# Maths vs Zombies

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## 1 Introduction

In the report I will use mathematics to model a Zombie outbreak, work has already be done in [1] In this model of a zombie outbreak there will be three 'populations', the living, the zombies and the dead (the dead includes, deceased zombies, bitten people (could be zombies), and deceased people.)

## 2 The problem

First I will need to define each variable.

i The Living = L

ii The Zombies = Z

iii The Dead = D

iv The time = t

v The rate of birth = l

vi The rate of zombie infection = a

vii The rate of zombie death = b

viii The rate of natural death = d

ix The rate of dead people turning into zombies = z

Now I will use differential equations to model a zombie outbreak, I will then use these equations in sage and find a solution as to who will win in the ultimate battle between Humans and Zombies.

$$\frac{dL}{dt} = l - aLZ - dL \tag{1}$$

$$\frac{dZ}{dt} = aLZ + zD - bLZ \tag{2}$$

$$\frac{dD}{dt} = dL + bLZ - zD \tag{3}$$

These equations are what I will use to calculate who will win, zombies or humans, if I give the constants certain values.

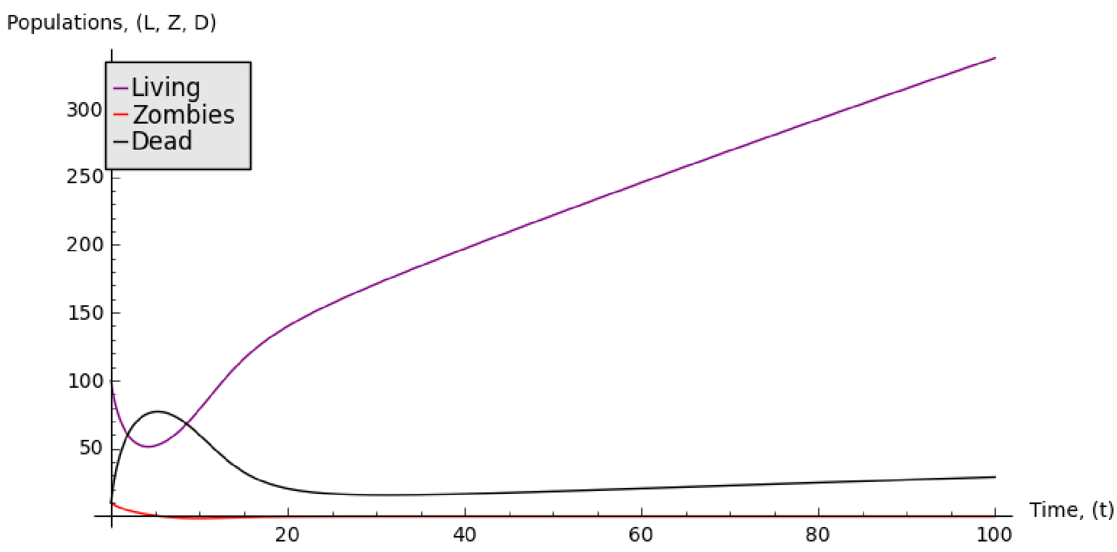
## 3 Modelling the Problem using code

To work out this problem I have used Sage to calculate this problem (see following code)

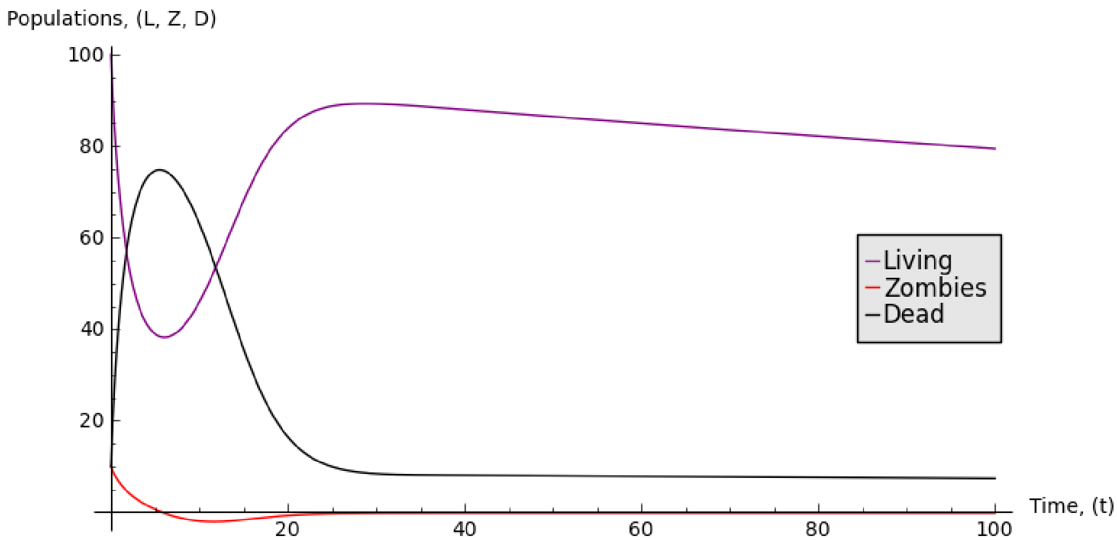
```
t, L, Z, D = var('t', 'L', 'Z', 'D')
b, a, z, d, l = 0.05, 0.045, 0.01, 0.01, 3
x = l - a*L*Z - d*L
y = a*L*Z - z*D - b*L*Z
q = d*L + b*L*Z - z*D
P = desolve_system_rk4((x, y, q), [L, Z, D],ics=[0,100,10,10] ,ivar=t,end_points=100)
p1 = list_plot([[t, L] for t, L, Z, D in P], plotjoined=True, color = 'purple', legend_label = 'Living')
p2 = list_plot([[t, Z] for t, L, Z, D in P], plotjoined=True, color = 'red', legend_label = 'Zombies')
p3 = list_plot([[t, D] for t, L, Z, D in P], plotjoined=True, color = 'black', legend_label = 'Dead')
A = p1 + p2 + p3
A.axes_labels(['Time, (t)', 'Populations, (L, Z, D)'])
show(A)
A.save('ZombieGraph.png')
```

