Influenza

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Introduction

Setting the Stage

Background The building of this model was inspired by an interest in the workings of disease and, especially, viruses. Ifluenza is a virus that attacks populations all over the world every year in the winter with a peak in the month of January. It has caused major epidemic outbreaks throughout history. Two of these are the world wide pandemic from 1918-19 and the Hong Kong influenza scare in 1997 in which all the chickens in Hong Kong were killed due to a belief that they were vectors. By contructing this system, I wanted to have the effects of an influenza virus on the United States population modeled and I wished to discover how we could prevent major outbreaks of influenza. There is a vaccine to influenza, but it lasts, on average, for six months and the rate at which influenza mutates often counteracts any advantage that vaccination gives. By finding a more effective vaccines and, possibly, better antibodies, it seems probable that a reduction of the widespread effects of influenza would prevail. In my influenza model, I chose to model the growth and decay of the vaccinated, non-vaccinated, infected, ill, immune, and dead populations in the United States in an attempt to convey the drastic effects of a viral outbreak.

Purpose of the Model The purpose of this model is to provide people with a realistic look at how influenza affects a population, present a look at how devastating the influenza pandemic that scientists have estimated will occur soon will most likely be, and to convey the urgency of finding more effective and economical means to reduce the effects of influenza and to offer proofs of possible solutions. The information attained is to be accepted by an audience including educators, doctors, scientists/researchers, and all those interested in the effects of viral outbreaks.

Stakeholders Scientists and researchers are the group who will most benefit from the information acquired from this model. They may be able to study the effects that the model simulates and, by adjusting important variables, receive an understanding of the most efficient route to take in terms of research into the reduction of the consequences of an influenza epidemic.

Resources Utilized

People To receive information neccesary for the construction of my influenza model, I had two major consultants. Wesley Samples, a good friend of mine who happens to be greatly interested in microbiology, provided me with several text book resources three times in particular from which I withdrew large amounts of data. Scott Guthrie, the System Dynamics teacher at Wilson High School, equipped me with some basic and general information and helped to aid partially in the construction of the model.

Reference Material All information was attained from science books and internet sites. Wesley Samples provided me with information from two books entitled Microbiology and The Cell, Scott Guthrie provided me with data from a book entitled Population Growth, and plentiful amounts of information were obtained from the internet sites of the Center for Disease Control (CDC) and the World Health Organization (WHO).

Data Sources In the 1918 pandemic, the world was attacked by a vicous strain of influenza that sweeped through populations and killed twenty million people worldwide. In this epidemic, five hundred thousand people in the United States died. This situation is very similar to the one which I am modeling and the similarity allowed for the contraction of recorded data.

Challenges

During the construction of the model, I encountered several difficulties. Correctly accounting for the Vaccinated, Non Vaccinated, and Initial and New populations was a difficult task to accomplish. Also, including the neccessary variables concerning the rate at which people are infected with the influenza virus was challenging. Rates and delay times were difficult to translate into the correct scales and keeping the model as simple as possible while still creating a realistic simulation was probably the most arduous challenge.

Reference Behaviors

Expectations The model is expected to produce a simulation in which everyone except for the people who have been vaccinated and upon whom the vaccine has worked become infected, then ill, then either dead or immune. The infected people should infect others until there’s no one else to infect, and, after a certain amount of time, everyone who isn’t dead or unsusceptible due to successful vaccination should be immune.

