FEDERAL INSTITUTE FOR RISK ASSESSMENT

Bundesinstitut für Risikobewertung

Epidemiological Modeling Introduction

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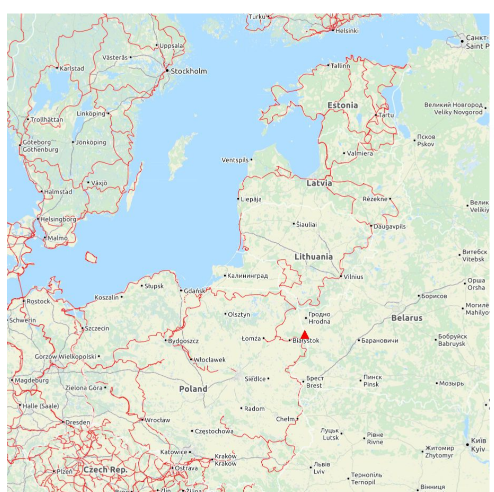
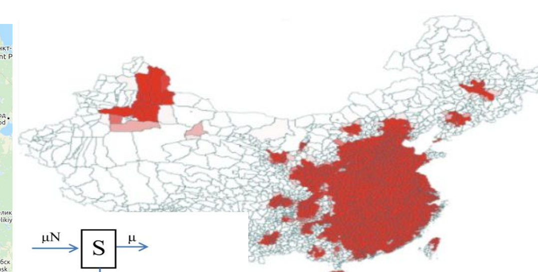
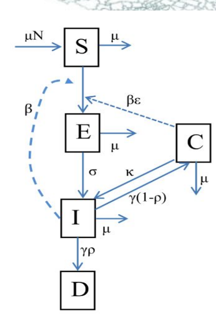
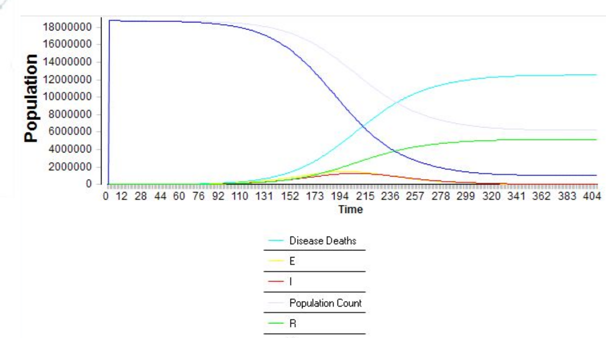


