The Development of a Pandemic with and without Restrictions

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What is a pandemic? Through the course of human history, it happened multiple times that a disease spread fast over the whole world. It begins with a few people, living in the same region, for whom the disease was observed. As time goes by, the disease spreads further, because it gets passed on by one human to another. As long as the disease only occurs in a specific region, a country for example, this is called an **epidemic**. When the disease spreads across borders along different continents, it develops into a **pandemic**.

Which diseases can cause a pandemic? A pandemic arises from infectious diseases. These are caused by small pathogens, such as bacteria (e.g. the black death) or viruses[1] (e.g. HIV). A person who carries the pathogen inside her or his body is called an **infected person**. An infected person does not necessarily show symptoms of the disease. Even though this person carries the pathogen, the pathogen might not cause any sickness, but it can be passed on to other people from the social environment of this person. That means, all infected people, sick or not, may infect the people with whom they have close contact. Different pathogens can be passed on through different ways. For some (e.g. the corona virus), a person can infect another only by standing close enough to one another, for example while having a conversation. The pathogen carried by water droplets in the exhaled air of the infected person can be passed on to another person.

Why does the disease spread so fast and how can we slow down the spread? Ask yourself: with how many people do you have a close contact in one day? As described above, it is already enough to have a 'normal' conversation with someone to get infected or to infect the other, if you are carrying the pathogen. Let's say, you are infected and you infect 2 other people. These 2 people will again infect 2 people each, resulting in 4 newly infected. These 4 will infect 8 others and these 8 will infect 16 and so on[2]. As you can see, this will lead very fast to an enormous high number of infected people in a population (a large group of individuals, living in a specific region, e.g. Germany, Europe, etc.). You can imagine, that the disease will spread even faster, if one person infects more people than 2. The huge problem is that there will be many sick people at the same time, this can overload the health system, for example there might not be enough beds in the hospitals. Therefore, we must slow down the spread of the disease. We try this by reducing our direct contacts to others. This is called **social distancing**. By doing so, it gets less likely that we will become infected and then infect others. In particular, when we have the symptoms, we need to protect other people by taking care not to infect someone. To do so, we can **isolate** ourselves. That means we will not have any contact with others, we will stay at home and therefore we will not spread the disease. A person, who isolates her or himself is in a so-called **quarantine**.

To get a better understanding of this, one can observe the development of the pandemic with and without restrictions for a population. To do so, it does not take a lot, you only need some color markers.
To see how you can simulate the spread of a disease, complete the project below.

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[1] For more information on viruses see the link below.
http://web.evolbio.mpg.de/evoltheo_corona/

[2] For more information on the described growth (exponential growth) see the link on the left.

Project: Pandemic on Paper

This exercise aims to show the impact of the current restrictions in our everyday life on the development of a pandemic. We want to investigate how the spread of the infection, caused for example by a virus, can be slowed down by stronger restrictions. Therefore, we want to look at different situations, to see how long it takes one individual to infect a whole population.

General Situation

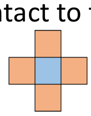
- Consider a population of 100 individuals, given by a table consisting of 10 times 10 small squares. Each small square represents one person.
- At the beginning, there is only one infected person.
- We want to observe the spread of the infection in the population for:
  - different situations with different restrictions
  - different points in time for each situation where each table is one point in time
- A person can be healthy or infected with the virus and additionally isolated (this means, this person cannot infect anyone anymore). This is illustrated by different colors:

Healthy person | Infected person | Just recently infected person | Isolated person

- In every point in time, there are different colors for the infected people. In blue are the people that were already infected in the previous point in time and in orange all newly infected people (in this point in time).

Situation 1 No Restrictions

- Everyone is free to move around
- Everyone has contact to their four direct neighbors:

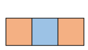


Situation 2 Social Distance

- Everyone is free to move around
- Everyone has contact to their left and right direct neighbors:

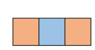
Situation 3 Social Distance & Less Movements

- Only every fourth person is free to move around
- Everyone has contact to their left and right direct neighbors:



Situation 4 Additional Isolation

- Every second individual is in isolation
- Every fourth person is free to move around
- Everyone has contact to their left and right direct neighbors:



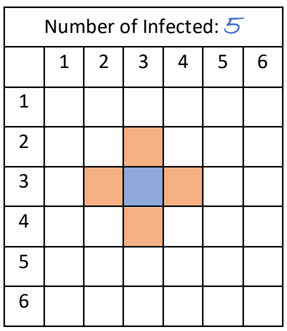
It works like this Fill out the tables for every situation until either everyone is infected or all tables are used. Proceed step by step for every table as follows:

Point in Time 1 Same Procedure for all Situations

1. Choose one square and color it in blue. This is your first infected person.
2. Infect the neighbors by coloring the corresponding squares in orange (depending on the situation, these are four or two).
3. Count **all colored squares** and write down the number of infected people in the header of the table.