The Model

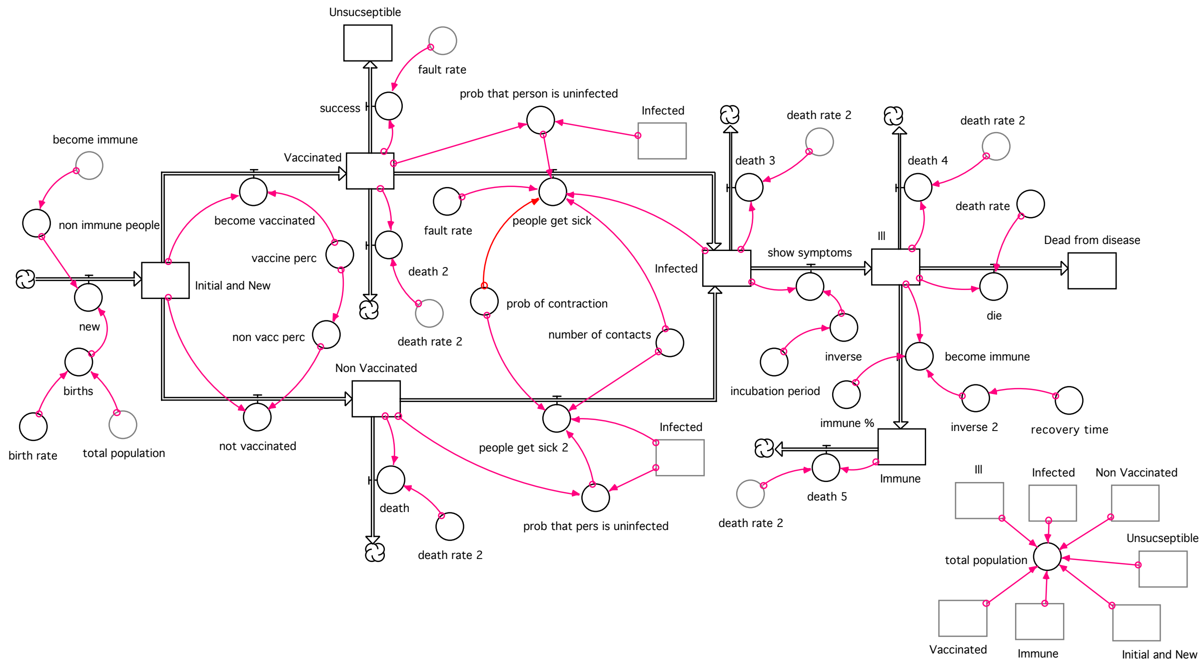
Model Description

Key Variables There are several variables neccessary to the function of my influenza model, but these are the most important: the vaccine percentage, which represents the average percentage of people in the United States who receive vaccinations; the fault rate, which represents the average percentage of vaccinated people upon whom the vaccine fails causing them to become infected; the probability of contraction, which represents the probability that a person will contract the influenza virus from an infected person that they have come in contact with; the number of contacts, which represents the average number of people that a person comes in contact with daily; the probability that a person is uninfected, which represents the probability that a person that someone comes in contact with is uninfected; the incubation period, which represents the time it takes for an infected person to become ill, meaning they start showing symptoms; the recovery time, which represents the average time it takes for an ill person to completely recover from the influenza virus; the immune percentage, which represents the percentage of ill people who, through the recovery process, develop an immunity towards the particular strain of influenza; and the death rate, which represents the rate at which ill people die from influenza and its side effects.

Key Interactions Among Variables There are many interactions important to the accurate workings of my influenza model and the following is a list of those which are key: as the vaccine percentage increases, the Vaccinated population increases and the Non Vaccinated population decreases because more people are recieving vaccinations; as the fault rate increases, the Infected population increases because more vaccinated people are susceptible; as the probability of contraction increases, the Infected population increases because more people are contracting the influenza virus; as the number of contacts increases, the Infected population increases because more people are contracting the influenza virus; as the probability that a person is uninfected increases, the Infected population decreases; as the incubation period increases, the Ill population decreases because it is taking longer for infected people to become ill; as the immune percentage increases, the Immune population increases because more ill people are developing an immunity towards the virus; and, as the recovery time increases, the Immune population decreases because it is taking longer for ill people to recover.

Model Structure

Model Diagram



Model Logic and Key Equations The influenza model begins with an Initial and New stock which represents the initial population of the United States (270,000,000) and new additions to the population. The inflow to Initial and New Population is fed by births, new born children added to the United States population, and non immune people, the people who fail to develop immunity to the particular strain of influenza virus and are re-inserted into the cycle. The Initial and New population has two outflows which lead into either the Vaccinated stock or the Non Vaccinated stock. The inflow into Vaccinated is fed by the vaccine percentage, and the inflow into Non Vaccinated is fed by the non vaccine percentage. The model is set so that a certain percentage (the vaccine percentage) of the Initial and New population flows into the Vaccinated stock while the rest (one minus the vaccine percentage) of the Initial and New population flows into the Non Vaccinated population.

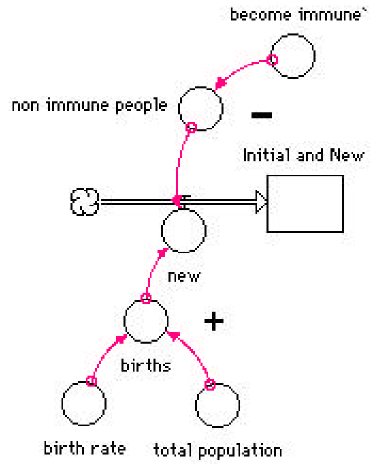
The Vaccinated stock has an outflow that represents death for reasons unrelated to the influenza virus, an outflow that leads to the Unsusceptible stock, and an outflow that leads to the Infected stock. The inflow into the Unsusceptible stock is fed by an equation in which one minus the fault rate is the percentage of the vaccinated people who become unsusceptible. The rest of the vaccinated people move to the Infected stock. The flow into the Infected stock is fed by three variables other than the fault rate: probability of contraction, number of contacts, and probability that a person is uninfected. The probability that a person is uninfected contains the equation "Vaccinated/(Vaccinated+Infected)" which gives the described probability. The four total variables are multiplied together in the flow to receive the product that describes the percentage of people who become infected daily. The Non Vaccinated stock also has an outflow for death and one that leads to the Infected stock. The equation, however, in the probability that a person is uninfected converter for this section contains the equation "Non Vaccinated/(Non Vaccinated+Infected)."