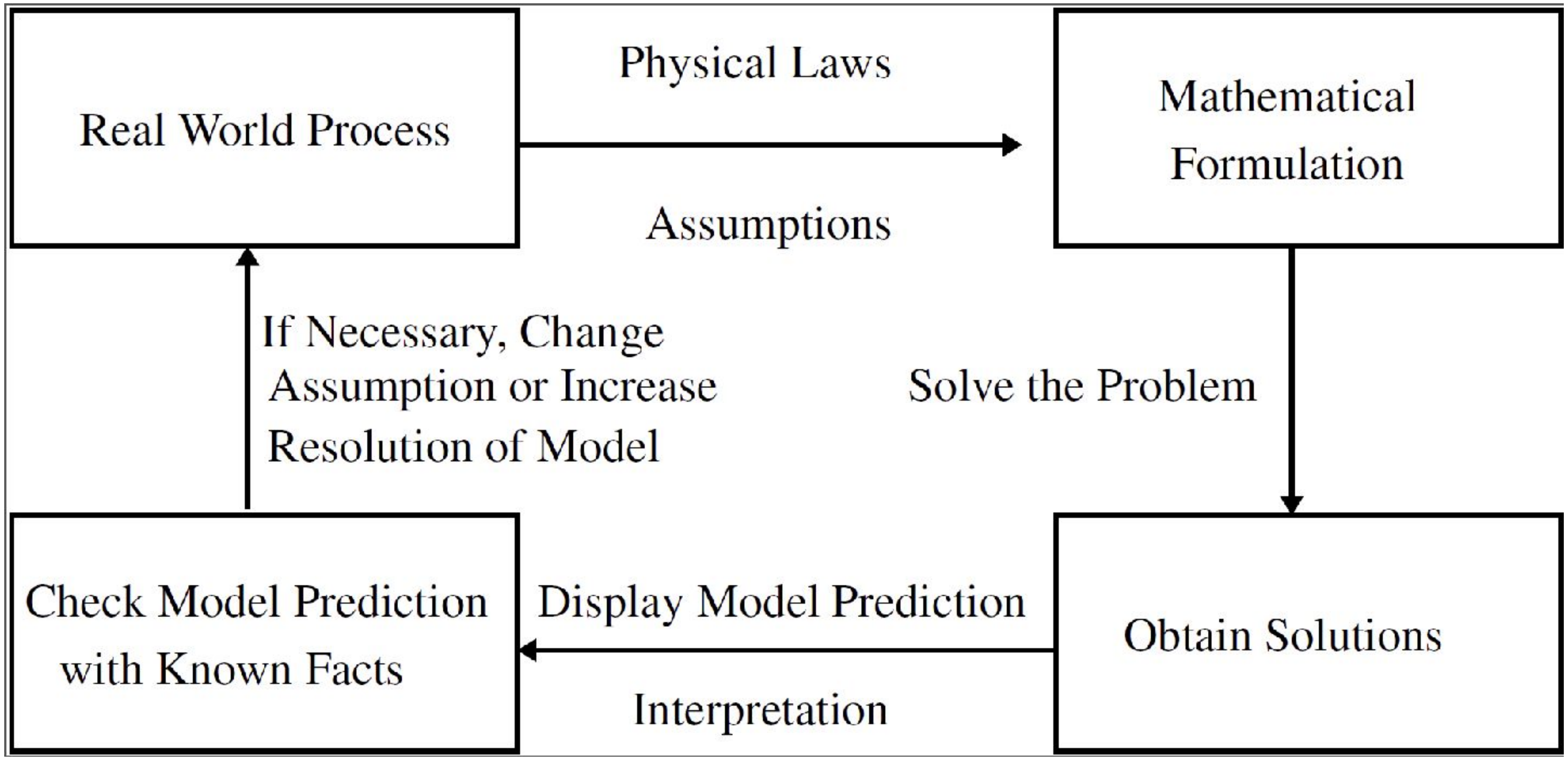






What is a mathematical model?

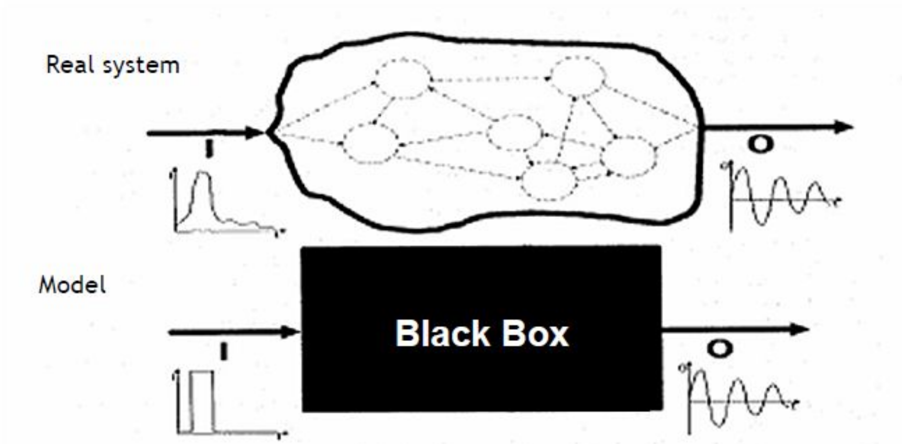
- simplification of scientific questions using mathematical annotations
- they can use empirical, deterministic and mechanistic approaches.



