NaN	NaN
6	46.502387	94.727972	NaN	18.567329	26.880016
7	55.155193	126.094176	NaN	73.293694	NaN
11	251.222209	333.136619	201.165288	126.820889	144.151300
12	341.175444	538.680724	316.382967	222.661158	193.401925
13	438.335387	669.929621	338.240373	244.726914	281.171233
14	859.952765	762.527617	411.958788	333.629836	294.886207
15	854.727952	923.717646	586.667016	367.475268	391.884141
18	1143.279505	NaN	991.881984	805.778850	744.954870
19	1645.406820	NaN	1219.899900	1030.034281	990.331786
20	1950.482691	NaN	1833.096551	1272.818884	1085.314905
21	NaN	NaN	2131.605693	1555.359077	1331.189667
22	NaN	NaN	NaN	1671.148523	1641.333918
24	NaN	NaN	NaN	NaN	1992.067465
25	NaN	NaN	NaN	NaN	NaN

Get the time vector. It is in days

In [4]:
```
time = df.index
time
```

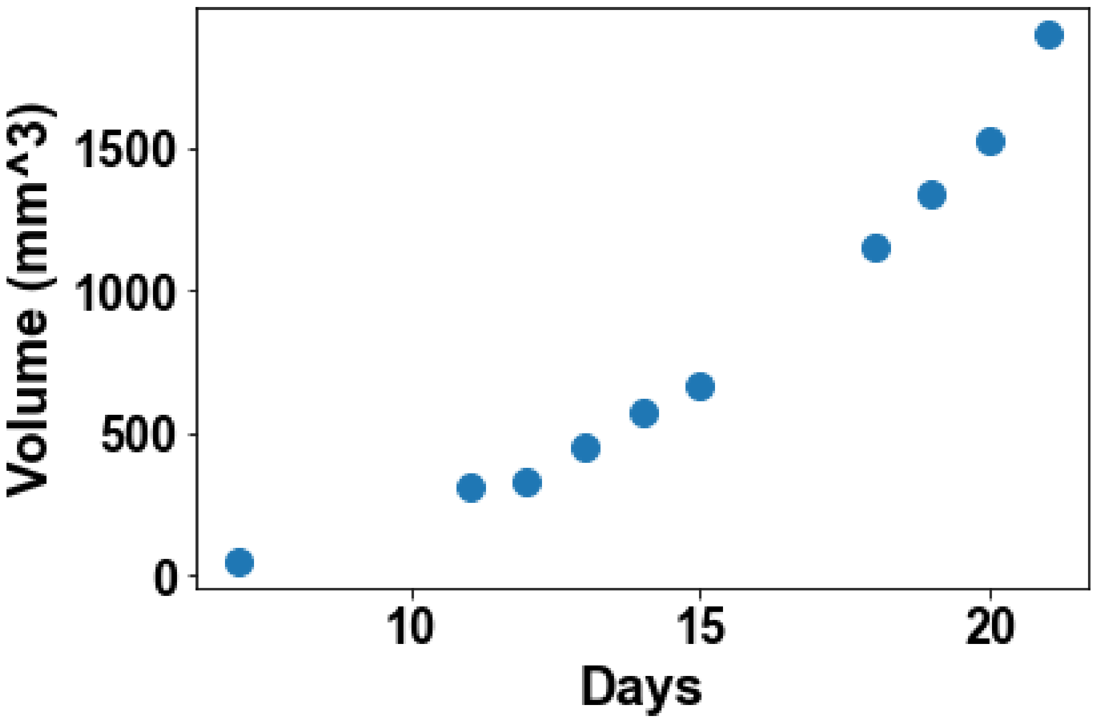
Out[4]:
```
Int64Index([5, 6, 7, 11, 12, 13, 14, 15, 18, 19, 20, 21, 22, 24, 25], dtype='int64')
```