The Infected stock has one outflow that calculates death and one that leads to the Ill stock. The flow that leads to the Ill stock is fed by the incubation period. The inverse of the value in the incubation period converter is taken in the inverse converter. The purpose of this is to show that a certain fraction of people are removed from the Infected stock into the Ill stock daily.

The Ill stock has three outflows. One calculates normal death, one leads to the Dead from Disease stock, and one leads to the Immune stock. The flow to the Dead from Disease stock is fed by the death rate and the flow to the Immune stock is fed by the immune percentage and the recovery time. The inverse of the value in the recovery time converter is taken in the inverse 2 converter to show that only a fraction of the Ill people become immune daily.

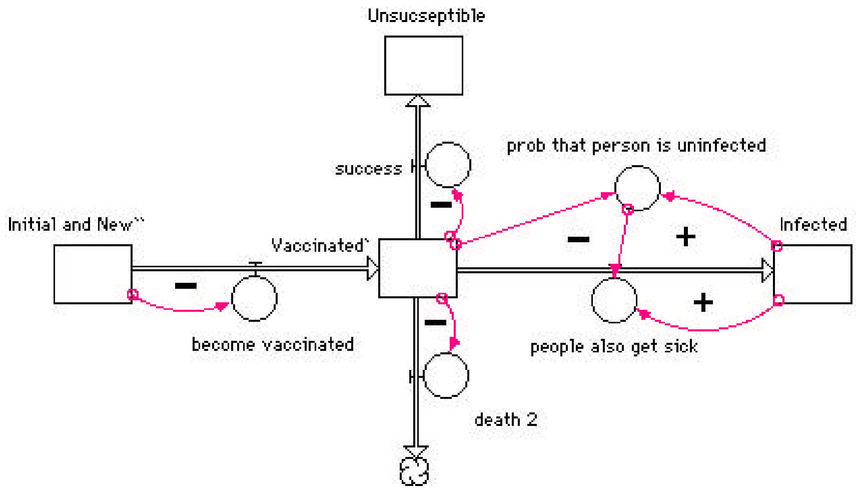
The Immune stock has only one outflow that calculates normal death.

<u>Identification and Analysis of Feedback Loops</u> The following list is composed of pictures of parts of my influenza model and text associated with the analysis of the feedback loops:



As the Initial and New population increases, all the consecutive stocks increase, and the flow labeled become immune increases. As the ghost of become immune increases, the non immune people convertor decreases, the new flow decreases, and the Initial and New Population increases slower, meaning that this loop is negative.

As the Initial and New population increases, the total population increases, the births increase, the new inflow increases, and the Initial and New population increases, meaning that this loop is positive. All stocks except for Dead from Disease have a feedback loop that passes through the total population and through the consequitive stocks and/or flows to the particular stock. All these, like the one described above, are positive.



As the Initial and New population increases, the become vaccinated flow increases, and the Initial and New population decreases, meaning that this loop is negative.

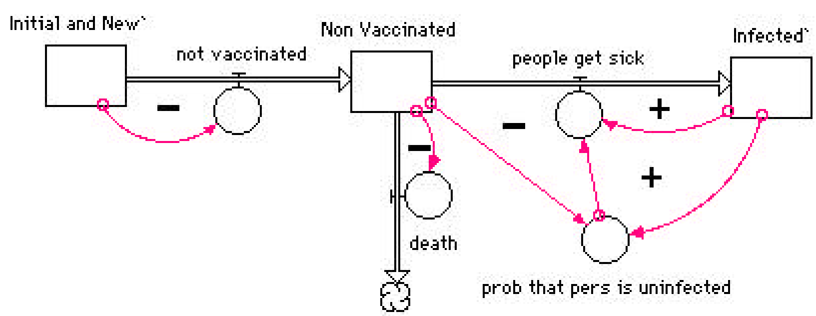
As the Vaccinated population increases, the success flow increases, and the Vaccinated population decreases, meaning that this loop is positive.

As the Vaccinated population increases, the death 2 flow increases, and the Vaccinated population decreases, meaning that this loop is negative.