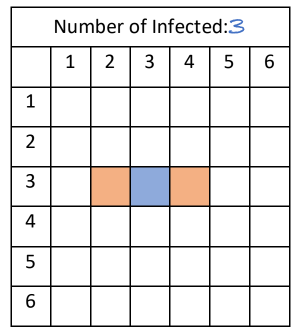
Example

Situation 1



1. the first person is infected (blue)
2. all four neighbors of this person become infected (orange)
3. the number of infected people is written down in the header
left (5), right (3)

Situation 2-4



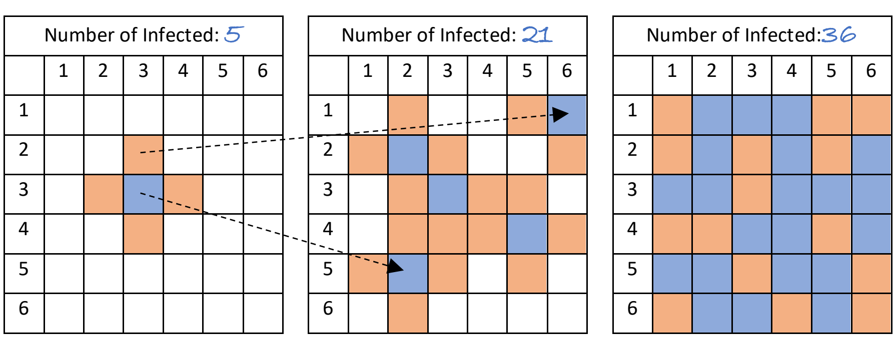
Situation 1 All other Points in Time

1. Since everyone can freely move around, choose as many squares in the new table, as there are infected people (blue and orange) in the previous and color them blue. You can choose the squares as you like, there is no rule for that.

Hint In your new table, now there must be the same number of colored squares as in the previous point in time.

2. Infect the neighbors by coloring the corresponding squares in orange.
3. Count **all colored squares** and write down the number of infected people in the header of the table.

Example

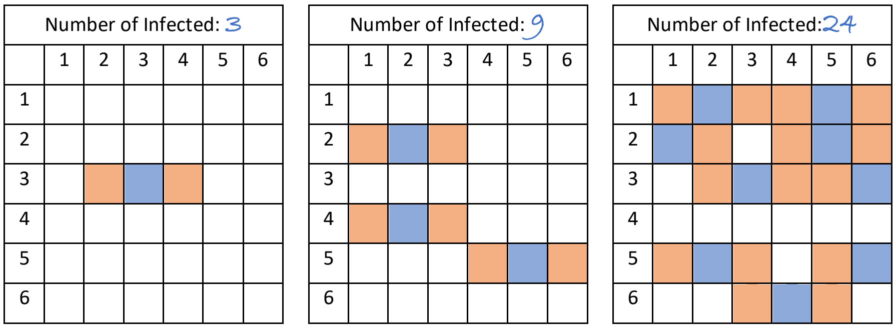


1. all infected people are copied in next the table (i.e. in the second table 5 squares are marked blue and in the third 21) – since they can move for every square, you can choose a different location in the new table (the movement for two squares is shown as an example by the arrows)
2. and 3. as above

Situation 2 All other Points in Time

For the situation 2, the steps are exactly the same as described for situation 1. The only difference is now that you don't consider all four adjacent squares as neighbors, only the left and right direct neighbors.

Example



1. all infected people are copied in next the table (i.e. in the second table 3 squares are marked blue and in the third 9) – since they can move for every square, you can choose a different location in the new table
2. and 3. as above

Situation 3 All other Points in Time

In the situation 3, only a fourth of all infected people are moving. For copying the squares in the new table (step 1) follow therefore this procedure:

1a) Divide the number of infected people from your previous table by four (in case of a decimal, round off, 3.6 will be then 3). For the number that you calculated, choose that many colored squares and mark them with a dot. You can choose them as you like, there is no rule for that.

