**5 Natural dynamics of ID (Measles)**

Set up the SEIR model with births and deaths for the transmission dynamics of measles in a closed population using differential equations:

Population 100000 people

Pre-infectious period 8 days

Infectious period 7 days

Basic reproduction number 13

Life Expectancy 70 years

Initial values (S,E,I,R)=(99999,0,1,0)

Using the parameters above, plot a graph from the 40th year to the 50th year which illustrates your answer for each question.

1. How does the net reproduction number change over time? What is the value of the net reproduction number when the daily number of new infectious peaks? What is its value when the daily number of new infectious persons reaches a trough?
2. What is the trend in the daily number of new infectious when Rn<1, Rn>1, and Rn=1, respectively?
3. What proportion of the population is susceptible to infection when the daily number of new infectious peaks or troughs? Is this consistent with what you expect and why?
4. Calculate the herd immunity threshold in this population.
5. What is the value of proportion of immune when the number of new infectious per day peaks or troughs? What do you notice about the value of proportion of immune when the daily number of new infectious is declining? What is its value when the daily number of new infectious is increasing? How does this relate to your estimate of the herd immunity threshold?
6. What is the long-term equilibrium value for the proportion of the population which is susceptible or immune? How do these values relate to the herd immunity threshold which you have just calculated and why?

Modify the model to include the vaccination which is introduced 50 years after the infection has been circulating in the population so that a proportion of newborn individuals are effectively vaccinated. Run the model for 80 years and plot the proportion of immune and the number of new infectious on each side of y-axis.

1. What happens to the number of new infectious persons per day if the proportion of the population which is effectively vaccinated is below (60%, 90% coverage) the herd immunity threshold? What happens to the number of new infectious persons per day if this proportion is above (93% coverage) the herd immunity threshold?

To explore how R0 and other factors (e.g. the vaccination coverage, the birth rate in the population) affect the inter-epidemic period, reset the proportion of the population which is vaccinated to be zero.

1. What is the inter-epidemic period 50-100 years after the introduction of one infectious case into this population? Are your results consistent with the following formula provided by Anderson and May?

where D’ is the average duration of the pre-infectious period, D is the average duration of infectiousness, L is the life expectancy.

1. R0 for measles was estimated to be about 5-6 in Kansas 1918-9, and 18 in England and Wales in 1950-68. Run the model for values of R0 of 5 and 18. How does the inter-epidemic period resulting from an R0 of 18 compare against that resulting from an R0 of 5? Why might this occur?
2. How might you expect the introduction of vaccination to affect the inter-epidemic period?
3. How might the birth rate in the population influence the inter-epidemic period? Test your hypothesis by changing the birth rate assuming that the population size remains constant over time.
4. Would you expect the inter-epidemic period for measles to be shorter than that for chickenpox? mumps? rubella? Why?
5. Change the parameters to be those for influenza (pre-infectious and infectious periods of

2 days and a basic reproduction number of 2), reset the birth rate corresponding to a life expectancy of 70 years and, making sure that no-one is vaccinated in the population. Why might you be cautious about using predictions of the inter-epidemic period for influenza from this model?