As the Vaccinated population increases, the probability that a person is uninfected increases, the people also get sick flow decreases, and the Vaccinated population decreases, meaning that this loop is negative.

As the Infected population increases, the probability that a person is unifected decreases, the people also get sick flow increases, and the Infected population increases, meaning that this loop is positive.

As the Infected population increases, the people also get sick flow increases, and the Infected population increases, meaning that this loop is positive.



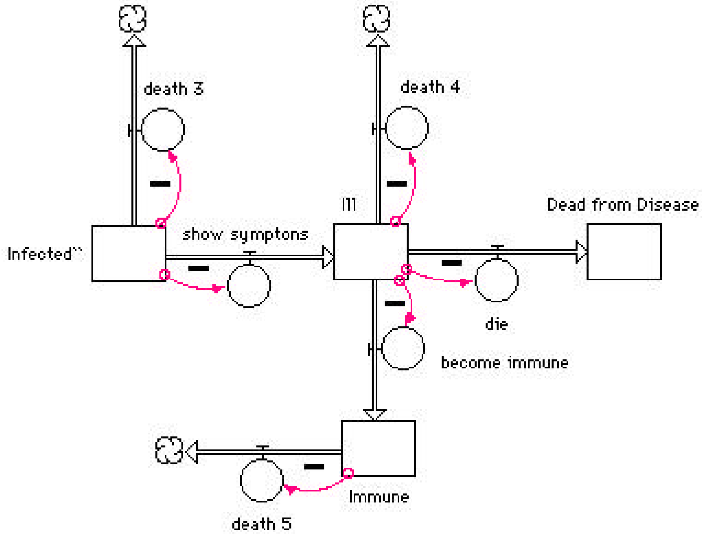
As the Initial and New population increases, the not vaccinated flow increases, and the Initial and New population decreases, meaning that this loop is negative.

As the Non Vaccinated population increases, the death flow increases, and the Non Vaccinated population decreases, meaning that this loop is negative.

As the Non Vaccinated population increases, the probability that a person is uninfected increases, the people get sick flow decreases, and the Non Vaccinated population decreases, meaning that this loop is negative.

As the Infected population increases, the probability that a person is uninfected decreases, the people also get sick flow increases, and the Infected population increases, meaning that this loop is positive.

As the Infected population increases, the people get sick flow increases, and the Infected population increases, meaning that this loop is positive.



As the Infected population increases, the death 3 flow increases, and the Infected population decreases, meaning that this loop is negative.

As the Infected population increases, the show symptoms flow increases, and the Infected population decreases, meaning that this loop is negative.

As the Ill population increases, the death 4 flow increases, and the Ill population decreases, meaning that this loop is negative.

As the Ill population increases, the die flow increases and the Ill population decreases, meaning that this loop is negative.

As the Ill population increases, the become immune flow increases, and the Ill population decreases, meaning that this loop is negative.

As the Immune population increases, the death 5 flow increses, and the Immune population decreases, meaning that this loop is negative.

Additional Aspects

<u>Major Assumptions</u> There was a need for me to make assumptions throughout the construction of my model. One of the assumptions made is that the normal birth rate stays constant even though it is likely that the birth rate would decrease when the infleunza virus is running rampid due to awareness or lack of possible or efficient conception. It is assumed that the average percentage of people in the United States who become vaccinated (the vaccine percentage) is 25% and that this number stays constant. The probability of contraction has an assumed constant

