An Introduction to Deterministic Infectious Disease Models. (n.d.). https://documents1.worldbank.org/curated/en/888341625223820901/pdf/An-Introduction-to-Deterministic-Infectious-Disease-Models.pdf

* Deterministic models are flexible enough to capture complex things, and simple enough to be understood by policy makers
* Can be preferred to stochastic or black-box models
* Used to understand why there are surges and the behaviors of spread early during an outbreak
* Three groups of people: susceptible (not exposed/affected yet), infected (both infected and infectious), and recovered (now immune)
* Going from susceptible to infected depends on disease transmission rate
* The rate of change of either state can be described using differential equations
* In the equations above, is the population, is the transmission rate, and is the recovery rate
* is the product of the average number of contacts at a given time per individual and the probability of transmission between susceptible and infected
* is the inverse of the infections period (i.e., it is the one divided by the average time of being infectious)
* One strategy is to minimize the transmission rate
  + Some examples include reducing contact with others, reducing the probability of transmission, etc.
* Another strategy is to minimize the infectious period, or maximize the recovery rate
* The reproduction ratio (average secondary infections divided by average primary infections) denoted by indicates if an outbreak is likely
  + In other words, we can think about this in terms of the recovery rate and transmission rate such that
  + We can continue to calculate this ratio as time passes, , which describes the outbreak in the current time
  + This reproduction ratio can be derived for many models besides SIR
* Vaccinations effectively move people from the susceptible group directly to the recovered group
  + This changes the initial reproduction ratio since the number of susceptible people at time zero is not equal to the population, hence (in the non-vaccinated case which is why the equation was simplified previously)
* The proportion of people that must be vaccinated to avoid an outbreak can be derived as
  + Alternatively, we can simplify this proportion to
* We can also account for mortality and birth rates, where is the mortality rate and is the birth rate
  + Historically, these things are usually equal
* Considering birth and mortality rates, the updated differential equations are
* And we must consider these new variables with the reproduction rate

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* Note that the number of vaccinated people to avoid an outbreak will be lower (i.e., the ratio of recovered people to the population need not be as big) because the reproduction rate at time zero will be smaller
* In summary, in the most simple form, infectious diseases can be modeled using a framework of three groups (susceptible, infected, and recovered) and a few different rates (reproduction, recovery, mortality, and birth rates), some of which are assumed, and others can be derived from the data itself
* There is s four compartment model called SEIR (susceptible, exposed, infected, and recovered), which has been used to describe COVID-19 and Ebola
* Where is the latent period and

Apolloni, A., Poletto, C., Ramasco, J. J., Jensen, P., & Colizza, V. (2014). Metapopulation epidemic models with heterogeneous mixing and travel behaviour. Theoretical Biology and Medical Modelling, 11(1). https://doi.org/10.1186/1742-4682-11-3

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* Infection rate might be lower in people living in high altitude for COVID-19
* Beginning at 1000 meters above sea level, the incidence rate begins to decrease for COVID
* Furthermore, transmission rates are lower at these elevation levels
* Finally, the severity of infections is lower at these altitudes (e.g., death-to-case ratio is lower, recovery percentage is higher, etc.)
* Possible explanations include more drastic changes in temperature between day and night, higher air dryness, higher solar radiation, long-term exposure to barometrical hypoxia (less oxygen at high altitude)
* This study did not consider different risk factors for different groups (e.g., sex, age, comorbidities, etc.)

‌Berkessel, J. B., Ebert, T., Gebauer, J. E., Jonsson, T., & Oishi, S. (2021). Pandemics Initially Spread Among People of Higher (Not Lower) Social Status: Evidence From COVID-19 and the Spanish Flu. Social Psychological and Personality Science, 194855062110399. <https://doi.org/10.1177/19485506211039990>

* Pandemics are thought to spread particularly through lower social status groups
* The hypothesis is that this is true for the later stages of pandemics
* This was analyzed over two studies: first analyzing region-level COVID-19 infection data, and second by analyzing historic data from the 1918 Spanish Flue pandemic
* For both, disease spread more rapidly through people of higher social status first, and in later stages this reverses

