## Mathematical modeling for biology and epidemics

* Modelling is a powerful tool to understand better a certain phenomenon.
* In any modelling endeavour, the starting point has to be the real-world setting rather than the mathematics
* None of our models are going to be “correct”. They will be based on data that is not perfect or assumptions that are clearly oversimplifications.
* models might have value by making general predictions about things like the impact of public health policies on the course of an epidemic.
* Definition of a mathematical model: A **Mathematical model** is a self-contained collection of one or more variables together with a set of rules (usually formulas and equations) that prescribe the values of those variables. Models serve as an approximate quantitative description of some actual or hypothetical real-world scenario. They are created in the hope that the behaviour they predict will capture enough of the features of that scenario to be useful.
* There is an emphasis on the uncertainty in the connection between the mathematical model and the real-world setting in which it is applied.
* Mathematics has the advantage of use certainty in its development. When a theory is demonstrated, it is true and must be accepted. In modelling claims about real world have the same significance of assumption used to build the model.
* Two main operations are done: characterization (understanding the broad range of possible behaviors) and simulation (visualizing the behaviour in specific examples).
* While we cannot hope our models will be “correct” for a real-world setting, we can aim to make them *valid*, in the sense of “giving meaningful results under a given set of real-world circumstances.

In a pandemic monitoring a model scope is:

* Collect info in a structured manner.
* Develop risk assessment.
* Make plausible predictions.
* Track epidemic dynamics.
* Suggest control strategies.
* The objective of our model is to look at the average behavior, not find day-by-day data.
* Mathematical models can be classified according to the method used to obtain them.
* **Definition 1.4.2**
* A **mechanistic model** is a collection of one or more variables, together with a self-contained set of rules
* that prescribe the values of those variables according to assumptions about the scientific principles that
* underlie the phenomena being modeled.

An alternative modeling approach is *mechanistic modeling*, in which we obtain a model from

* assumptions based on theoretical principles

In these cases, the model gains explanatory value. In other

* cases, we may be able to discover a model not previously identified empirically.
* Mathematical models are constructed from components at several levels of detail.
* **Definition 1.4.3**

An **empirical model** is a mathematical model based on the examination of numerical data. We were able to fit the data

* quite well, but an empirical justification such as this limits a model’s explanatory value

**Definition 1.4.4**

A **conceptual model** is an approximation of a real world scenario that serves as a verbal description of

* a mathematical model.

The aim of the model plays a large role in determining the type of analysis and the criteria for validation

In any particular instance of a mathematical model, we have one or more dependent variables and one

or more independent variables,31 and a set of given values are assigned to the parameters. The focus

of a simulation is on determining how the dependent variables depend on the independent variables.

This is the *narrow view* of mathematical models.

In contrast, there is a *broad view* of mathematical models, in which the objective is to understand

the effect of the parameter values on the model outcomes. Here, we can study the effects of changes in the parameter values. In the narrow view, the dependent variables are (usually) functions of time. In the broad view, the outcomes are

functions of the parameter values. In mathematical modeling, functions are often defined in much more subtle ways; for example, as the solution of a mathematical problem rather than as a mathematical formula.

**BROAD CLASSES OF MODELS**

* Continuous time, continuous state, mean field, compartment bast. They are analytical tractable. SI(x) family
* Individual based model. Digital twins of a certain population. Need tons of data and are almost only based on simulation.
* Patch model, interconnected SI(x) models, representing various regions.
* Network models, network of regions or of individuals, with simple connecting rules.

PARTE 1.5

These unrealistic features of standard models help make them useful by keeping them simple; however, they can give amisleading impression of the biological scenario. For this reason, it is helpful to gain some experience with a more intuitive model. *Agent-based models* (ABM) offer a nice introduction to modeling because of their intuitive nature.

**Definition 1.5.1**

An **agent-based model** (also called an **individual-based model**) consists of a database of *individuals*,

each identified by one or more *attributes* that can change over time, and a set of *rules* that update the

attributes of each individual at each time step.