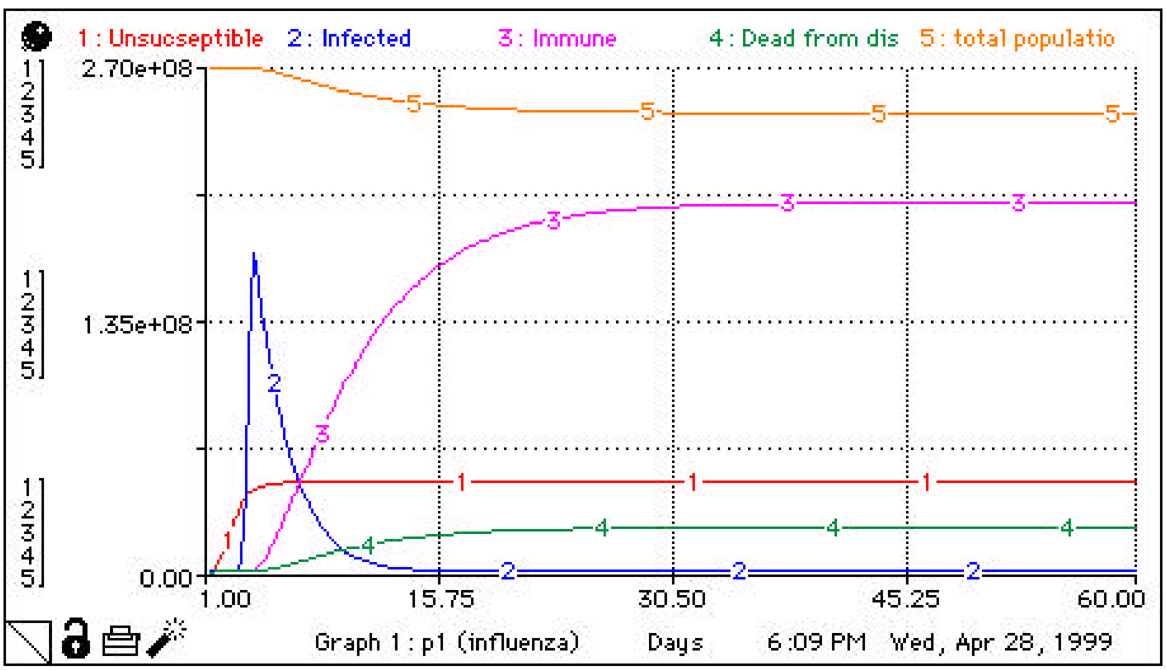
value of 10% and the number of contacts is an average that was attained through the conduction of a small survey. It is also assumed that when a person is ill and in the Ill stock, they are at home and aren't risking the infection of others.

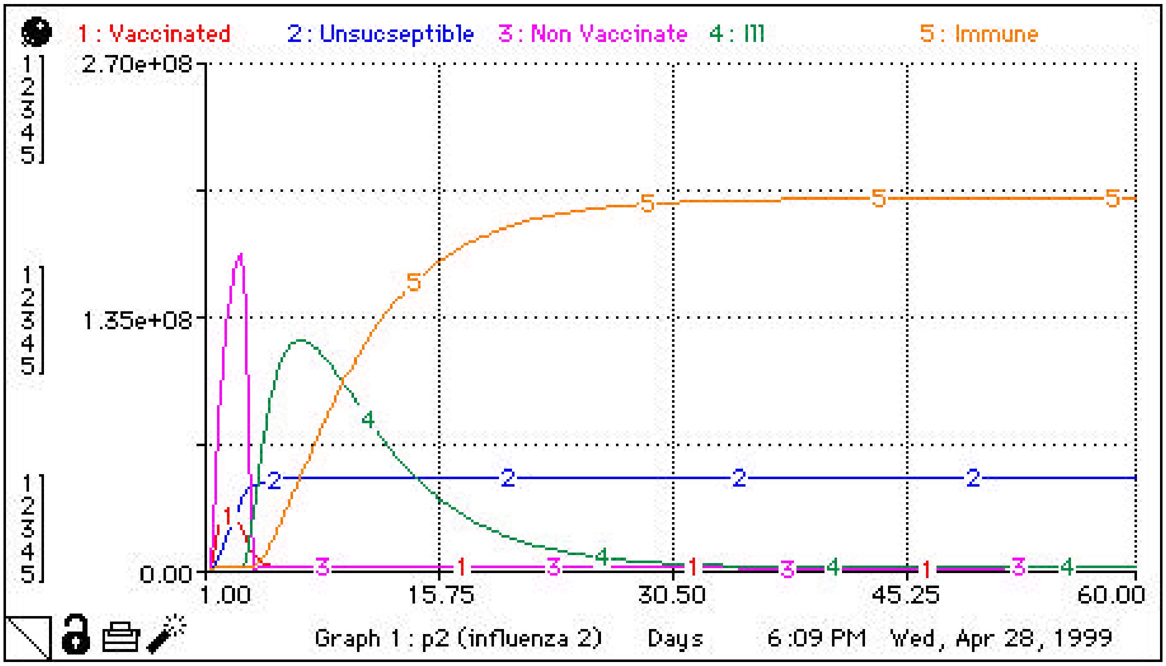
Paramater Values The values that serve as growth rates and the initial value of the Initial and New stock were all attianed from the resources listed in the source materials section of the paper. The delay times were acquired by taking the average of spans of numbers which were also attained from the listed references.

Choice of Time I chose the unit of time for my model to be days because an influenza virus infects a population quickly and running the model in months would have brought upon difficult conversions of growth rates. The ending time of sixty days was chosen because, by that time, all the values had reached a point at which they were in equilibrium. Because it allowed for accurate results, I chose .25 as my DT.