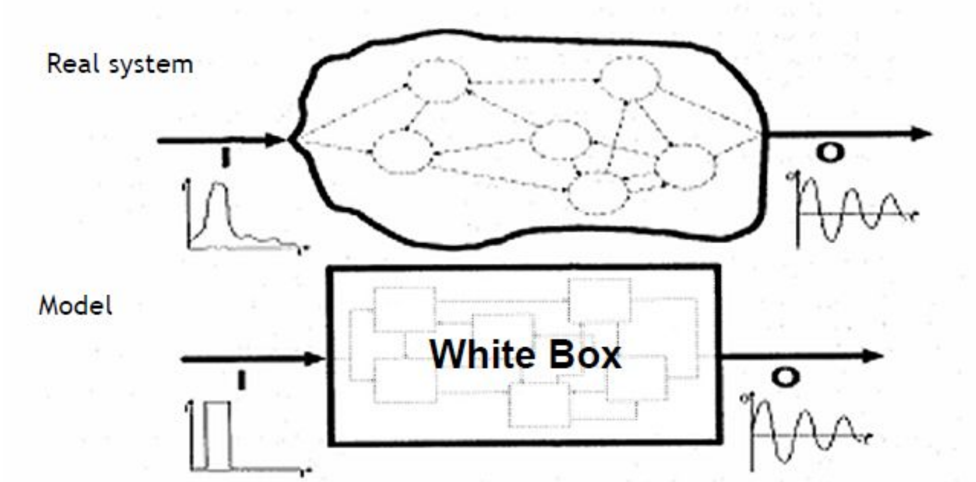
(IBM Health Corps 2017 Epidemiological Modeling Introduction)

Kinds of mathematical models

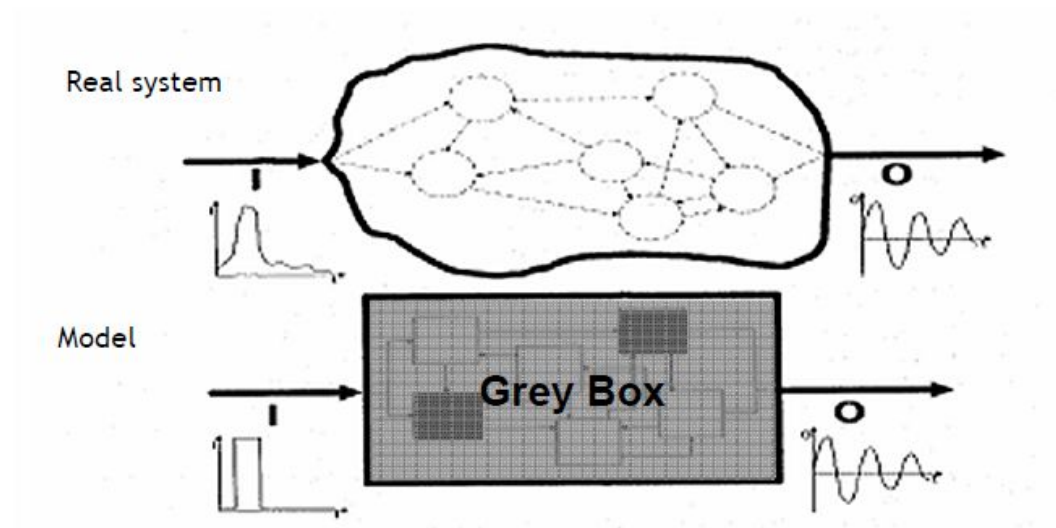
Empirical model



Mechanistic model

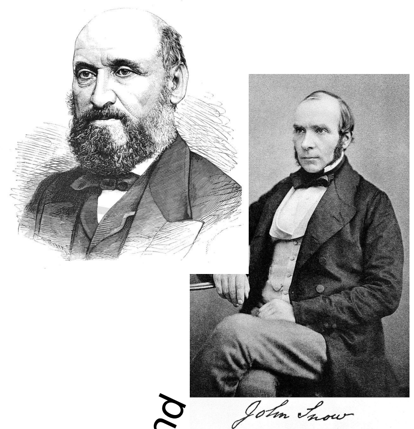


Semi-mechanistic hybrid model



(Claas Nendel 2016 Lecture:"Introduction into Modelling of Crop System")