‌Colizza, V., Barrat, A., Barthelemy, M., Valleron, A.-J., & Vespignani, A. (2007). Modeling the Worldwide Spread of Pandemic Influenza: Baseline Case and Containment Interventions. PLoS Medicine, 4(1), e13. <https://doi.org/10.1371/journal.pmed.0040013>

* H5N1 avian influenza virus is a potential candidate for a severe pandemic
* Studied spread using metapopulation stochastic epidemic model on a global scale
* Model considers air travel flow among urban areas
* Temporal and spatial evolution with sensitivity analysis
* Compared different containment strategies against a base case (e.g., travel restrictions and antiviral drugs)
* Considering air travel is vital when modeling these epidemics
* Large-scale application of antivirals seems possible and would effectively mitigate some of the spread

Colizza, V., Barrat, A., Barthelemy, M., Valleron, A.-J., & Vespignani, A. (2007). Modeling the Worldwide Spread of Pandemic Influenza: Baseline Case and Containment Interventions. PLoS Medicine, 4(1), e13. https://doi.org/10.1371/journal.pmed.0040013

* Used metapopulation stochastic epidemic model on a global scale
* Considering airline travel among urban areas
* Compared baseline with containment strategies such as travel restrictions and antiviral drugs
* Considered that not all areas have similar stockpiles of antiviral drugs
  + One scenario is that wealthy nations keep their antiviral medications
  + Another scenario is that these nations collectively allocate smaller stockpiles for global consumption
* Air travel is crucial in assessing the probability of transmission
* Readily available antiviral medication in hit countries could accommodate a reproduction rate of 1.9
* Furthermore, the more cooperative nations are in containment efforts, the more effective the containment is

Cooper, B. S., Pitman, R. J., Edmunds, W. J., & Gay, N. J. (2006). Delaying the International Spread of Pandemic Influenza. PLoS Medicine, 3(6), e212. <https://doi.org/10.1371/journal.pmed.0030212>

* Hypervirulent subtypes of flu are emerging
* Efficient spread through humans would be problematic
* Control would be limited by availability of vaccines
* Key measure would be to delay spread
* Higher international travel could lead to faster global spread than previous pandemics
* Analysis involves stochastic models of the internation spread of influenza based on extensions of coupled epidemic transmission models
* Restrictions on air travel demonstrate little values on delaying the spread of virus
* Only ceasing all travel has a significant impact on preventing the epidemic
* Local transmission control measures are better methods for controlling the spread of disease

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* Combined data from CDC ranging from 1997 to 2009
* The magnitude of the pandemic is measured by cumulative incidence proxy (CIP)
* There is a negative association between the CIP and pandemic season (i.e., CIP gets smaller as season progresses? Building immunity?)
* Method for estimating CIP involves looking at the incidence of each strain (or its complement) and see how long it takes for the CIP to reach some threshold
* Early circulation of one strain is associated with a reduced total incidence of the other strains

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* SEIRS and SVEIRS epidemic modes are considered here to capture the main characteristic of transmission of influenzas epidemic
* Least squares (i.e., minimizing the sum of squared differences between the measurements and the model predictions) is used to estimate the unknown parameters
* These tuned models capture the dynamic nature of the data
* Vaccine efficacy and vaccination prevalence are important things to consider in the model

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* There have been four influenza pandemics in the past one hundred years
* Modern globalization and society have impacted the way that these things develop/spread
* Influenza/pandemics are a product of human development, and we should consider the context for which they spread
* Progress in controlling pandemics can be attributed to pharmaceutical intervention and surveillance
* Persistent challenges include pandemics happen in unpredictable waves and virus jump unpredictable from animals to humans
* Historically, pandemics spread through dominant trade routes, but this is less clear with globalization since there are so many more routes for transmission
* The uncertainty means that we must have flexible policies for handling them when they do occur

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* Mitigation strategies (e.g., closing schools, limiting air travel, etc.) are some of the only was to address pandemics at the moment
* This is because stockpiles of resources (e.g., antiviral medication) are not likely to be had, nor will vaccines be very prevalent
* Large-scale agent-based model to analyze isolation scenarios (e.g., school closures and fear-based home isolation)
* Certain changes in behavior can be effective at curtailing the spread of disease (e.g., school closures throughout the pandemic can decrease clinical attack rates by 50%)
* Also, stopping intervention/mitigation strategies too soon can lead to a second wave of infection

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