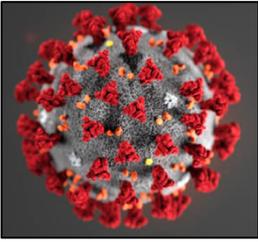


The Mathematics Behind the Coronavirus Spread - Part 2

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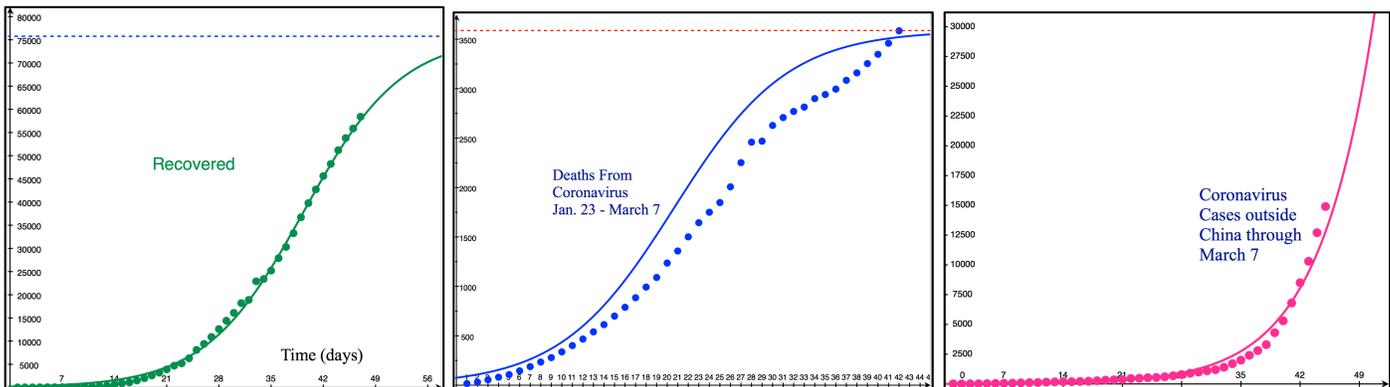


In my previous blog, I traced the growth of the Coronavirus (COVID-19) from its beginning cases in Mainland China. I looked at how the numbers first showed exponential growth and then logistic growth through 7 weeks. At the end of this time, it appeared that the growth was indeed slowing down and the logistic curve leveling off. Between March 9 and March 10, there were “only” 22 new reported cases in Mainland China compared to 4,067 new cases between February 4 and February 5. And while there is no guarantee that the growth has been stopped, it appears that the measures that the Chinese government imposed, as draconian as they were, have helped. It remains to be seen whether the crisis is over in China as people go back to work and begin to congregate in larger groups.

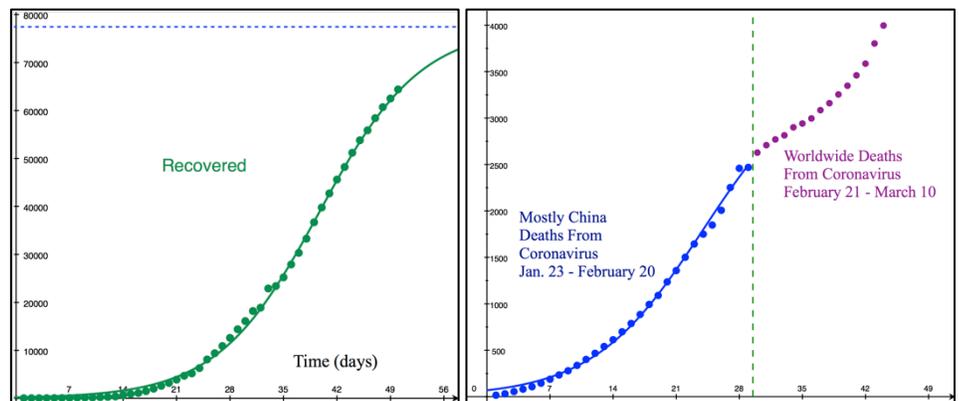
If you haven't read the previous blog, you can find download it at: <http://www.mastermathmentor.com/mmm-archive/CoronaVirus.pdf>

In this part 2, we now concentrate on the growth of coronavirus in the World and the United States.

March 7: While the recovery curve still is increasing quickly, it is quite clear that the logistic model for deaths from the coronavirus is now well out of whack. The reason as stated before that for the most part, most of the deaths came from inside China and now every day, there are increasing numbers of deaths outside China. So the deaths curve has stopped leveling off and on an exponential growth spurt, at least for now. In the next update I will split the deaths curve from pre-February 20, and then February 20 and beyond.