Small History



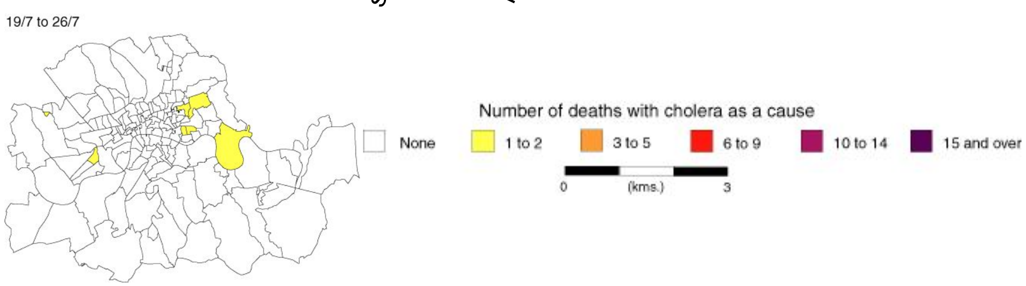
1760, Bernoulli
- smallpox variolation prediction

1840, Farr and Snow
- smallpox infection
- description of number of deaths from

1906, Hamer
- epidemic progression
- function of contact: S and I

1911, Ross
- first mathematical model of malaria dynamic

1927, Kermack, McKendrick
- def. of a reproductive of infection



$$\frac{dS}{dt} = -\lambda S,$$

$$\frac{di}{dt} + \frac{di}{da} = \delta(a)\lambda S - \gamma(a)i,$$

$$\frac{dR}{dt} = \int_0^\infty \gamma(a)i(a,t)\,da,$$

Src: https://en.wikipedia.org/

Introduction into epidemiological modeling

- linked to a **population**
- model of the natural **disease progression** with **statistical rates**

- based on the transfer between different disease states/compartments

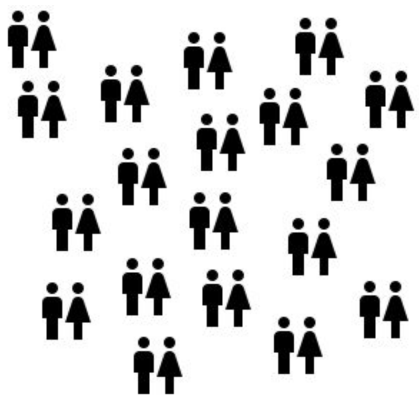
- understanding on disease spread necessary
- relevant factors:
  - → pathogens?(parasites, bacteria, viruses…)
  - → kind of transmission
  - → disease mechanism
  - → prevalence
  - → others

(IBM Health Corps 2017 Epidemiological Modeling Introduction)

Compartments & typical model parameters of a population

Compartment:

