# COVID-19: some graphs to understand what is happening

A paper for science and math teachers
to explain the epidemic to their students,
*or for people who want to understand what is happening.*

The pandemic we are experiencing is causing significant problems to the society. Therefore, it is of great interest to be able to understand and to predict the evolution of the number of cases in the coming days and weeks. In this document, we propose to review the evolution of the epidemic in South Korea since the process began there before and serves to see the type of predictable behavior. We will use some graphs to understand each of the ideas we want to convey. The first case in Korea was diagnosed on January 20, 2020, this will be day 1 on all the graphics.

1. *Evolution of the number of cases over time*

We can divide the evolution into two stages. The first for the number of cases which have been predominantly imported, people who have arrived infected from other countries:
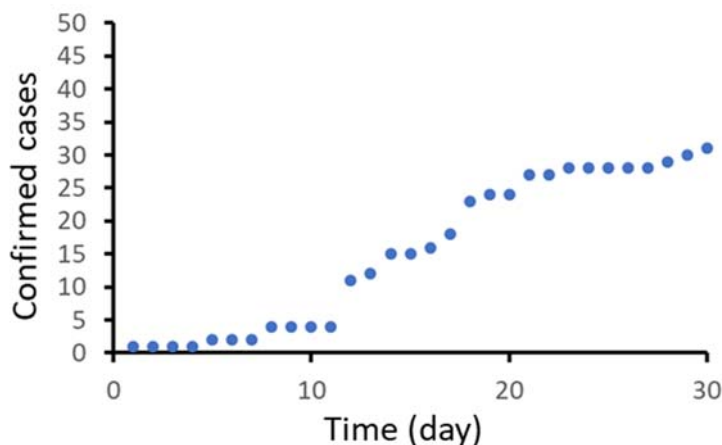
And a second stage where local infections predominate:
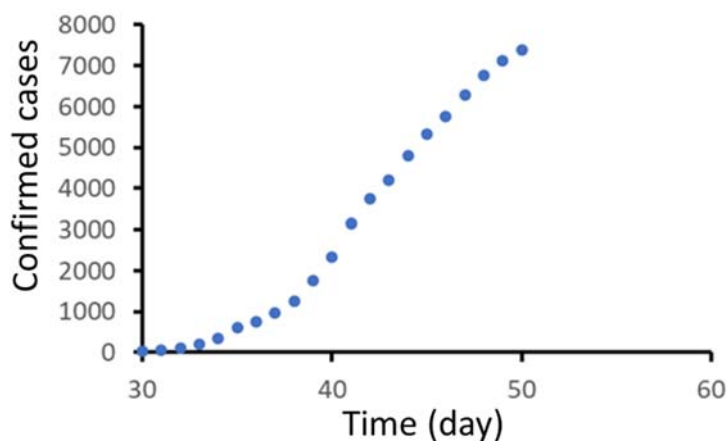
Note the axis of ordinates, which is very different in the two graphs. We separated the two stages to show what was happening before and after the 30 day. If we show both data together:
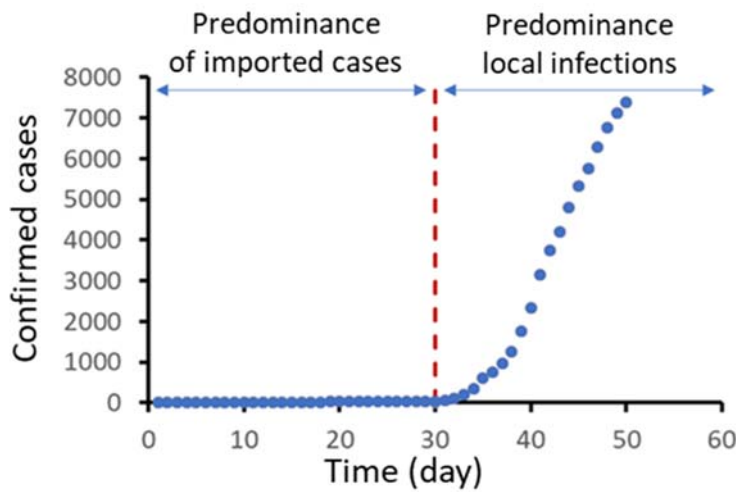

