# The SIR model:

There are 3 compartments in this model:

* S: the group of **susceptible** individuals
* I: the group of currently **infective** individuals
* R: the group of **removed** individuals, could either be from death or becoming immune to the disease

*An important assumption for this model is that we are ignoring the birth rates, immigration rates and death rates. The population size remains a constant over time.*

The size of these 3 groups can change over time as the disease progresses. Therefore, we can represent them as 3 variables that dependant on time: S(t), I(t), R(t).

The only way for an individual to leave the susceptible group is by becoming infected. Suppose that each person from the infected group meets b people per day. So the infected group meets b\*I(t) people each day. Only a fraction of these people is from the susceptible group. Therefore, the number of new infections each day can be calculated as:

If the duration of each infection is k days, each day 1/k of the infective group either recovers or dies. Calling this 1/k fraction a, we have the removed equation:

We can also find the infected equation:

# Application to COVID-19:

We can make a few adjustments on this model to suit our application better. Firstly, a new Death compartment is added, and the Removed group is renamed as Recover, which of course only includes the number of people that recovered. Suppose COVID-19’s death rate is a fraction δ. The equations for number of new deaths and new recovery each day are:

We also adhere to the SIR’s assumption that people who recovered from COVID-19 are much less likely to become reinfected. This number is assumed to be negligible.

# Incorporating vaccination:

Suppose that v% of the population is vaccinated, and a vaccinated individual is x% less likely to become infected, and y% less likely to die from infection. We also need to divide the susceptible and infective compartment into the vaccinated and unvaccinated groups. All the variables we have now are: Sv(t), Suv(t), Iv(t), Iuv(t), R(t), D(t).

We have the following sets of equations:

# Initial values and parameters:

Now that we have a complete set of equations, we still need the initial value Suv(0), Sv(0), Iuv(0), Iv(0), D(0) and the parameters a, b, δ, v, x, y to calculate death rates and daily cases at any t. We can set current time as the initial time (t=0).

Many studies show that an average COVID-19 case lasts 15 days, and its average death rates is 1% [1]. Therefore, a is 1/15, which is approximately 0.07, and δ is 1%. As for b, we can assume that it is 5. Vaccination rates (v) will be provided by the users. As for x and y, there is not an official result for the efficiency of Pfizer or AstraZeneca yet. So we can make assumption here that they are both 80%.

**S(0)**: This can be the country’s most current population size minus the number of current infectives (I(0)). Sv(0) and Suv(0) can be found using S(0) and vaccination rate.

**I(0):** We know that a COVID case lasts 15 days, so to get I(0), we can add up the number of cases in the last 15 days. Since we are applying the new vaccination rate from today, we can assume that all current infections are from unvaccinated individuals. Hence, Iv(0) = 0 and Iuv(0) = I(0).

**D(0)**: This is the total number of COVID death in each country from the beginning of the outbreak till now.