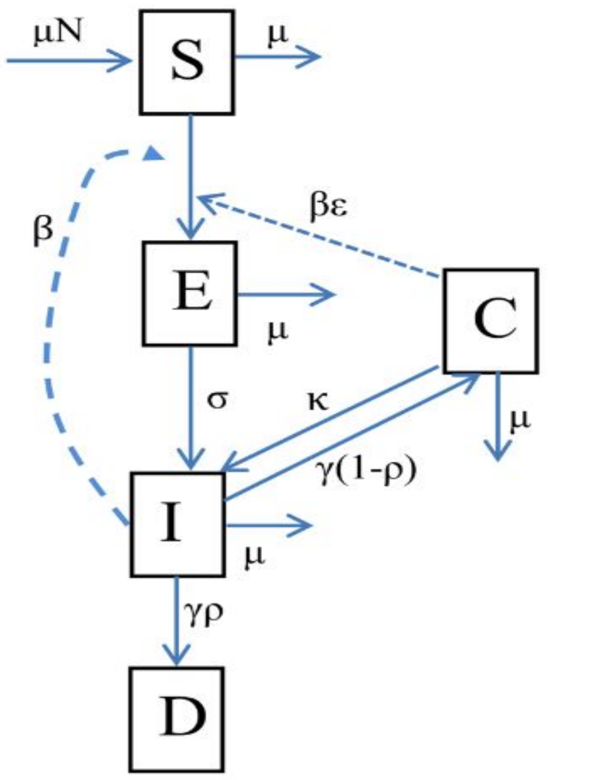
N



Population related parameters

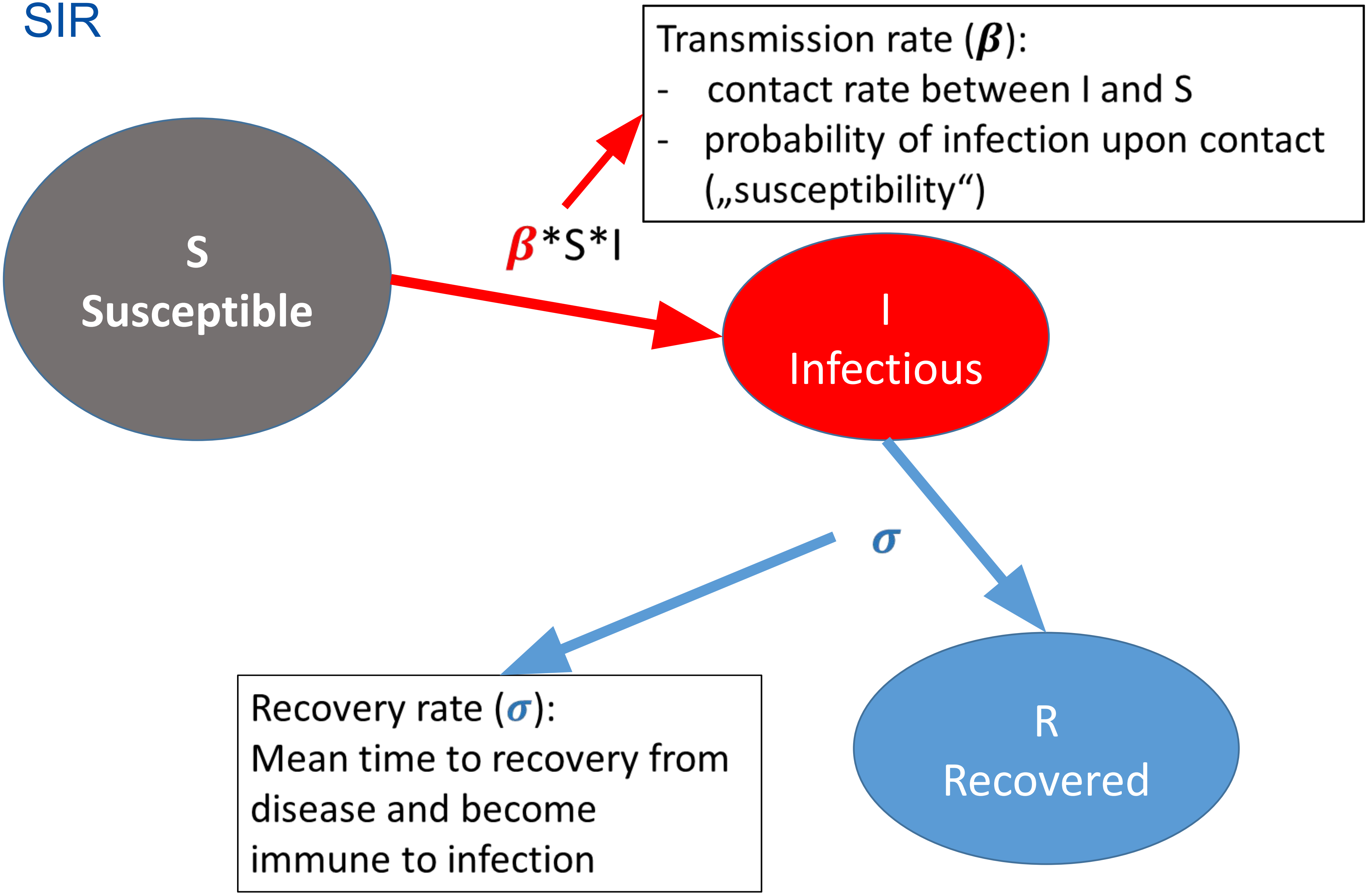
- born/ growth rate
- death rate
- migration rate