## 4 Graphs of who will win

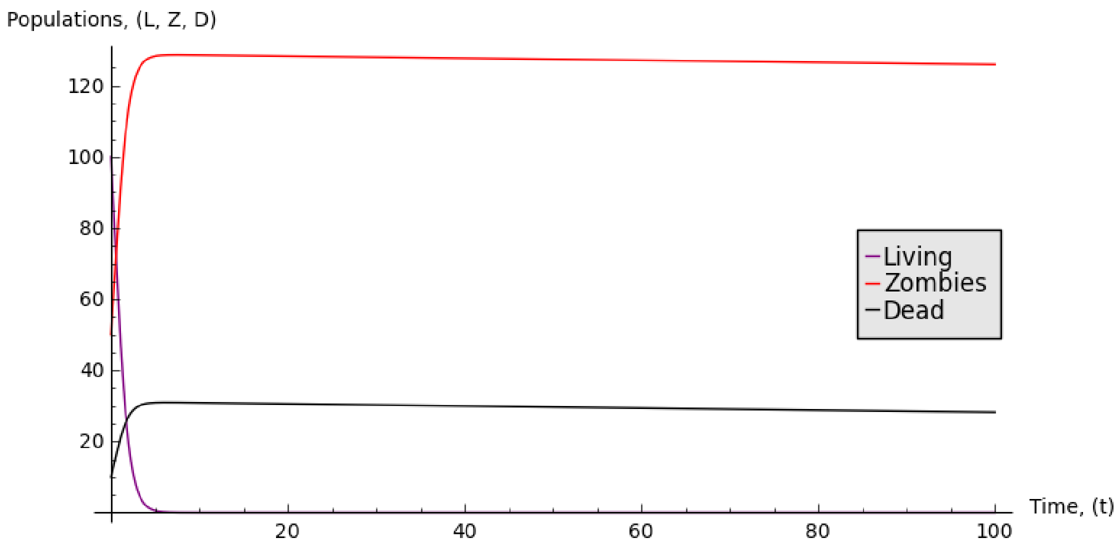
This graph is where; b = 0.05, a = 0.045, z = 0.01, d = 0.01, l = 3 The graph clearly shows that when given these conditions, the Living will survive and the zombies clearly die out very quickly.




This graph is where the conditions are the same as the previous on, but the birth rate is zero, i.e since the zombie apocalypse, the human race has become infertile. You can see that the zombies still quickly die out, but the human race is in decline.




This next graph shows what conditions we would need to have for the zombies to kill all the humans. Obviously this is the worst condition for the humans. b = 0.002, a = 0.0095, z = 0.001, d = 0.001, l = 0




## 5 Problems with the code

Originally I intended on splitting the living into two populations, the men and the women, but when coding this in sage, I found it very difficult to have the 4 variables (Lf, Lm, Z and D) with three equations. So therefore I decided to simplify my problem to have the one population of the living.

## 6 Conclusion

As you can see from the above graphs the when given different conditions different things with happen with who wins between zombies and humans. For the humans to win they have to kill the zombies faster than the zombies kill them and they have to reproduce.

## References

[1] D. Joyner. Love, War and Zombies - System of Differential Equations using Sage. Accessed: 2014-12-11.