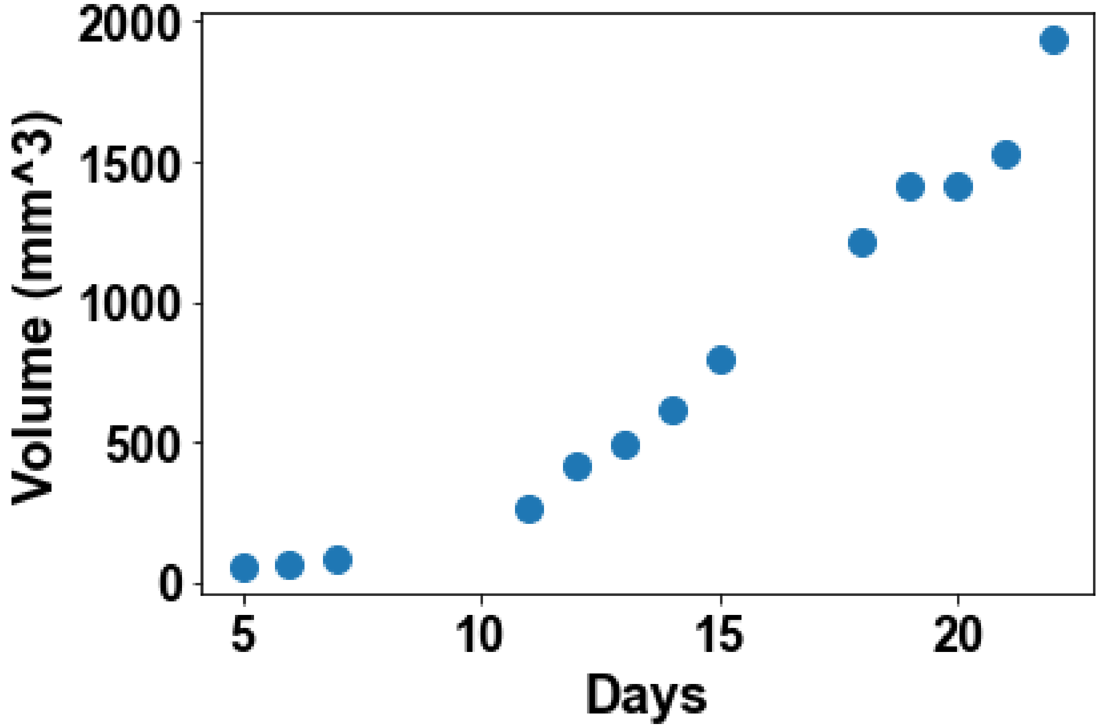
Plot the growth of the first three mice.

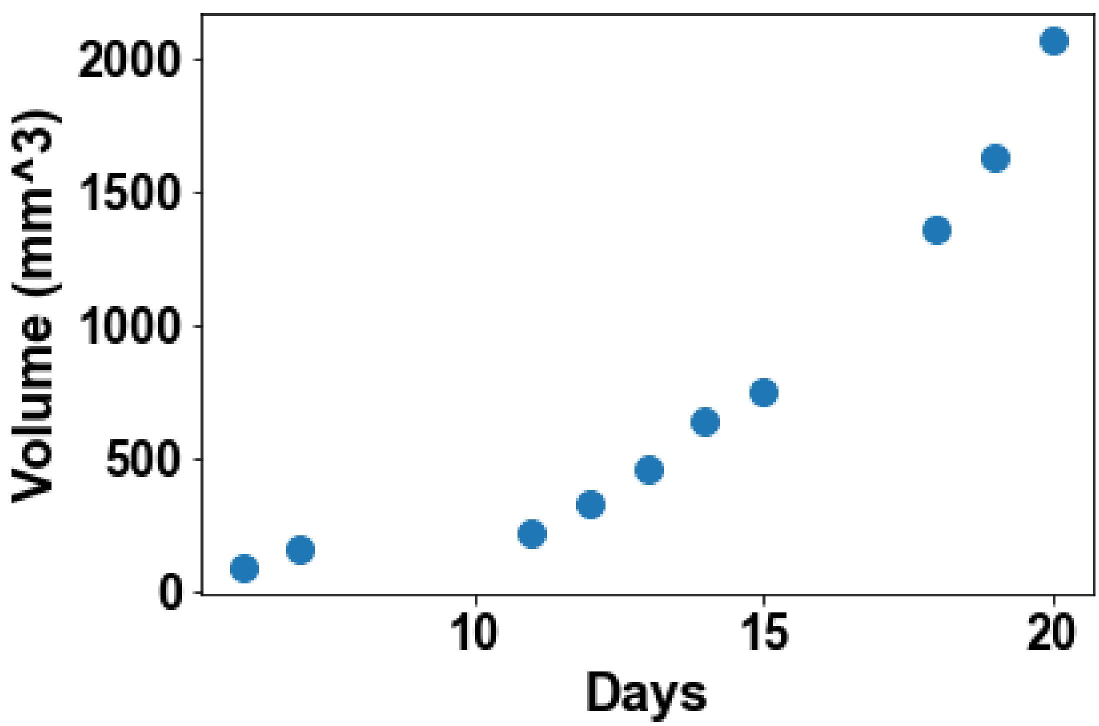
In [5]:
```
# Mouse 1
plt.figure(1)
plt.plot(time, df[1], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')

# Mouse 2
plt.figure(2)
plt.plot(time, df[2], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')

# Mouse 3
plt.figure(3)
```

```
plt.plot(time, df[3], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')
```