Core Model Results

Graph for the Model





Tabular Output for the Model

Days	Unsuceptible	Infected	Immune	Dead from disease	total population
1.00	0.00	1.00	0.00	0.00	270,000,001.00
6.00	47,745,015.02	64,400,821.84	33,403,525.26	4,044,019.52	265,948,144.94
11.00	48,033,206.89	5,604,027.58	121,564,100.30	14,718,177.30	255,247,864.01
16.00	48,035,082.08	462,084.97	166,717,873.13	20,186,812.19	249,754,067.93
21.00	48,035,094.71	37,940.15	185,458,449.38	22,458,245.73	247,457,927.38
26.00	48,035,094.80	3,114.05	192,944,835.45	23,367,400.13	246,524,252.65
31.00	48,035,094.80	255.59	195,904,437.96	23,728,602.82	246,138,605.85
36.00	48,035,094.80	20.98	197,063,765.00	23,871,888.03	245,970,908.59
41.00	48,035,094.80	1.72	197,508,795.89	23,928,709.80	245,889,689.32
46.00	48,035,094.80	0.14	197,670,552.24	23,951,241.81	245,842,767.39
51.00	48,035,094.80	0.01	197,719,980.25	23,960,176.48	245,809,447.60
Final	48,035,672.80	3,563.45	197,725,241.17	23,963,764.53	245,792,497.63

Interpretation of the Graph and Table The Initial and New population begins at 270,000,000, then drops down to zero as all of the people enter either the Vaccinated or Non Vaccinated stocks. As the people flow in to these two stocks, their values rise, peak, and descend as people enter either the Unsusceptible or Infected stocks. The Unsusceptible stock rises as it is filled with people but soon reaches a balance point because a certain percentage of the Vaccinated people have been determined as unsusceptible. The Infected population rises sharply and drops off as the infected people enter the Ill stock. The Ill population then rises and lowers again as people enter either the Immune or Dead from Disease stock. Because several people have recovered from the virus, the Immune population rises and soon reaches a balance when there are no infected people to infect others. The Dead from Disease population also rises as the Ill population lowers because people have now either died, recovered, or become susceptible again. Throughout this, the total population decreases from its initial value (270,000,001) as people begin dying, and reaches a balance once all values have settled down.

Verification and Validation

Verification

Preliminary Testing The first step I took to make sure that the model that I had constructed worked accurately was to study the feedback loops of the model. I tested the parameters in areas of the model in which accuracy was a question. By changing the parameters, I was able to discover flaws and to reconstruct the particular parts of my model before retesting to affirm accuracy.

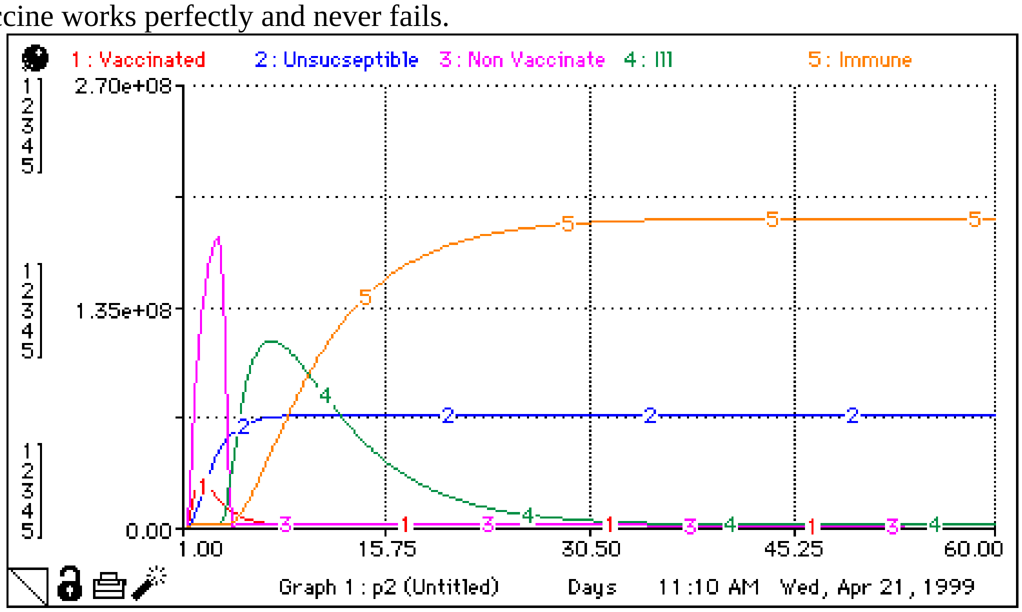
Validation Alison Yahna, a biology teacher at Wilson High School has briefly studiud my model, and believes that it shows accurate and plausable results. In talking to her, she stated that it shows how devastating the estimated soon to come influenza pandemic could easily be.

