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Mathematical endeavours to explain biological phenomena

Abstract

The use of mathematical methods and models is continually increasing in many areas of contemporary biological research: in genomics, molecular modelling, structural biology, neurobiology, biology of systems and so on. In this paper we discuss the importance of Mathematics, mathematical modelling and dynamic visualization, with the aid of technology, in the field of Biology and Medicine. We emphasize that the language of Mathematics and the graphical display is remarkably powerful and flexible, and the modes of understanding and thinking about phenomena can yield deep insight into it that pervades the modern life.

Keywords: mathematical biology, mathematical models, biological systems, geometrical display, covid-19

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Introduction

Mathematical Biology is the application of mathematical concepts, modelling and techniques to solve problems in biology, physiology, psychology and in medicine, as well. By the use of mathematics many researchers are helping to better understand the biological world. "The field of biophysical and molecular biology continues to be one of the most exciting and dynamic areas of science. Over the past few decades, the spectacular progress in this field has occurred due to the conceptual synthesis of ideas from biology, physics, chemistry, mathematics, statistics and computer science."[1]

Mathematics helps the scientists and the researchers of biosciences to understand many biological and medical phenomena such as: population growth, biological oscillations and pattern formation, the spread of disease, human physiology, systems and organs, the growth of tumors etc. Their considerable emphasis relates to models building and development.[2]

Nevertheless, our understanding is limited and never complete, even it contains errors, because we are observing, studying and analysing biological systems that are continually changing, and the most mysterious feature is their behaviour. This is true not only for a biological system but for its subsystems as well, and moving far deeper to the smaller entities like cells with their complex structure and content. This fact does not discourage the scientists and the researchers of any field-their work and contribution will continue and never there will be rest.

The future research will at the first glance combine these seemingly contradictory directions and, if necessary, switch back and forth between them in order to understand these living beings.

The knowledge will be increased and new revelations about the world and its phenomena will be done. Nowadays, the assistance of the computers, of the computer programs and simulations is necessary to solve problems in mathematical biology. Experimental techniques are used to investigate biological systems by generating large amounts of data. "The researchers are building mathematical and computational models to understand and make quantitative predictions of data as to how biological systems will behave in different conditions".[3]

The advancement of mathematical modells, computer equipment and programs, and computational methods has made it possible to describe in detail the situation and consequences related to COVID-19 throughout the world. The creation of mathematical models: equations, formulas, graphs, models, tables, methods etc makes possible to describe and predict natural occurrences, such as organism behavior, patterns, population changes, the spread of diseases or viruses over time. Mathematical graph or display helps us to understand, describe and interpret the spread of COVID-19.

In developmental biology genomics groups in ESAM are using tools from statistics, machine learning, and statistical physics to build data-driven mathematical models to address it.[4]

In addition to the traditional tools of ordinary and partial differential Equations, today graph theory and random graphs have been applied to epidemiology and gene networks.[5]

On the other side, the interaction biology-mathematics is raising new mathematical questions. Mathematics is stimulated by biology and more core mathematicians have gotten acquainted with and involved in biological problems. Biology has created fundamentally new questions in statistics.[6,7]

The theory of biochemical reactions has stimulated new theorems in dynamical systems.[8,9] Many biologists use mathematical functions and models to plot graphs in order to understand a biological phenomenon, they run small "trial and error" tests, develop algorithms, and use the R project (Reverse phase analysis) to analyze protein sequences and structures.[10]

It is important to emphasize here the distinction between physics and biology. In physics, objects are assumed to follow stable equations which can be found on the basis of quantitative transformations and invariants under these transformations and symmetries. Changes are then quantitative changes of state in the predefined state space. By contrast, in biology, the changes also impact these invariants and symmetries.[11]

But the change or variation is also a variation of the relevant equations and a biological object cannot be defined by its invariants and symmetries, and a mathematical structure cannot be probed by experiments. In biology, objects are always historic singularities, they are determined by history and cultural perspectives. Each singular organism has its own historicity that overthrows the current mathematical primacy of invariance—a primacy with very powerful

knowledge effects, but which may prove an obstacle to understanding life, especially when it is disfigured in the genocentric approach to DNA and the myth of the "program", as the informational invariants.[12]

Many studies are conducted to investigate the cause of COVID-19 and the relationship between perception of causes of COVID-19, attitudes towards vaccine and trust in information sources from an infodemic perspective. The rapid spread of this disease around the world was associated with new data about the pandemic that spread constantly.