Out[5]: Text(0,0.5,'Volume (mm^3)')

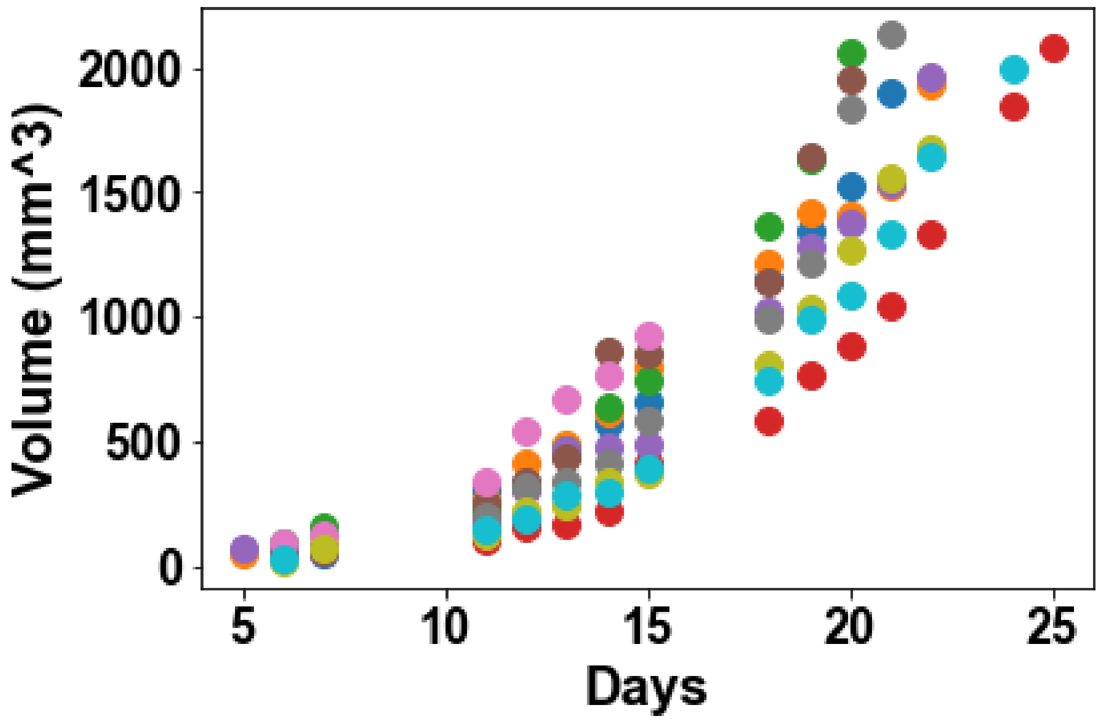



2000
1500
1000
500
0
Volume (mm^3)
5
10
15
20
Days


2000
1500
1000
500
0
Volume (mm^3)
10
15
20
Days

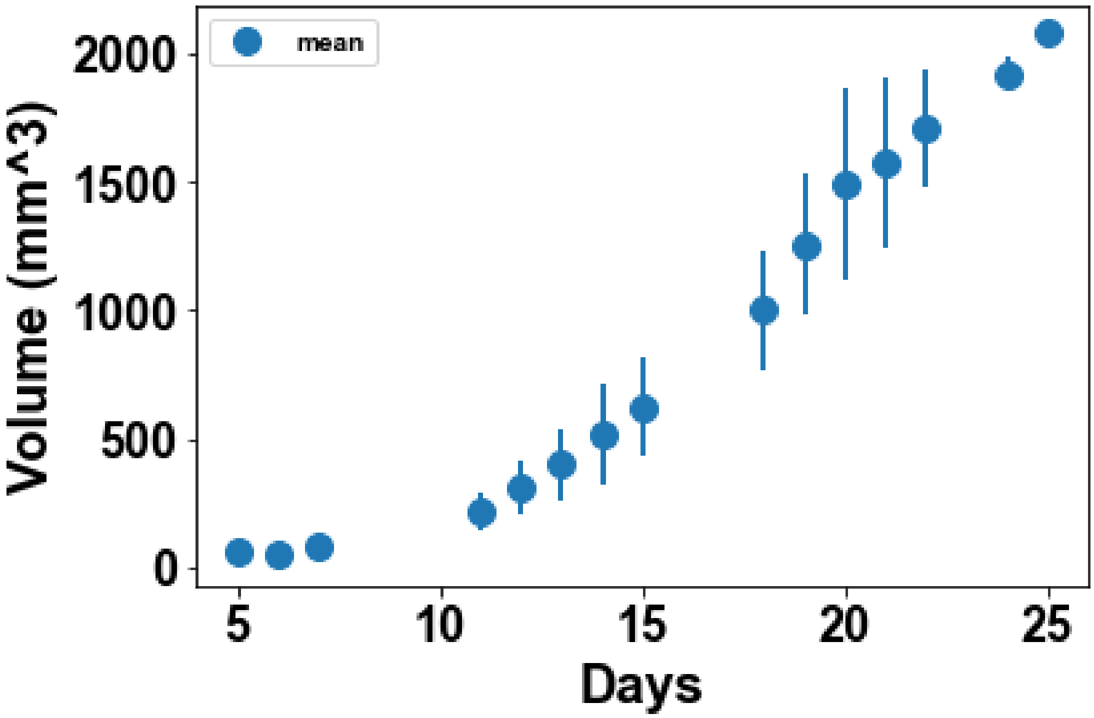
Plot all tumor growth on the same panel

```
In [6]: for mouse in df.columns:
            plt.plot(time, df[mouse], 'o')
            plt.xlabel('Days')
            plt.ylabel('Volume (mm^3)')
```



Plot the average of the data with error bars as standard deviations

```