"Error" Analysis There is one notable error in my influenza model. The immune percentage, the death rate, and the death rate 2 all add together to equal one. This is an ideal situation, but if the death rate or the immune percentage is changed, then all other values have to be changed manually.

Testing the Model

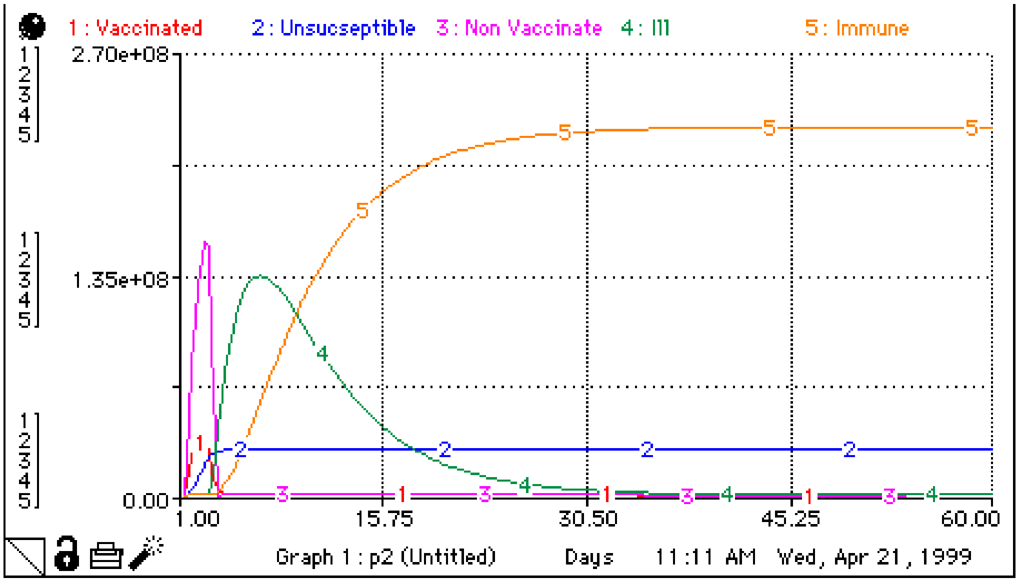
Vaccine Fault The following graphs show how the model will change if the fault rate of the vaccine is changed because of the possible discovery of more efficient vaccines or the use of less efficient vaccines. In the original model, the vaccine fault rate is 20%.

This graph shows what will happen if the fault rate of the vaccine is zero, meaning that the vaccine works perfectly and never fails.



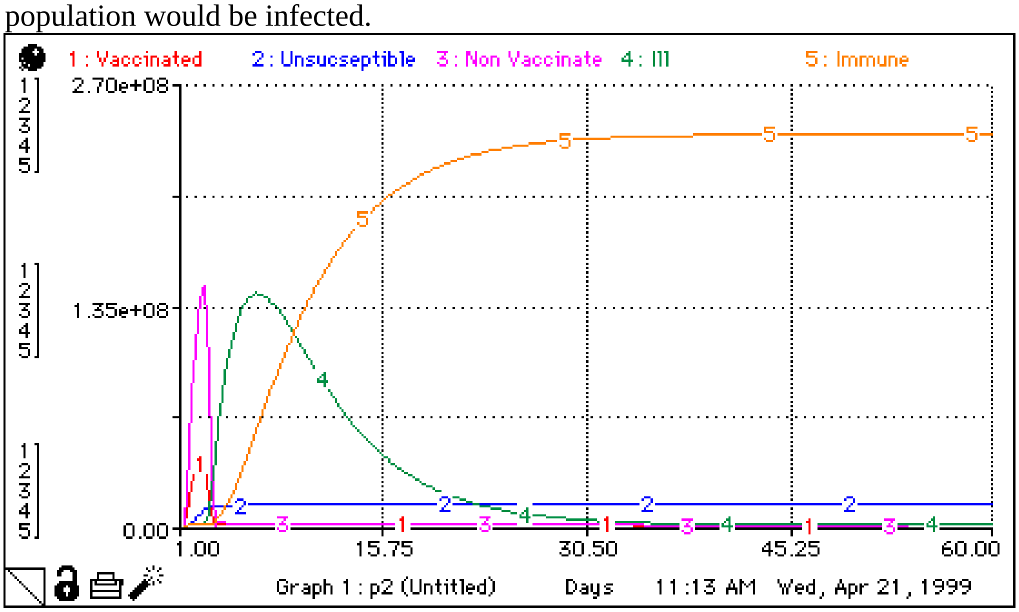
The number of unsusceptible people is higher than before because the vaccine works flawlessly. Because fewer people become infected, fewer people become immune and the Immune population reaches a balance at a lower number.