Deceptive and fake news propagated with high speed. The World Health Organization defined it as "a massive collection of information emerging during an epidemic, some of which is true, some of which is wrong, that spreads rapidly like a virus and complicates the health organization".[13]

Because of conspiracy theories (biological weapon, strategy of controlling the population, plague of the modern age due to sins committed by people and so on) COVID-19 has deeply affected all areas of life and has become a determinant of individuals' and societies' behaviours and thought patterns. This fact is confirmed by several study results that show that many people display a positive attitude towards getting the vaccine, also many display vaccine hesitancy. The real root of COVID-19 is not known yet, and the methods and tools to fight it will require a very long-term project. Why? Because we are dealing and analysing biological systems that are continually changing, adapting to new situations and behaving in mysterious ways. It is a worldly known fact that "Half a century of cancer research had generated an enormous body of observations about the behaviour of the disease, but there were essentially no insights into how the disease begins and progresses to its life-threatening conclusions".[1] We add here the other fact that there is a restricted stability in biological objects. So has been with COVID-19, its behaviour has not been stable. The constraints are only stable for a limited time and can be used as invariants at a given time scale. The constraints of an organism mutually stabilize and reconstruct each other so that the organism can maintain itself over time.

This is called closure of constraints and the closure of constraints is a hallmark of biological organisms.[14]

Data analysis may help by focusing on a few constraints that are stable among the individuals considered, but jointly analyzing the set of many individuals leads to mixing together different organizations and levelling down their specificity.

Data and methodology

Data are provided from Ontario Data Catalogue and include:

I. Reporting date of the deaths involving COVID-19

II. Total number of deaths involving COVID-19

III. Number of deaths with "COVID-19 as the underlying cause of death"

IV. Number of deaths with "COVID-19 contributed but not underlying cause"

V. Number of deaths where the "Cause of death unknown" or "Cause of death missing" (death for COVID-19 positive individuals with cause of death still under investigation, or for which the public health unit was unable to determine cause of death).

VI. Summary of cases associated with outbreaks, by outbreak setting and date-Canada

VII. Summary of ongoing outbreaks by outbreak setting

VIII. Summary of ongoing outbreaks by Public Health Unit (PHU)

IX. daily and total doses administered

X. individuals with at least one dose

XI. individuals fully vaccinated

XII. total doses given to fully vaccinated individuals

XIII. vaccinations by age

XIV. percentage of age group

XV. individuals with at least one dose, by PHU, by age group

XVI. individuals fully vaccinated, by PHU, by age group

XVII. COVID-19 cases by status: not fully vaccinated, fully vaccinated, vaccinated with booster

XVIII. individuals in ICU due to COVID-19 by status: unvaccinated, partially vaccinated, fully vaccinated, unknown

XIX. rate of COVID-19 cases per 100,000 by status and age group

XX. rate per 100,000 (7-day average) by status and age group

Results and interpretations

There is a huge amount of COVID-19 data gathered by different governmental institutions and non-governmental organizations, including WHO as well. Because there is a huge amount of data, there is no room to present them here. Also, if we present them here no one can get a picture and understand how the virus is spread and what are the fatal consequences. To get a clear picture about the spread of the virus, about the affected people and the fatal consequences, and about the reaction of the people to the virus and to the vaccines, we have used one of the most useful and the best methods (to understand the content and the message of the numbers) of mathematics which is the geometrical display of data. Looking at the geometrical display or graph any one can understand and interpret the phenomenom under study, and grasps the message given by it. So, we utilize geometrical research design to analyze the given data provided by different public sources: World Health Organization- https://covid19.who.int ,Johns Hopkins University (JHU), Ontario Agency for Health Protection and Promotion. Excel software was used to geometrically display the data for analysis and interpretation, and drawing conclusions.[15]