In [7]: # Generate columns with mean
        df['mean'] = df.mean(axis=1)
        # Generate columns with std
        df['std'] = df.std(axis=1)
        df[['mean']].plot(fmt='o', yerr=df['std'])
        plt.legend(loc='upper left')
        plt.xlabel('Days')
        plt.ylabel('Volume (mm^3)')

Out[7]: Text(0,0.5,'Volume (mm^3)')
```



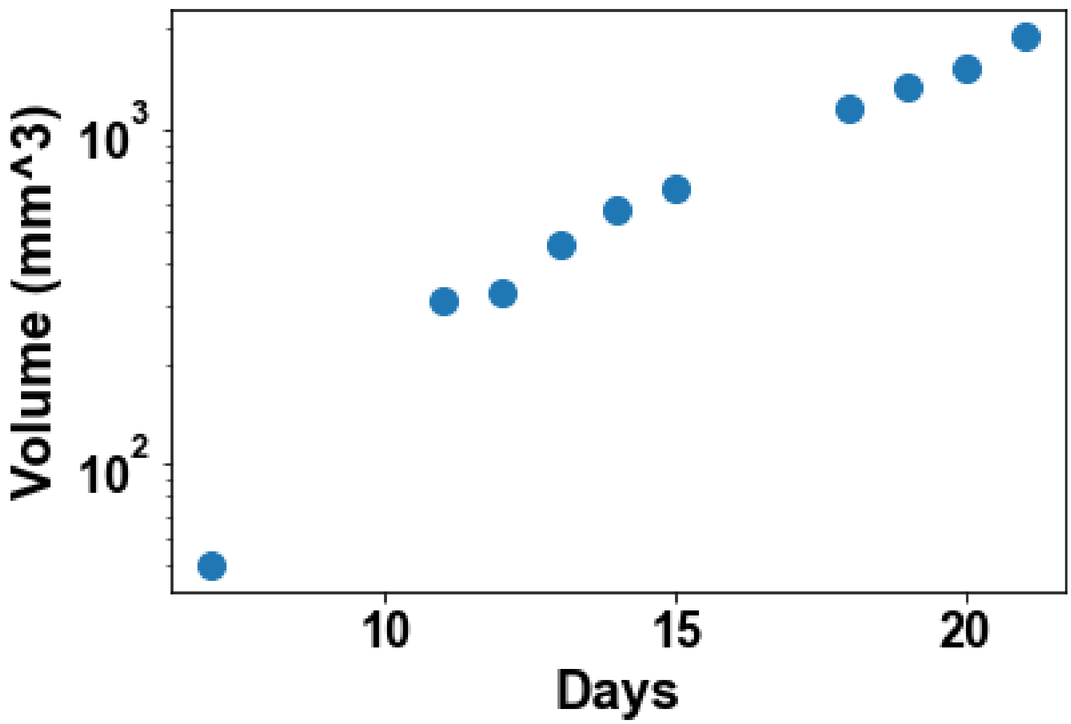
From the individual plots, what tumor growth pattern/equation would you suggest? How could you simply graphically test it? What do you conclude?