Compartments & typical model parameters of a disease



Compartments	*Disease related parameters*
S= Susceptible E=Effective I= Infected R= Recovered C= Contagious D= Dead	•transmission rate (β) •recovery rate (σ) •disease death rate •Reactivation rate •Incubation rate

A standard infectious disease model: SIR



Implementation of compartment models -equations

- epidemiological models set of Ordinary Differential Equations (ODEs)
- describes the change in time (instantaneous) of the occupation number of a class or compartment
- solving ODE‘s through numerical integration
  → different Algorithms (Runge-Kutta, Stochastic, Iterative) available
- one equation per variable
- all the arrows need to be accounted for Sum of ODE‘s= 0 conserved population (detailed balance)
- direction of the arrow dictates the sign

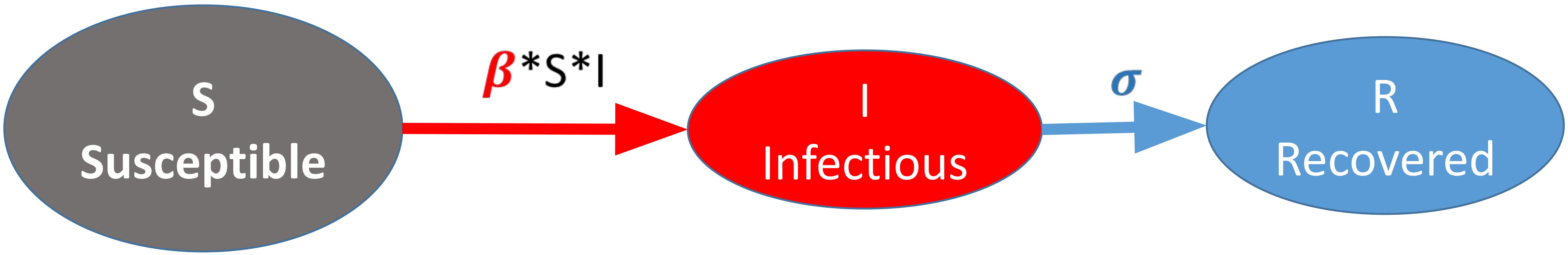
(IBM Health Corps 2017 Epidemiological Modeling Introduction)

Compartment → Equation

dS/dt	time variation
βSI	Transition
σI	Recovery
β	Transmission rate
σ	Recovery rate

1. **$dS/dt = -(\beta/N)SI$**
2. **$dI/dt=(\beta/N)SI - \sigma I$**
3. **$dR/dt = \sigma I$**

Pros and Cons of compartment models



Pros

- are most commonly used in epidemiology studies
- no fine detail required or obtained in the results
- have low data and computational demands

Cons

- usually assume a homogeneous, well mixed population
- are not good for the early or late stages of an outbreak when stochastic (random) events matter

(IBM Health Corps 2017 Epidemiological Modeling Introduction)

Snares in mathematical modelling

- The simplest vs most realistic model (KISS and Occam's Razor)
- Predictions/ Extrapolations
- Sensitivity to initial conditions
- Over-/underdetermination of parameters
- Over-/underfitting of parameters

(IBM Health Corps 2017 Epidemiological Modeling Introduction)