A COVID-19 Model for March 2020

Glenn Ledder

Department of Mathematics
University of Nebraska-Lincoln
gledder@unl.edu

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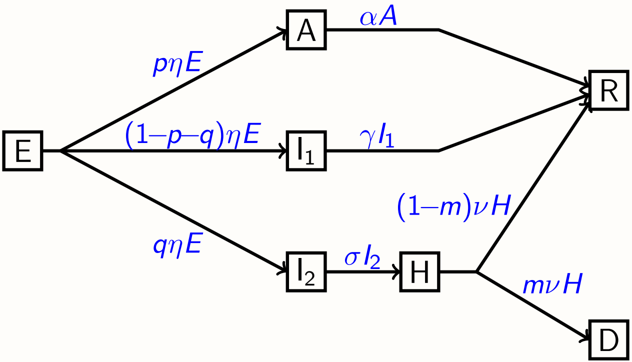
Key Differences from SEIR

- Some patients are asymptomatic, with lower infectivity and shorter infectious duration.
- We need to track hospitalizations.
- Public health policies can decrease infectivity, but in different ways for different classes.

Multiple Infectious Classes

- Asymptomatic (A)
  - Shorter duration, reduced infectivity, less likely to be tested
  - Always recovers
- Symptomatic (I_1)
  - Base duration and infectivity, more likely to be tested
  - Always recovers
- Pre-Hospitalized (I_2)
  - Base infectivity, more likely to be tested
  - Always becomes hospitalized
- Hospitalized (H)
  - Limited infectivity
  - Either dies (probability m) or recovers

An SEAIHRD Model – Transitions



Infectivity Details

- We replace the factor I in the SEIR transmission rate formula βSI with an 'effective infective population' X. Without mitigation, $X = I + f_a A$, where $f_a < 1$.
- Testing
  - Isolation lowers infectivity from 1 (I) or f_a (A) to f_c
- Risk Reduction
  - Social distancing reduces contact rates of untested individuals (A and I)
  - Masking reduces infectivity of untested individuals (A and I)
  - Contribution of untested A and I individuals is reduced by a factor δ.

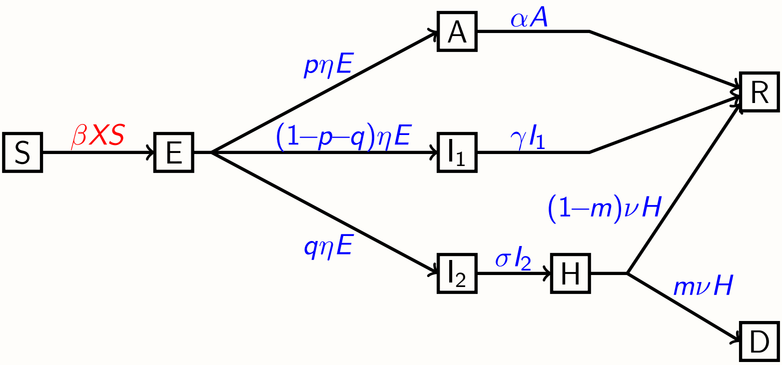
An SEAIHRD Model – Transmission

$$\boxed{S} \xrightarrow{\beta X S} \boxed{E}$$

$$X = f_c(c_i I + c_a A) + \delta[(1 - c_i)I + f_a(1 - c_a)A].$$

- c_i and c_a are the fractions of confirmed cases for symptomatic and asymptomatic infectives.
- f_c, f_a are the infectivities of confirmed cases and asymptomatic cases, relative to an unconfirmed symptomatic infective.
- δ is a 'contact factor' that incorporates social distancing and mask use for unconfirmed cases.

An SEAIHRD Model



transitions, transmissions

Pedagogical Resources

- See **https://www.math.unl.edu/SIR-modeling** for
  - Details on a classroom activity in disease modeling;
  - SIR and SEIR teaching modules using Excel and Matlab;
- See **https://www.math.unl.edu/covid-module** for COVID-19 teaching modules.
- Ledder and Homp, Using a COVID-19 model in various classroom settings to assess effects of interventions, PRIMUS 2021
  https://www.tandfonline.com/doi/full/10.1080/10511970.2020.1861143
  - Includes details about parameter estimates.
- Ledder and Homp, Mathematical epidemiology, in Mathematics Research for the Beginning Student Volume 1: Accessible Research Projects for First- and Second-Year College and Community College Students before Calculus, ed. E.E. Goldwyn, A. Wootton, S. Ganzell. Birkhauser, in press

Resource for Modeling and Analysis

- Ledder, Mathematical Modeling for Epidemiology and Ecology, 2ed, Springer, in press
  1. Modeling in Biology
  2. Empirical Modeling
  3. Mechanistic Modeling
     - 3.1 Transition processes
     - 3.2 Interaction processes
     - 3.3 Compartment analysis: The SEIR epidemic model
     - 3.4 SEIR model analysis
     - 3.5 Two scenarios from the COVID-19 pandemic
     - 3.9 Adding demographics to make an endemic disease model
  4. Dynamics of Single Populations
  5. Discrete Linear Systems
  6. Nonlinear Dynamical Systems
     - Nullcline analysis and linearized stability analysis
- **Shoot me an email to receive updates or offer feedback!**
  gledder@unl.edu