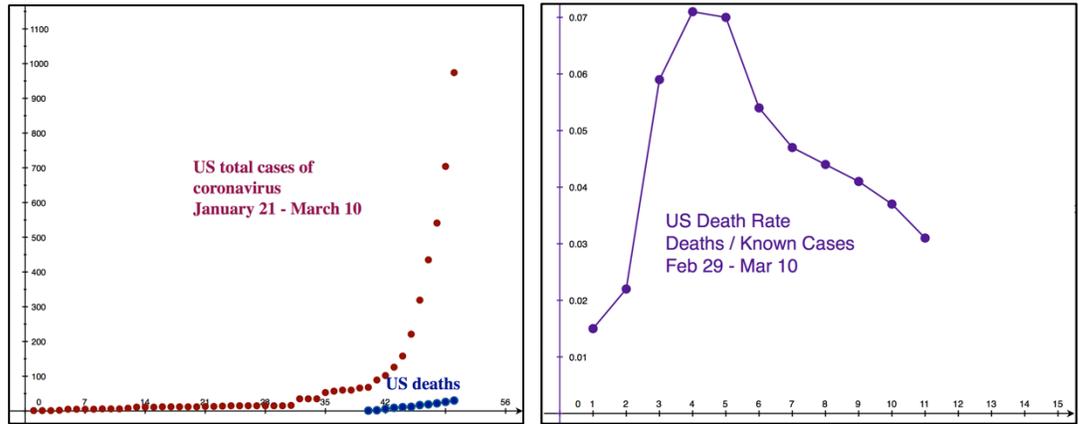


March 10: The Recovery curve is starting to level off. It is assumed that this is occurring because the number of cases in Mainland China has leveled off, the worldwide cases are growing and people who have COVID-19 haven't had sufficient time to be considered recovered. As the number of new cases decrease in China and increases everywhere else, it may be necessary to split this curve into a piecewise function.



As promised, I split the death curves into a piecewise function with February 20 representing the split. That is the time when worldwide cases started to spike and China cases had started to decline. I made no attempt to generate a curve to describe the worldwide deaths from March 21 through March 10 because it contains data from both China and the rest of the world.

We now focus on the United States for the first time. It can be seen that the number of known cases hovered less than 20 for about a month. But the necessary containment didn't occur and the virus spread very quickly in exponential manner since then. If

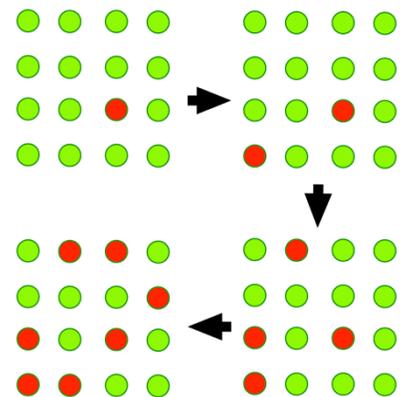


there is any good news, it has taken over a month for there to be 1,000 new cases. In China, it took less than a week. But the growth is still exponential and unchecked, the number of cases will reach China's level unless there is some mitigation that occurs, either naturally or manmade.

There has been talk in the media about the United States' death rate from coronavirus. With relatively few deaths so far and the number of known cases still relatively low, the death rate, defined as the deaths divided by the known cases will fluctuate before setting down. Once as high as 7%, it is now down to about 3%. Remember however, that people do not die immediately from the coronavirus. So the number of deaths will always be "behind" the known cases. Also, because of lack of testing, the number of known cases is probably much higher. So there is a good chance that the death rate will come down.

Quarantine and Community Spread: When people get an infectious disease like coronavirus, the first plan of action is quarantine. The goal is to make sure that it doesn't spread. People self-quarantine or if possible, are quarantined within a medical facility. Still, it is very difficult to make sure that people do not infect others, especially with this type of virus that may not show symptoms for awhile.

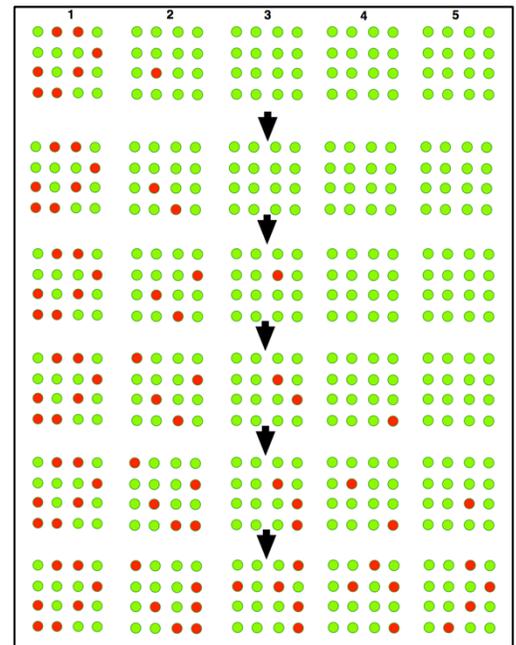
In the figure to the right, the 16 people represent a cluster, which we will call a community. One person in red gets coronavirus. He or she infects other people in the cluster and they in turn infect others. It is possible and quite probable that everyone within this community will end up with coronavirus. However, if this community is quarantined, the worst that will happen is that the entire community gets the virus. It cannot get to anyone else. That was the thinking behind the Diamond Princess cruise ship that was quarantined in Japan for 14 days. It was thought that if the people were quarantined within their staterooms, the disease couldn't spread to anyone else on the ship. They were wrong. Still, since the ship itself was quarantined, those people couldn't infect anyone on the outside.