In Figure 1, the graph describes rates of the accumulated deaths(blue), Covid total deaths(brown) and ratio of Covid total deaths with accumulated deaths(grey) from April 01, 2020 to June 01, 2022.[16] The numbers corresponding to the ratio, which are smaller than 1, are found on the right-side scaling. Excluding few abnormalities, the death rates similarly increase. Observing the area between the brown and blue graphs we see that it is becoming wider as the time flows. This fact shows that the number of non-covid 19 deaths is greater. Our expectation is that the number of covid 19 deaths be greater. We cannot explain why because it is very difficult to detect a rule or to find a model explaining the death rates of human beings. The biological systems are continually changing and adapting to new situations and behaving in mysterious ways.

Figure 2, 3 represent the bar plot of outbreak groups and the outbreak graphs, respectively. They display the clinical data of COVID-19 outbreak groups in Canada from November 01, 2020 to June 01, 2022.[17] A bar represents the percentages (starting from the bottom) of Congregate Care Group (blue), Congregate Living

Group (red), Education Group (grey), Workplace Group (yellow), Recreational Group (light blue), Other or Unknown Group (green) and Out of Province Group (black). Each bar shows the percentages of COVID-19 outbreak groups for the corresponding month. We cannot accept that the given data reflect the real situation in Canada or any other country. Must be understood that there are underestimations related to restrictions caused by high-risk populations and settings. This implies that the observed trends over time should be interpreted with caution. We cannot forecast what will be the situation in the future. The largest outbreaks have been in Congregate Care group (blue) and Workplace group (yellow) and Education group (grey).

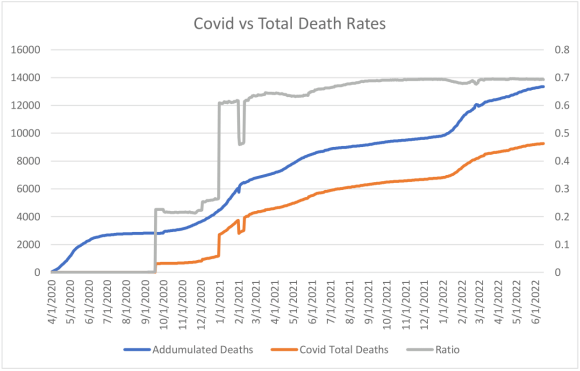

Figure 1 Graph of covid versus total death rates.

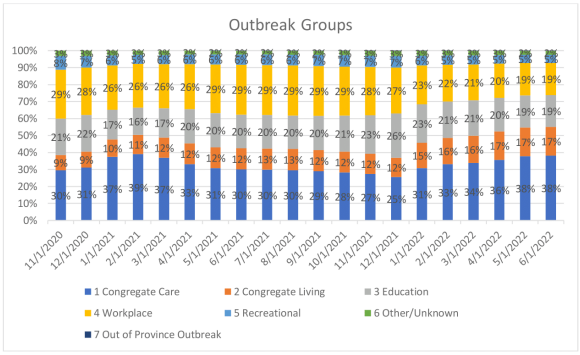

Figure 2 COVID-19 outbreak bar plot.

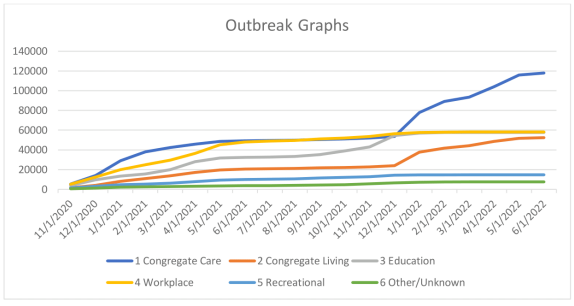

Figure 3 COVID-19 outbreak graphs.

