

```
In [ ]: import numpy as np
from scipy.integrate import odeint
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd

def model(y, t, pop, b, g):
    S, I, R = y
    dsdt = -b * S * I / pop
    didt = b * S * I / pop - g * I
    drdt = g * I
    return dsdt, didt, drdt
```

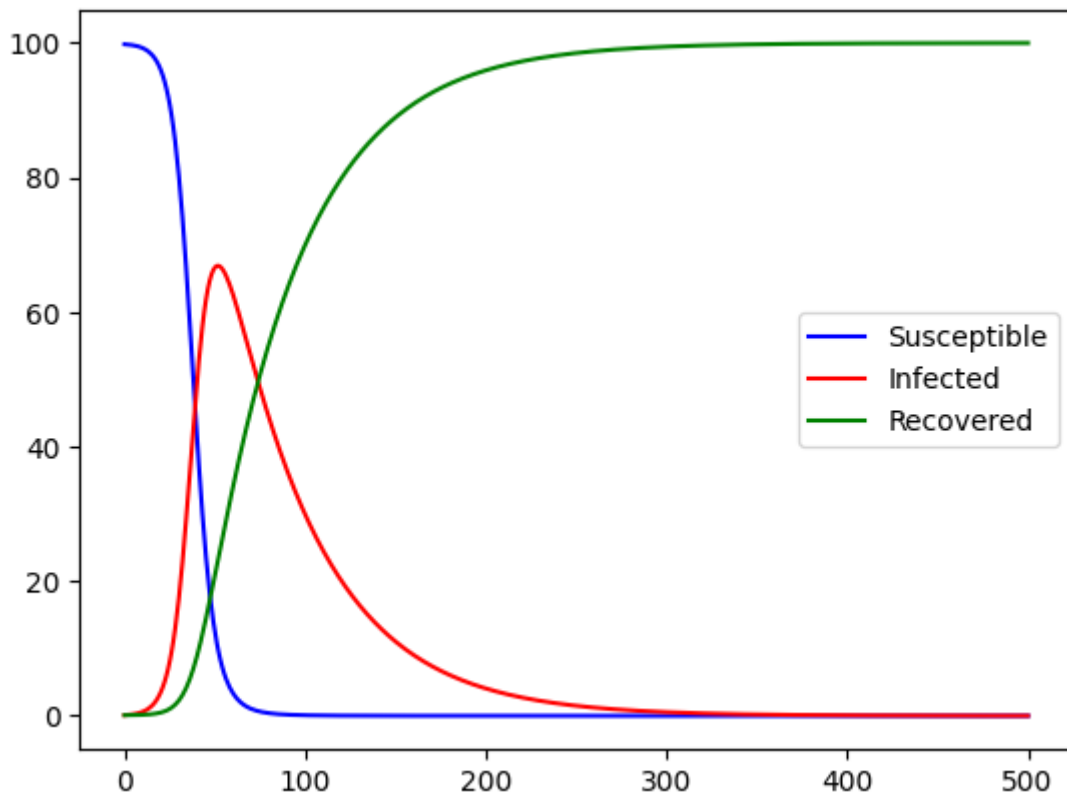
```
In [ ]: pop = 100
I0 = 0.1
R0 = 0.1
S0 = pop - I0 - R0
b = 0.2
g = 0.02
t = np.linspace(0, 500, 500)

y0 = S0, I0, R0

data = odeint(model, y0, t, args=(pop, b, g))

data = pd.DataFrame(data, index = t, columns=['Susceptible', 'Infected', 'Recovered'])
sns.lineplot(data=data, dashes = False, palette=['b', 'r', 'g'])
```

Out[]: <AxesSubplot:>



```
In [ ]: pop = 100
I0 = 0.1
R0 = 0.1
S0 = pop - I0 - R0
```