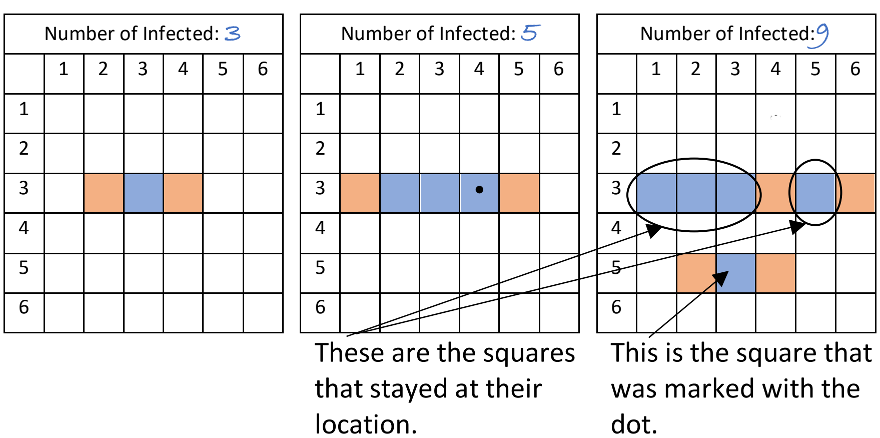
1b) For every not marked colored square, color the same square in the new table in blue.

1c) For the squares, that are marked with a dot, color a different square in the new table in blue.

Hint in your new table, now there must be the same number of colored squares as in the previous point in time.

The steps 2 and 3 stay the same as above.

Example



1a) first, the number of infected from the previous table is divided by four:
   1. Tab: 0.75 rounded 0
   2. Tab: 1.25 rounded 1
   (for the 3. Tab. It would be 2)

1b) all infected that are not marked with a dot, are copied at the exact same location in the new table

1c) for all marked squares, a square at a different location is marked in the new table (short arrow)

2. and 3. as above

Situation 4 All other Points in Time

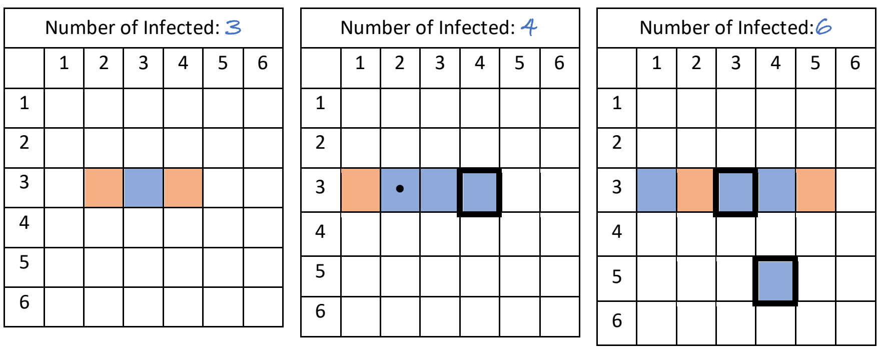
In situation 4 in addition to the restrictions in situation 3, half of the infected people will isolate themselves. This is will be done after copying the infected squares from the previous table, whereby the copying is done as described in 1a) to 1c) for situation 3. The isolation happens as follows:

1d) After you copied all squares into the new table, half of these people will isolate themselves. For that, divide the number of infected (the same number as above) by two and round off again. Now surround that many blue squares in the current table in **black**. Here again, you can choose these squares as you like. Those people will not infect their neighbors in step 2.

Hint in your new table, now there must be the same number of colored squares as in the previous point in time.

In every point in time new individuals will be chosen for isolation, so you don't have to copy the black surrounding in the step 1 for your next table. The step 2 and 3 are the same as above.

Example



1a) - c) as above

1d) after copying the blue squares into the new table, half of the blue squares are surrounded in black.

2. Tab: 3/2 = 1.5 rounded 1

3. Tab: 4/2 = 2

People with a surrounded square cannot infect its neighbors

2. and 3. as above

Analysis Comparison of the Number of Infected People

After completing all situations, fill out the diagram on the last page. On the x-axis it shows the different points in time (for the nine tables of a situation) and on the y-axis it shows the number of infected people. There is a different color for every situation. For every table of a situation draw a bar, where the height of the bar shows the number of the infected people to that time.

At the beginning there was always one infected person, this is already shown in the diagram at the time zero.

Answer the following questions:

- What are the differences between the situations in your result?
- What restrictions are best in slowing down the spread of the virus?
- What is your general conclusion of this project?