2. *Can we foresee how it will continue to evolve?*

We have found that the Gompertz function reproduces the behavior quite well over the total number of cases accumulated. Gompertz's function is similar to the logistic function and to other functions used to describe system growth (for example, population growth in a country or growth in a tumor). It is a sigmoid function that has three parameters: the initial value (N_0), the maximum value (K) and a parameter that determines the rate of growth (a). The function reads:

$$N(t) = Ke^{-ln\left(\frac{K}{P_0}\right) \cdot e^{-at}}$$

Adjusting a function means finding the parameter values that make the behavior of the function as close as possible to the experimental values. Thecoefficient R^2 measures whether the adjustment is good or not, the closer to 1 the better the adjustment.
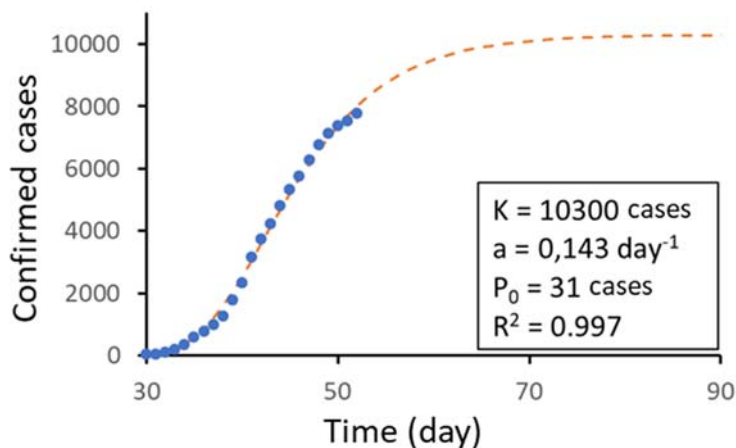
In the figure, the dashed line shows the forecast of Gompertz's function. We note that the forecast indicates that growth will continue to be quite significant until approximately the day 70th. In Korea they are doing a good control; therefore, the fact that the number of cases continues increasing does not mean that the epidemic is out of control.

The forecast needs to be reviewed daily, as it is only valid in the short term. Adding a point can

make the adjustment again and improve our forecast. Mathematical models of complex systems are not a crystal ball. They help to understand and to predict, but they are not totally deterministic.

3. *Is the number of cases growing exponentially? No!!!*

Surely everyone remembers the myth of the origin of chess: the creator of the game asked to pay for his work 1 grain of wheat for the first box, 2 for the second, 4 for the third, and so on.


At first it seemed like a very low price for such an entertaining game, but really no one could pay such a high price! In the last box should be placed 2^{64} grains, which corresponds to approximately 9 10^8 grains (9 followed by 18 zeros, 9 million millions of wheat grains!). In fact, this corresponds to an exponential growth: 2, 4, 8, 16, 32, 64, ...

In the following figure we have represented the number of wheat grains to be placed in the first 16 boxes:
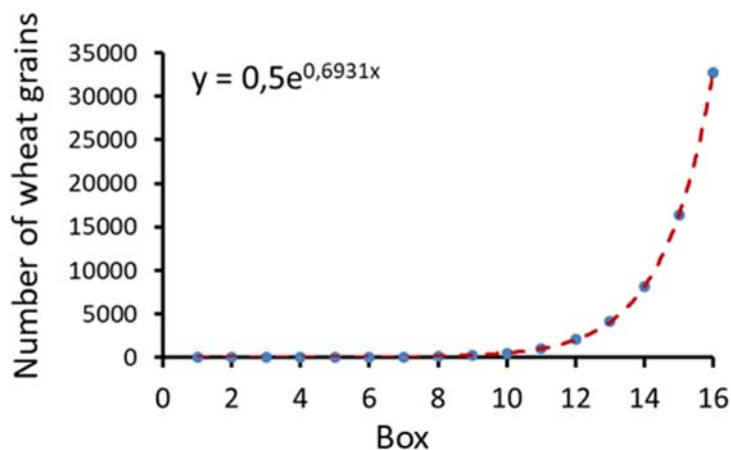