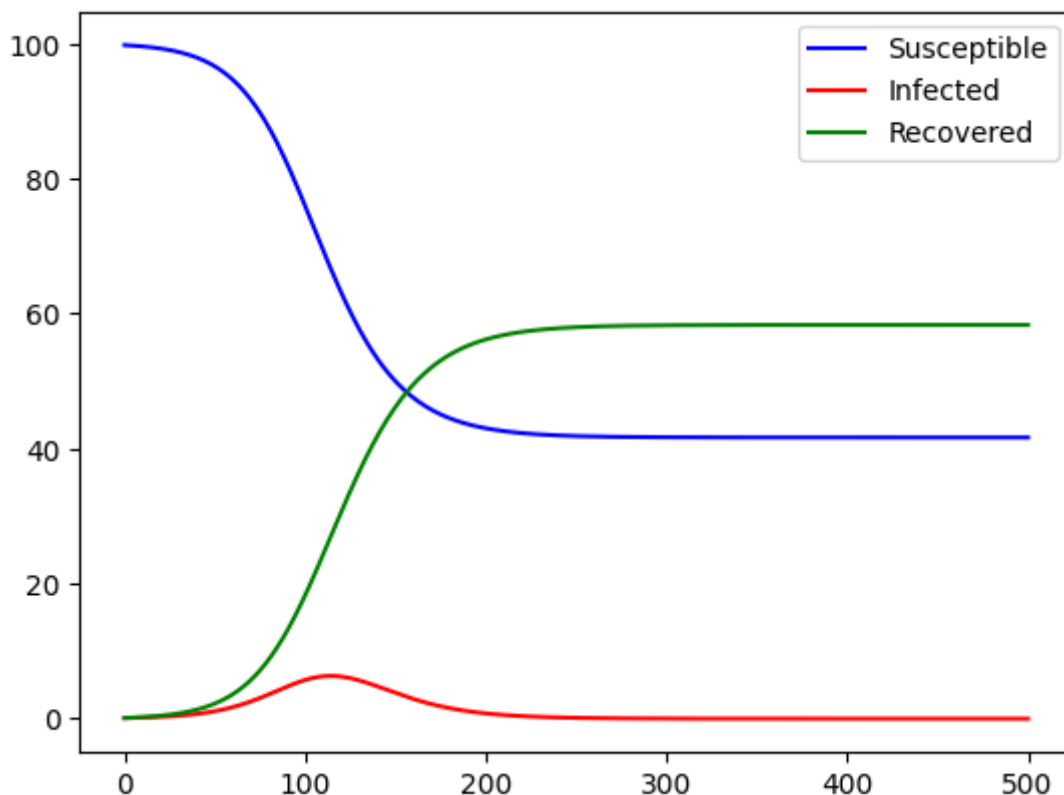
```
b = 0.15
g = 0.1
t = np.linspace(0, 500, 500)

y0 = S0, I0, R0

data = odeint(model, y0, t, args=(pop, b, g))

data = pd.DataFrame(data, index = t, columns=['Susceptible', 'Infected', 'Recovered'])
sns.lineplot(data=data, dashes = False, palette=['b', 'r', 'g'])
```