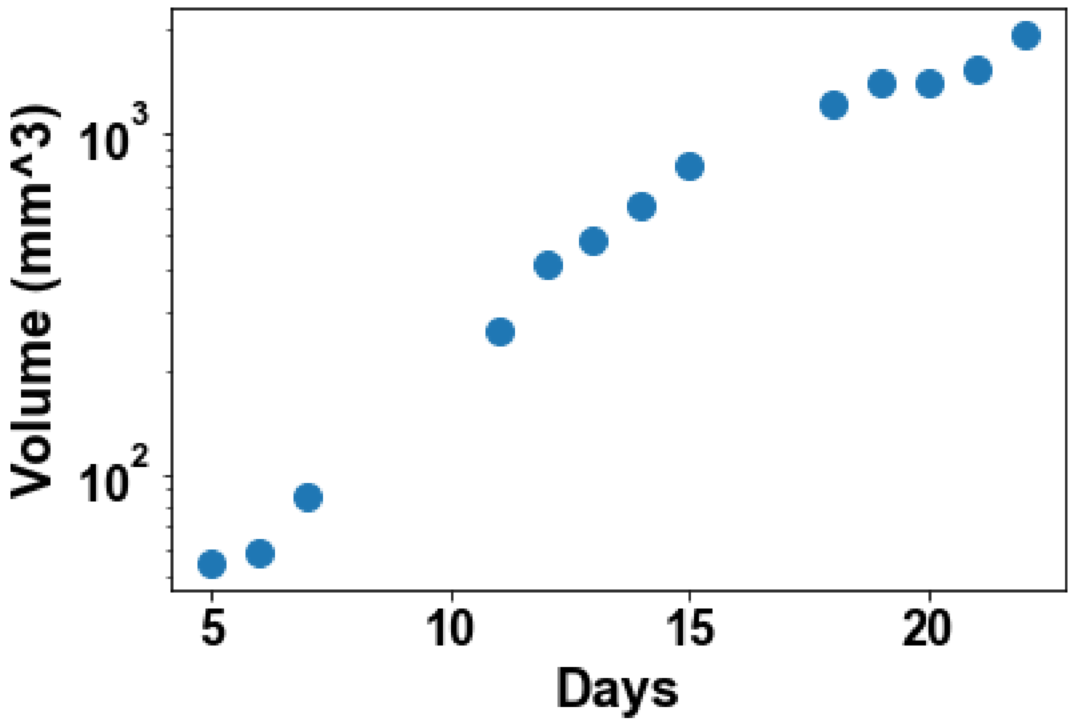
In [9]:
```
# Exponential growth
# Should be linear in log scale
# Mouse 1
plt.figure(1)
plt.semilogy(time, df[1], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')

# Mouse 2
plt.figure(2)
plt.semilogy(time, df[2], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')

# Mouse 3
plt.figure(3)
plt.semilogy(time, df[3], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')

# Mouse 4
```

```
plt.figure(4)
plt.semilogy(time, df[4], 'o')
plt.xlabel('Days')
plt.ylabel('Volume (mm^3)')
```