The dashed line is the exponential function that fits perfectly with this set of points. Another way to represent an exponential function is to represent the logarithm of values or use a logarithmic axis, as in the following figure:
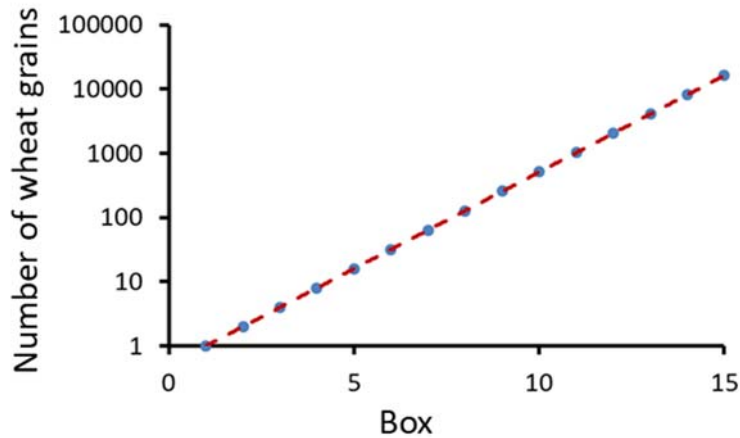
Note that on the y-axis the distance from 1 to 10, from 10 to 100, from 100 to 1000, ... is always the same. We see that by representing an exponential function using the ordinate axis with a logarithmic scale, the result is a straight line.

Let's check if the Covid-19 epidemic in South Korea continues to grow exponentially. Representing the cumulative number of cases using a logarithmic scale, we see that, despite the first points seeming to obey exponential growth, the complete behavior over time is not.
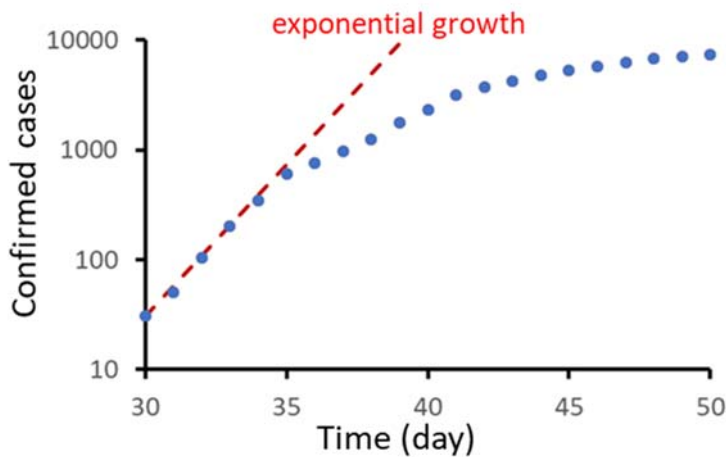
In fact, the number of cases is growing slower than exponential growth. This decrease in growth rate is due to confinement and surveillance activities to control the epidemic.