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Out[ ]: <AxesSubplot:>
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In [ ]:
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```
pop = 763  
I0 = 1 / pop  
R0 = 0  
S0 = pop - I0 - R0  
b = 2.1  
g = 0.6  
t = np.linspace(0, 25, 35)  
t1 = np.linspace(-5, 25, 35)
```

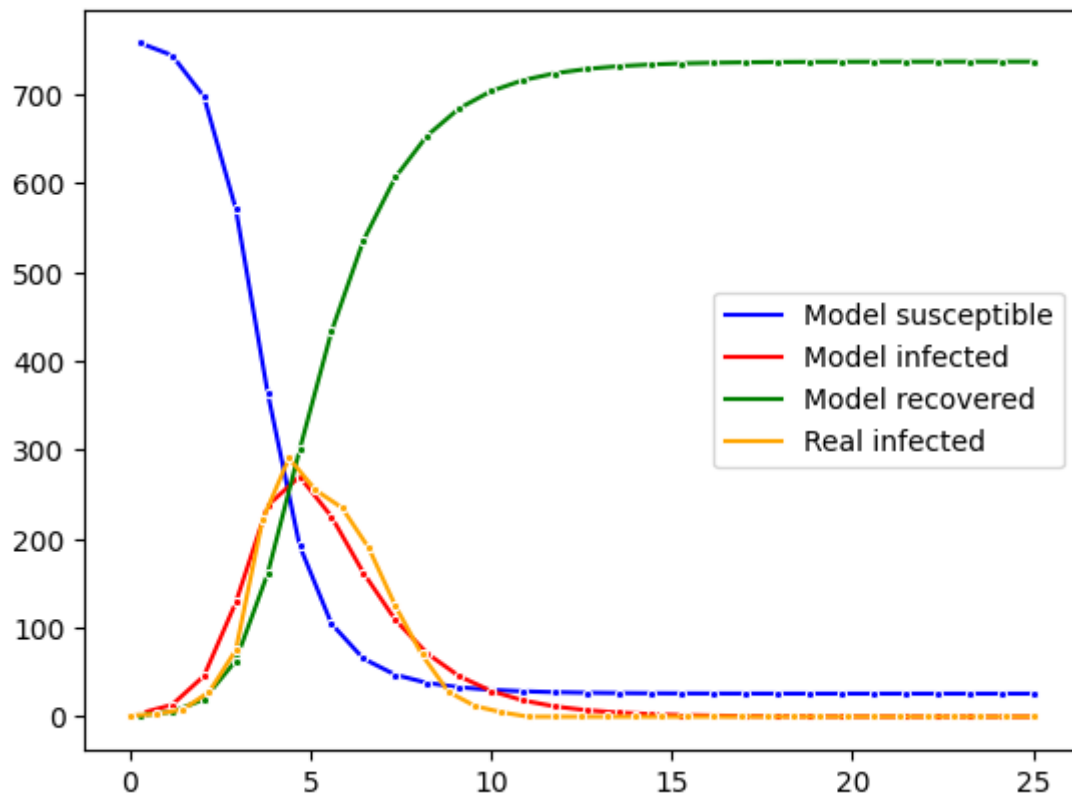
```
real = [1,3,8,28,75,221,291,255,235,190,125,70,28,12,5,0,0,0,0,0,0,0,0,0,0,0,0,0]  
real = pd.DataFrame(real, index = t, columns=['Real infected'])
```

```
y0 = S0, I0, R0
```

```
data = odeint(model, y0, t1, args=(pop, b, g))  
data = pd.DataFrame(data, index = t1, columns=['Model susceptible', 'Model :'  
data = data[data.index > 0]
```

```
sns.lineplot(data=data, marker = '.', dashes = False, palette=['b', 'r', 'g']  
sns.lineplot(data=real, marker = '.', palette=['orange'])
```

```
Out[ ]: <AxesSubplot:>
```



Vaccination strategies

1. Slowing the spread

A vaccine is introduced that aims to reduce the speed at which the disease spreads from infected individuals to susceptible individuals. All boys receive the vaccine. The vaccine reduces the transmission value of the disease by 25%. In the model, this is achieved by multiplying the b value by 0.75. We expect this change to lower the peak and spread out the number of cases over a longer period of time. Both of these changes should make it easier for supporting health care providers to aid the boys recovery.

```
In [ ]: vacc_b = b * 0.75

vacc = odeint(model, y0, t1, args=(pop, vacc_b, g))
vacc = pd.DataFrame(vacc, index = t1, columns=['Vacc susceptible', 'Vacc infected', 'Vacc recovered', 'Vacc deceased'])
vacc = vacc[vacc.index > 0]