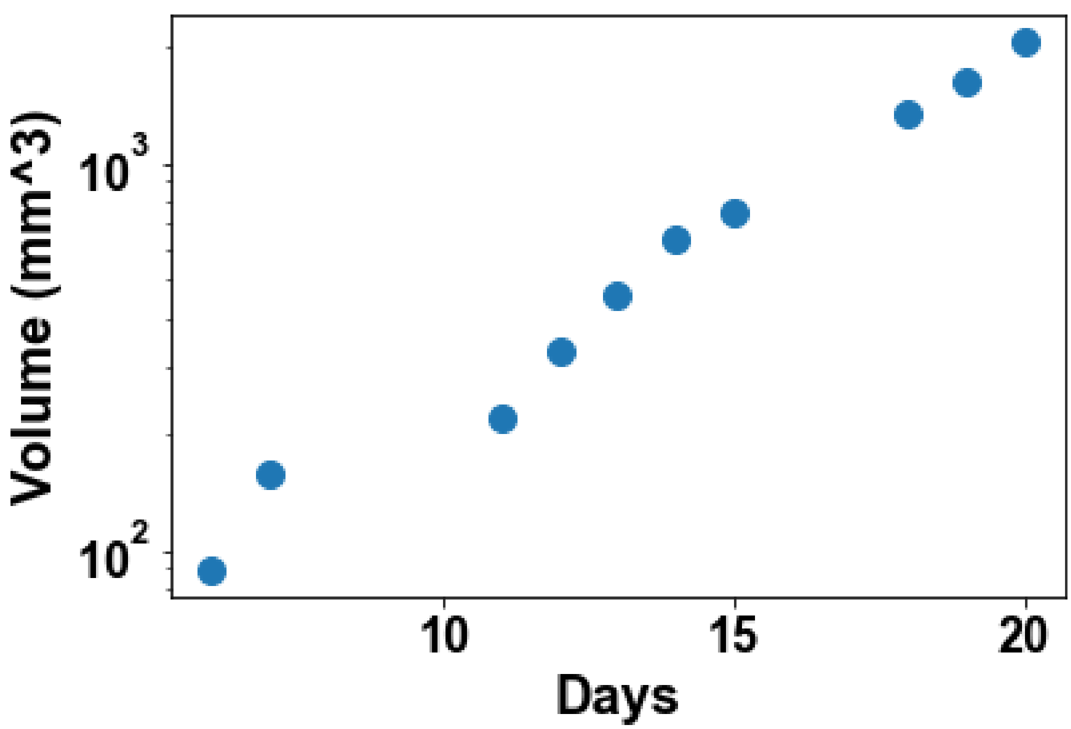
```
Out[9]: Text(0,0.5,'Volume (mm^3)')
```

```
/Users/benzekry/anaconda3/lib/python3.6/site-packages/matplotlib/scale.py:111: RuntimeWarning: i
  out[a <= 0] = -1000
```

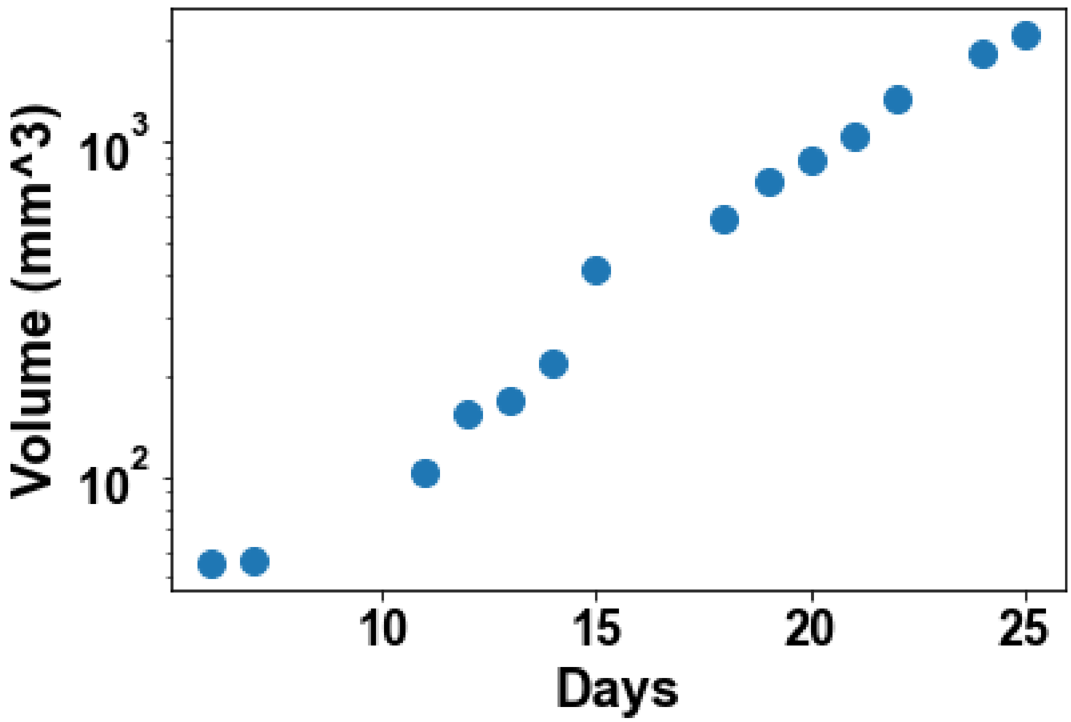




Volume (mm^3)
10^3
10^2
5
10
15
20
Days



Volume (mm^3)
10^3
10^2
10
15
20
Days



Volume (mm^3)
10^3
10^2
10
15
20
25
Days