On the website *http://web.evolbio.mpg.de/evoltheo_corona/PandemicOnPaper_CN/* you can find a tool for making computer simulations of what you just did by hand. Here you can compare your results and you can try additional situations.

Situation 1 No Restrictions

Number of Infected:										
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Number of Infected:										
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Number of Infected:										
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Situation 2 Social Distance

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Situation 3 Social Distance & Less Movements

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Situation 4 Additional Isolation

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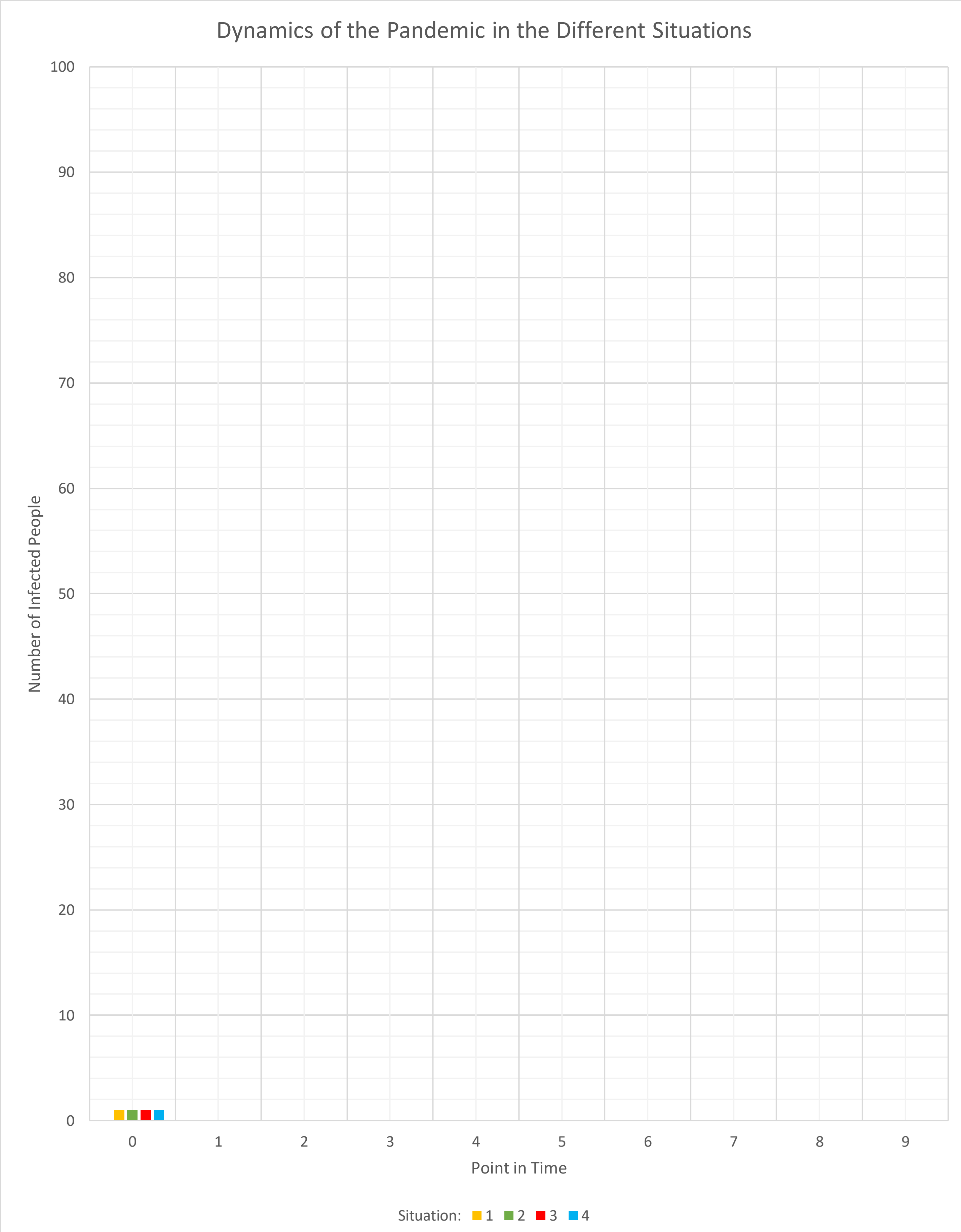
Dynamics of the Pandemic in the Different Situations
Number of Infected People
100
90
80
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9
Point in Time
Situation: 1 2 3 4