This is due to the concentrations of people. However, we cannot explain why there is increase, during the first part of the year 2022, in the Congregate Care group whereas there is decrease in the Workplace group during the same period! - in a time when industries are put at work in full capacity. This puzzle can be observed in the corresponding graph of the Congregate Care group which is separated from the other graphs.

Figure 4 represents the graphs of 3 Doses Rates by Age Bands. The graphs display the administered data in Canada from January 01, 2022 to June 01, 2022. The legend clearly shows what the age bands are. Here are not included the data of less than 3 doses rates. The rates are calculated per 100 K. No need for explanations.[18]

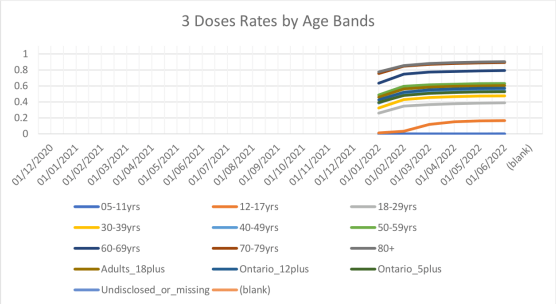

Figure 4 Graphs of vaccination status-3 doses rates by age bands.

In Figure 5 are displayed the graphs corresponding to the quantities of doses used for the individuals fully or partly vaccinated. The horizontal axis contains the units of periods of 16 days starting with day 1, which is the first day of administering data. For the four left graphs, originating at day 1, we have: the graph corresponding to the total individuals fully vaccinated (yellow), the graph corresponding to the total individuals at least one time vaccinated (blue), the graph corresponding to the total doses given to fully vaccinated individuals (violet), the graph corresponding to the total individuals taking ACC doses (green). In addition, there are two graphs on the right: the graph corresponding to the total individuals partially vaccinated (brown and almost horizontal) and, the graph corresponding to the total individuals taken 3 doses (light blue). From the graphs we understand that over time the people become more conscious of being vaccinated. But, still, are raised questions about the second part of the graphs corresponding to the total individuals fully vaccinated (yellow) and the graph corresponding to the total individuals at least one time vaccinated (blue): why the numbers of distributed vaccines between them are almost equal? There is not a determined answer because the people are biological systems that are continually changing and adapting to new situations and behaving in mysterious ways. The decision makings certainly depend on such dynamics.[19]

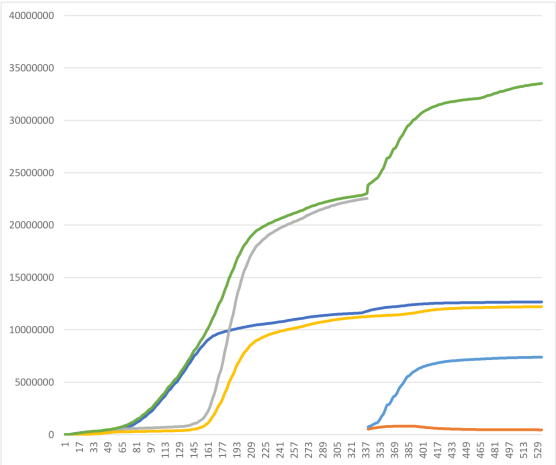

Figure 5 COVID-19 vaccination doses graphs.

Discussion and conclusion

The popularity and the necessity of mathematical biology in today's scientific world are well-recognized and will further be considered. Mathematical Biology is making and will continue to

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make real contributions in many important life sciences: physiology, psychology, medicine etc.

Mathematical models and geometrical representations in Biology are very good and useful approaches to study and explain the biological systems.

The general public can't understand the mathematics, but they certainly can understand the applications, they can clearly understand the meaning and the message of the above graphs. Bear in mind: we cannot explain all the details of a phenomena by using mathematical models or graphical display because these models and geometrical representations correspond to numbers or data collected from different living samples. Behind these numbers there are biological systems that are continually changing and adapting to new situations and behaving in mysterious ways. We can find a model or a rule describing the current behaviour of a biological organism or biological system but we cannot say that it is the final model or rule. It will not fit to the future behaviour of the biological organism or biological system.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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