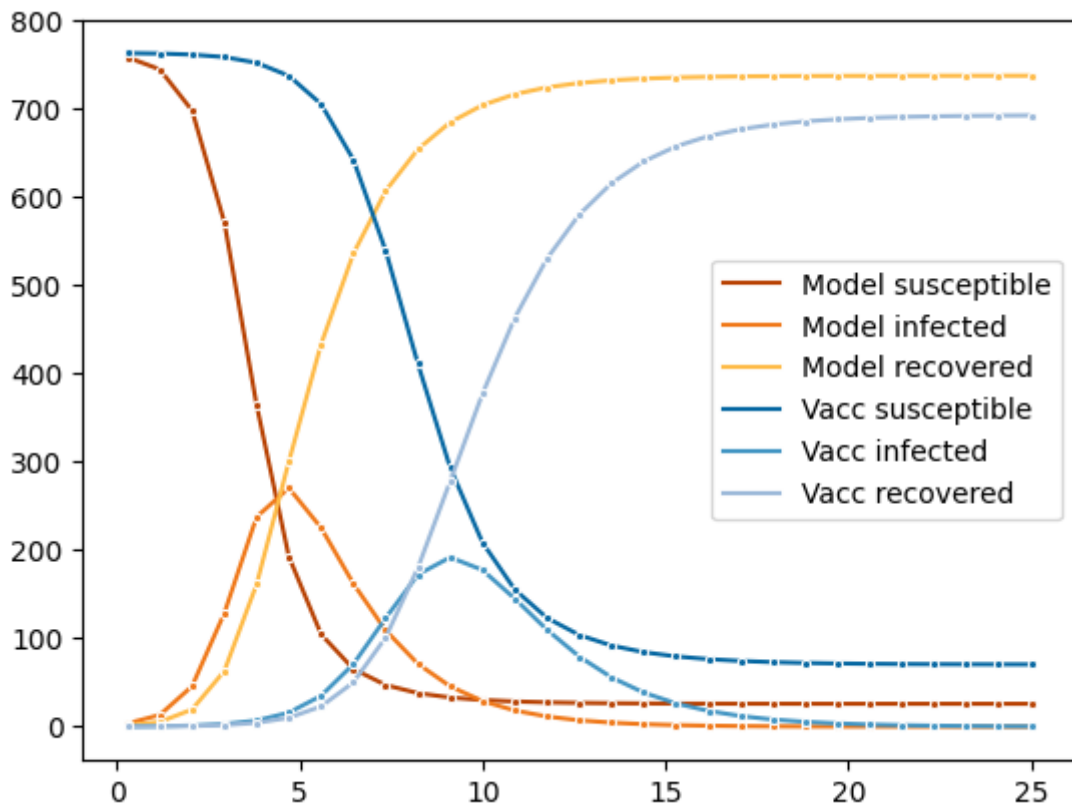
palette_model = sns.color_palette("YlOrBr_r", 4)
palette_vacc = sns.color_palette("PuBu_r", 4)

sns.lineplot(data=data, marker = '.', dashes = False, palette=palette_model)
sns.lineplot(data=vacc, marker = '.', dashes = False, palette=palette_vacc)
```

/tmp/ipykernel_6679/1659404486.py:10: UserWarning: The palette list has more values (4) than needed (3), which may not be intended.
 sns.lineplot(data=data, marker = '.', dashes = False, palette=palette_model)

/tmp/ipykernel_6679/1659404486.py:11: UserWarning: The palette list has more values (4) than needed (3), which may not be intended.
 sns.lineplot(data=vacc, marker = '.', dashes = False, palette=palette_vacc)

Out[]: <AxesSubplot:>



Results

Compared the model with no vaccination strategy, the results show a decrease in the height of the peak. We also observe a small increase in spread over time as well as a longer delay before cases reach peak height. The decrease in height of the peak is quite significant and we also observe a larger spread of cases of time. Furthermore, we observe the rate of new infections be decreased, as the slope is less steep.

2.0 Recovery

A vaccine is introduced that aims to increase recovery after infection with the disease. All boys receive a vaccine. The vaccine doubles the rate of recovery. In the model this is achieved by multiplying the g value by 1.25, for consistency with the previous experiment. We expect this decrease the total number of infections at any time as through faster recovery there is a smaller chance of susceptible children to become infected by one that is infectious.