4. *More and more cases are being diagnosed every day ... out of control? No!!!*

The following figure represents the number of new cases found each day. We see that in the epidemic there are two stages, the first where the number of new cases is increasing every day, and the second where the daily number of new cases is decreasing. It is the dynamics that is also observed as a result of the confinement of people who may be infected and the surveillance of those who are sick.
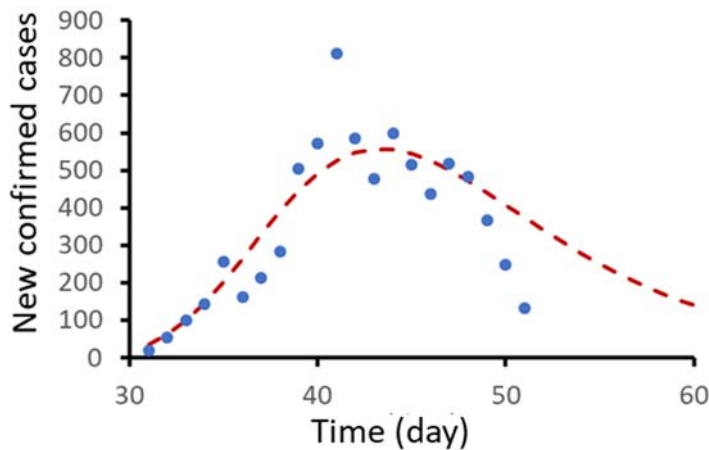
The dashed line is the result we get using the Gompertz equation.

We need to be patient. In Catalonia and in Spain we will also experience the same process, although it is difficult to keep calm while the number of diagnosed cases is growing. Restraint measures are being taken, and the descent stage will come!

5. *Will we all die? No!!!*

Mortality in Korea is quite low, dying on the order of 0.7% of patients. Mortality in each country may be different, depending on many factors: the age distribution of the population, the capacity of healthcare, the rate of diagnoses (especially among asymptomatic and mild cases) ... but in any case, it is a small mortality. It is not an epidemic that has to make the population down. Really, in most cases it is a mild disease.

The following figure shows the number of deaths in Korea against the cumulative number of cases, and shows that there is a linear correlation.
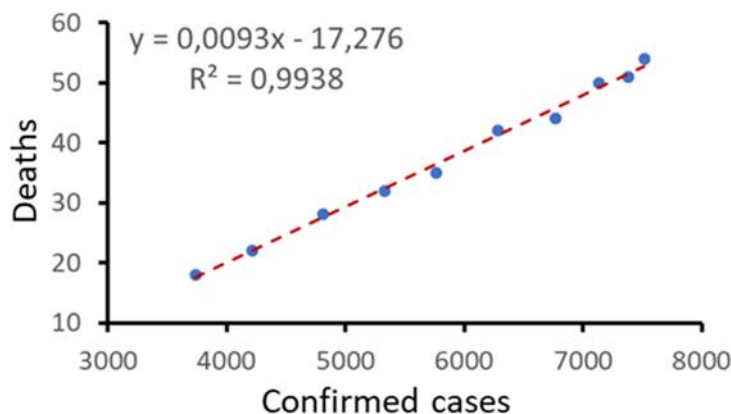
We have seen how with the help of mathematics and graphical representations we can begin to understand what is happening.

6. *And to conclude ...*

Despite economic and social problems, despite health and mortality, we can also see a positive side. For the first time in human history, we are experiencing a pandemic with daily information and good public health monitoring and control systems. It is a privilege to live in the 21st century.

COVID-19 should also remind us that we should not neglect all other infectious diseases that cause epidemics, some of which are much worse than COVID-19. Tuberculosis causes one and a half million deaths a year, worldwide. In Catalonia, about 1,200 cases of tuberculosis are detected each year, which is still very important. Measles in 2018 caused more than 140,000 deaths in the world, and it is having catastrophic effects in some countries, such as the Democratic Republic of the Congo, from 31/12/2018 to 5/II/2020, causing 334,360 cases and 6,326 deaths. The dengue epidemic in Latin America caused more than 3 million cases during 2019. Viruses and bacteria have no boundaries. The current epidemic of COVID-19 has taught us that co-operation and mutual work are absolutely necessary for the safety of all.