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Commentary

The Spherical Horse and COVID-19

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The SIRD model is a classic reference and serves as a base for many of the deterministic models proposed for the COVID-19 spread. Here we bring to the reader's attention a conceptual shortcoming of this model. This has been treated in detail elsewhere.

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> *A compulsive horse races gambler goes to his friend the mathematician with a suggestion -You are good in mathematical models, and I know about horses. Just write down a mathematical model of a running horse. If I use it in my bets, we will both become rich.*
>
> *-O.K., says the mathematician: Let us consider a spherical horse that rolls along a smooth plane with no friction...*

When I was a student in La Plata, a relatively small city where two very respected institutions coexisted, the University and the Hippodrome, I thought this was just a joke about the unrealistic assumptions that were so frequently made in the classes. Only much later I understood that practically all the mathematical models are spherical horses.

SPHERICAL HORSE: An assumption that deviates from the real phenomenon being considered but instead enables the formulation of a calculable mathematical expression that will represent that phenomenon.

Ridiculous as they may seem, spherical horses are useful stuff, if they bring a satisfactory result. In fact, most of the objects around us are manufactured by methods and models that are, in part at least, based on such spherical horses. Just consider the theories of mass, heat, and momentum transfer. Many of the assumptions that those theories are based on can be seen by the strict eye as departures from reality, spherical horses. And still, they work *satisfactorily* within certain limits.

The problem appears when the spherical horse becomes approved and generally accepted due to its satisfactory performance. People begin to feel **that it is a real horse, and not a sphere**. In other words, the assumptions made in the development of the model are so widely accepted that they are not mentioned any more, and the fact that they are assumptions is seldom mentioned and almost forgotten. This happens in the classic and successful compartmental model representing the spreading of viral infective diseases *SIRD* (Susceptible, Infected, Recuperated, Dead) by Kermack and McKendrick [1],

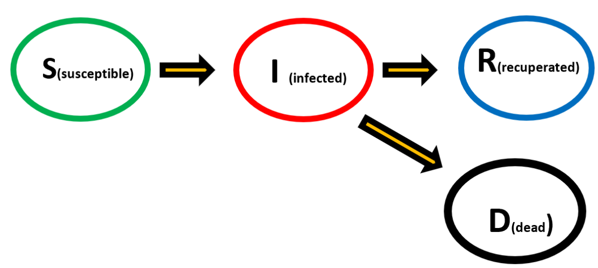

Figure 1. The classic SIRD model; all the compartments are assumed to be "perfectly mixed"

A scheme of the model dynamics is shown in Figure 1, where the circles stand for compartments, and the arrows symbolize the equations describing the flow of the population from one compartment to the other.

The last COVID-19 pandemic motivated a huge increase in the number of research studies on the various aspects of the matter, among them the modelling of the spread of the viral disease. Many of the models proposed are based on or are modifications of SIRD. And there is one characteristic of this compartmental model that in most cases is forgotten: The compartments are basically considered perfectly mixed. The probability of an individual leaving the compartment is independent of its history, that is, of the time it has spent in it. If we take the compartment of the infected, I, any patient inside it has the same probability of leaving it, independently of how long he has spent there. So, at any time **t**, a person who stays infected for one day has the same probability of recuperating as one who has been infected for 10 days. It also opens the theoretical possibility of a patient to remain infected for an exceedingly long time, approaching infinite. This bluntly contradicts our experience about the characteristics of the disease and reveals the model as a spherical horse, while the real nature of it has been forgotten.

The reason is that the equations representing the model open the possibility of a wide distribution of the time that an individual remains infected. This is corrected in the practical applications of the model by the process of fitting to experimental data, which cuts off the extremes of the distribution that are so improbable. On the other hand, all our experience indicates that the compartment of the infected behaves much more like a conveyor belt in which each of the patients spends approximately the same time. Today we know that this time differs from one virus variant to the other, nonetheless, this characteristic of the disease is always present.

A reasonable alternative is to consider the compartment of the infected, I, as a conveyor belt, or in terms of process design, a plug flow compartment. The dynamics in this compartment are FIFO type, first in, first out. Obviously, in practice, there will be a certain scattering around the mean residence time in this compartment, as expected from the individual characteristics of the patient. Such a modification of the original SIRD model was proposed not long elsewhere [2]. The scheme shown in Figure 2 depicts the model. There are several differences between the schemes in Figures 1 and 2. In Figure 2 we see a discrimination between symptomatic and asymptomatic infected patients, I_d and I_{nd} respectively, the addition of a separate compartment for patients needing hospital attention, A, and one compartment more considering the quarantined members of the population, Q. But conceptually, the main difference is shown by the shape of the compartments: the rectangular compartments stand for plug flow in them, where the length of the infected state of the patient is considered a constant. This constancy is widely recognized. It is even used by sanitary authorities to qualify a person as “Recuperated” without the requirement of any tests within a certain number of days since the infection passes.

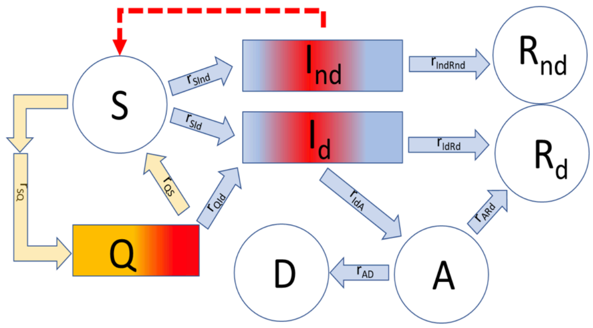

Figure 2. The circles stand for perfectly mixed compartments, and the rectangles stand for “plug flow” compartments. Details can be found in the reference.

The publication mentioned above has not yet received the attention it deserves. The authors declare that “It is expected that the key ideas in this model will become useful building blocks for the construction of more complex and generalized “supermodels” that should include metapopulations, agent-based elements, statistical tools, cultural and economic aspects, and their influence on the spread of pandemics such as COVID-19”. We will add here that we hope that such an expected supermodel will also diverge, as much as possible, from being a spherical horse.

Acknowledgements

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References

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2. ^*Merchuk, J. C., García-Camacho, F., & López-Rosales, L. (2021). Infection Units: A Novel Approach for Modeling COVID-19 Spread. Processes, 9, 2272. https://doi.org/10.3390/pr9122272.*

Declarations

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