```
In [ ]: vacc_g = g * 1.25

vacc2 = odeint(model, y0, t1, args=(pop, b , vacc_g))
vacc2 = pd.DataFrame(vacc2, index = t1, columns=['Vacc susceptible', 'Vacc infected', 'Vacc recovered'])
vacc2 = vacc2[vacc2.index > 0]

palette_model = sns.color_palette("YlOrBr_r",4)
palette_vacc = sns.color_palette("PuBu_r", 4)

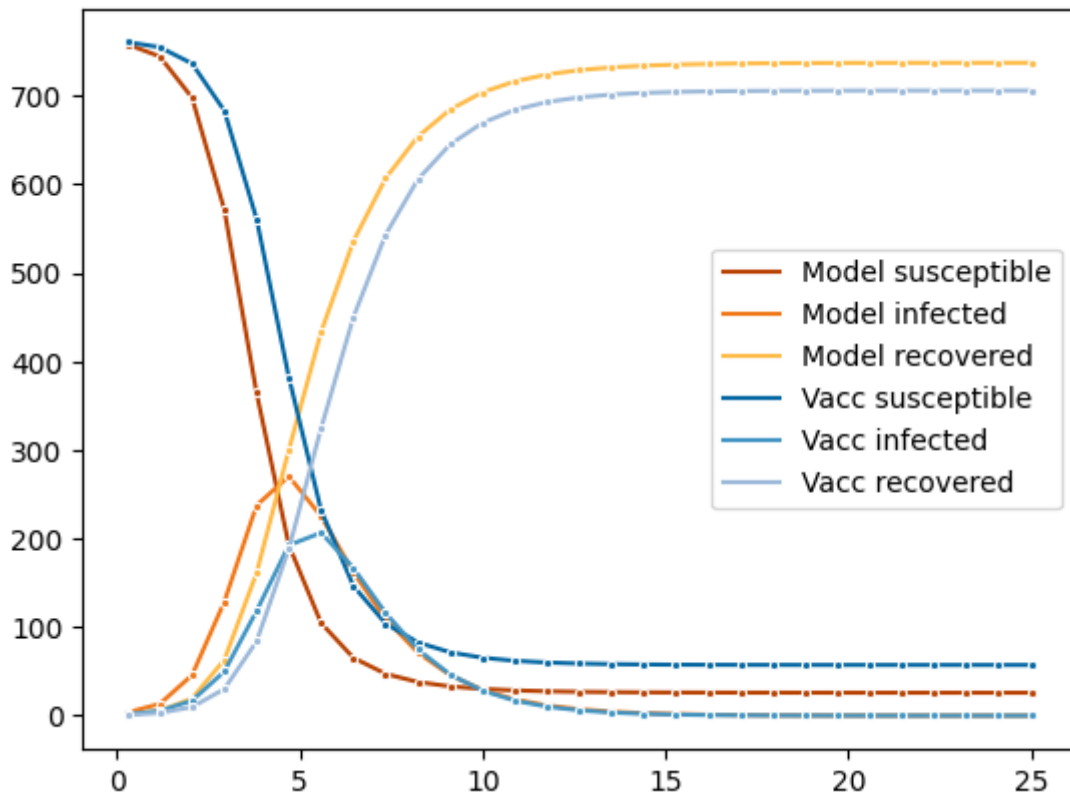
sns.lineplot(data=data, marker = '.', dashes = False, palette=palette_model)
sns.lineplot(data=vacc2, marker = '.', dashes = False, palette=palette_vacc)
```