When a person is found to have coronavirus, they are asked to remember anyone with whom they had contact in the past several days. That isn't very easy to do. If for instance, they were at a veterinarian, contact with be made with the vet and the people who work there as well as people in the waiting room that day. They will be told to self-quarantine. Think of all the hours this will take. If they were at a theatre production, an email might go out to everyone who had tickets for that show that night telling them to self-quarantine. The goal obviously is to keep any spread to within the cluster of people that person came into contact with. Of course, those people have families and and friends and it would be prudent for them to self-quarantine as well. But it is an almost impossible task.

China managed it, or so it appears by literally cordoning off the city of Wuhan which was the center of the spread. As much as possible, they quarantined the city.

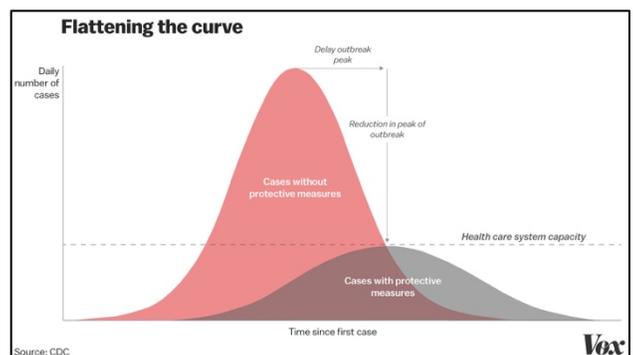
You may have heard the term “community spread” in the media. Community spread means people have been infected with the virus in an area, including some who are not sure how or where they became infected. In the diagram above, the person who was originally infected infects others within his or her circle of friends, acquaintances, people that he met that can be tracked down. But it is extremely possible that he can infect people who have no idea how they were infected. For instance, several people who work at the Fort Lauderdale Cruiseport tested positive. They have no idea who infected them. But they interact with hundreds of people who are coming on or leaving cruise ships. If one of them were infected, we have the start of community spread. The virus is now in Ft. Lauderdale. The figure to the right shows how the virus, which was confined to community #1 can easily spread to other communities in a short period of time.



We now have exponential growth at first in all the communities. So instead of one exponential growth situation, there are a huge number or smaller ones.

Once community growth starts to occur, there is little that can be done in terms of containment. Efforts have begun for mitigation. When we are in the containment phases, the idea is that you can find every case and stop it. Mitigation recognizes there is community spread. It recognizes that there are not enough resources to trace every single case. It means moving to take more population-based actions. Those mitigation steps include promoting more social distancing, limiting large gatherings at which the virus might spread, and potentially even closing schools or canceling sporting events.

The aim is to limit the spread of the virus so that the public health system does not become overwhelmed. If serious mitigation steps are taken, the virus may still infect the same number of people, but over a much longer period of time, allowing the health system to treat and release patients and open new beds for the newly infected.



While you are practicing social distancing, I recommend you watching the movie *Outbreak*. This is a 1995 medical disaster film directed by Wolfgang Petersen starring Dustin Hoffman, Rene Russo, Morgan Freeman, Cuba Gooding, Jr. and Donald Sutherland. The film focuses on an outbreak of a fictional Ebola-like virus, in Zaire and later in a small town in the United States. It is primarily set in the United States’ Army Medical Research Institute of Infectious Diseases and the Centers for Disease Control and Prevention and the fictional town of Cedar Creek, California. *Outbreak*’s plot speculates how far military and civilian agencies might go to contain the spread of a deadly, contagious disease. When the movie came out, my precalculus and calculus students were given an assignment to see it, and many felt that they better understood exponential growth and efforts to stop it much better. You might recommend it to your students as well. It is rare that a movie focuses on the mathematics behind a current world issue (the movie *Hidden Figures* being an exception).

Roger Ebert of the Chicago Sun-Times gave it three-and-a-half out of four stars, calling *Outbreak*’s premise “one of the great scare stories of our time, the notion that deep in the uncharted rain forests, deadly diseases are lurking, and if they ever escape their jungle homes and enter the human bloodstream, there will be a new plague the likes of which we have never seen.” The ending is happy, shallow, somewhat predictable, and leaves the impression that no problem cannot be solved by Hollywood heroics. But the premise of the movie is very similar to what we are seeing today. It is worth watching.