```

/tmp/ipykernel_6679/2949167026.py:10: UserWarning: The palette list has more values (4) than needed (3), which may not be intended.
sns.lineplot(data=data, marker = '.', dashes = False, palette=palette_model)
/tmp/ipykernel_6679/2949167026.py:11: UserWarning: The palette list has more values (4) than needed (3), which may not be intended.
sns.lineplot(data=vacc2, marker = '.', dashes = False, palette=palette_vacc)

```

Out[]: <AxesSubplot:>



Results

The results show a small decrease in the peak number of cases. There is no significant delay or increase in spread of the infections. There is also no real increase in rate of recovery from infection.

Comparison and conclusion

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In [ ]: sns.lineplot(data=vacc, marker = '.', dashes = False, palette=palette_model)
sns.lineplot(data=vacc2, marker = '.', dashes = False, palette=palette_vacc)

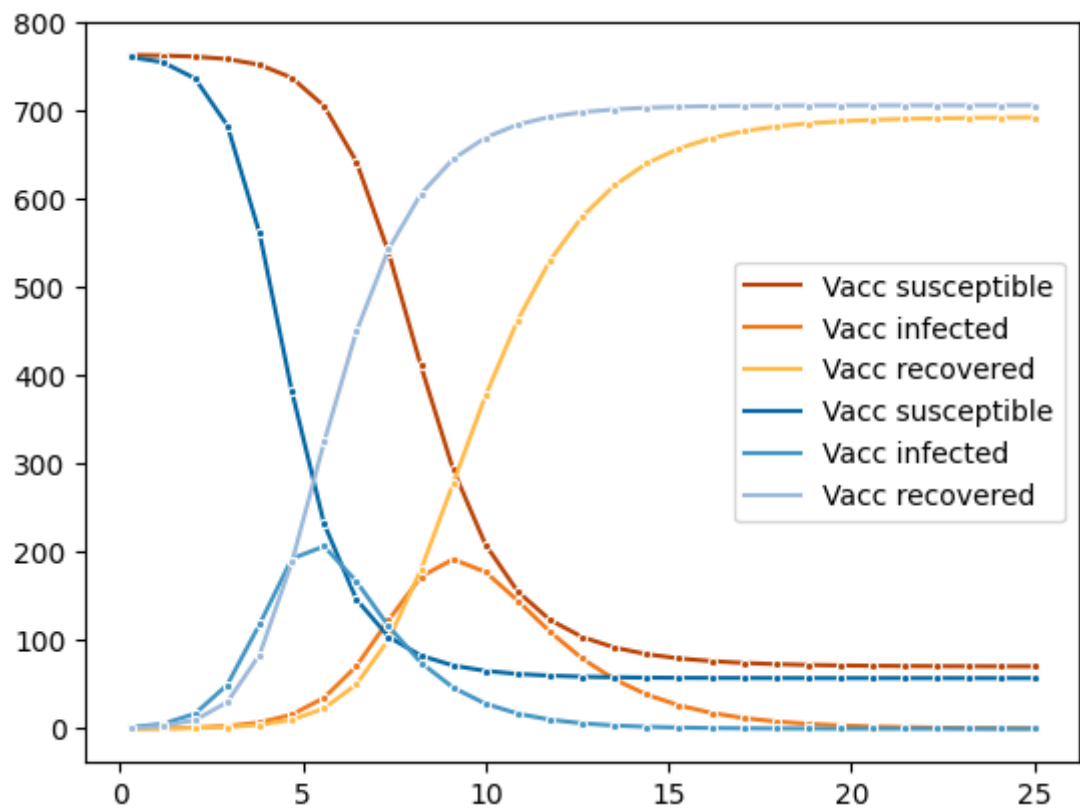
```

```

/tmp/ipykernel_6679/699838897.py:1: UserWarning: The palette list has more values (4) than needed (3), which may not be intended.
sns.lineplot(data=vacc, marker = '.', dashes = False, palette=palette_model)
/tmp/ipykernel_6679/699838897.py:2: UserWarning: The palette list has more values (4) than needed (3), which may not be intended.
sns.lineplot(data=vacc2, marker = '.', dashes = False, palette=palette_vacc)

```

Out[]: <AxesSubplot:>



```
In [ ]: #print(vacc2["Vacc infected"].to_numpy())
        #print(vacc["Vacc infected"].to_numpy())
```

```
In [ ]:
```