This graph shows what will happen if the fault rate is 50%, meaning that half of the vaccinated population would be infected.



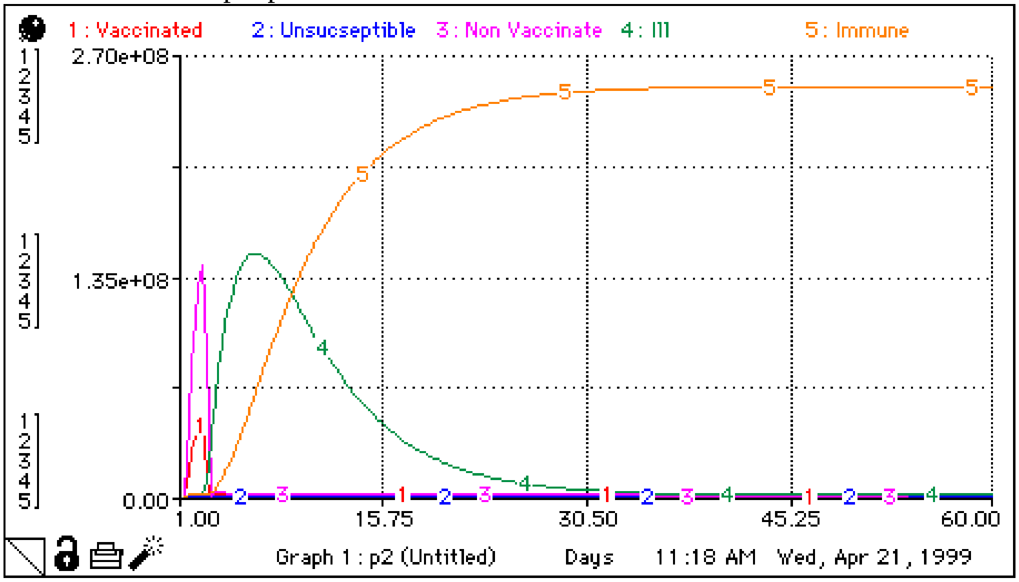
The number of unsusceptible people is lower than the original graph because more people are becoming infected. Because more people are infected, there is a larger Immune population.

This graph shows what will happen if fault rate is 75%, meaning that three quarters of the vaccinated population would be infected.



The number of unsusceptible people is lower than previously because even more vaccinated people are being infected, and because of this, the immune population is higher.

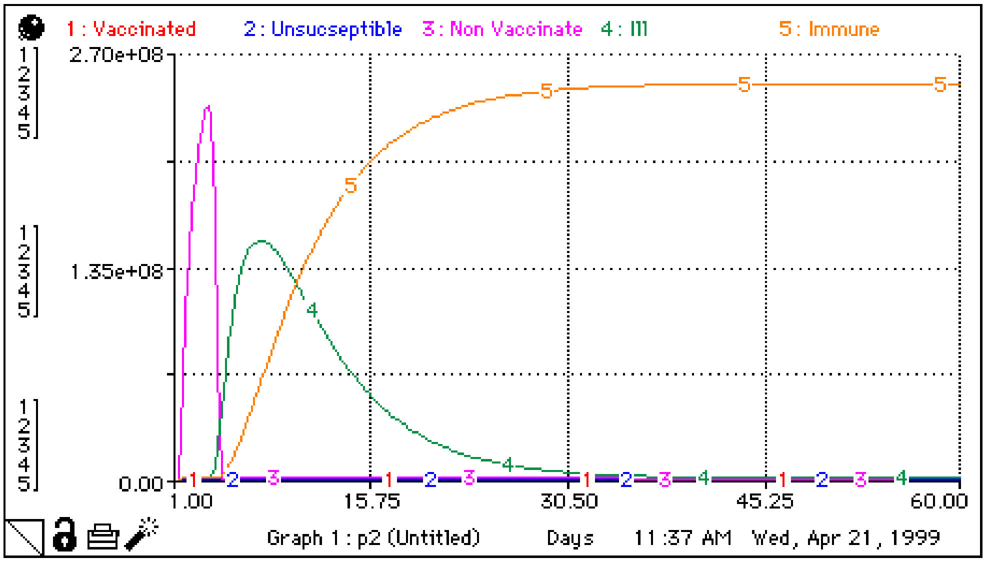
This graph shows what will happen if the fault rate is 100%, meaning that the vaccine never worked and all the people who became vaccinated were infected.



The Unsusceptible population is zero because all the vaccinated people are becoming infected. The Immune population, again, is higher than previous.

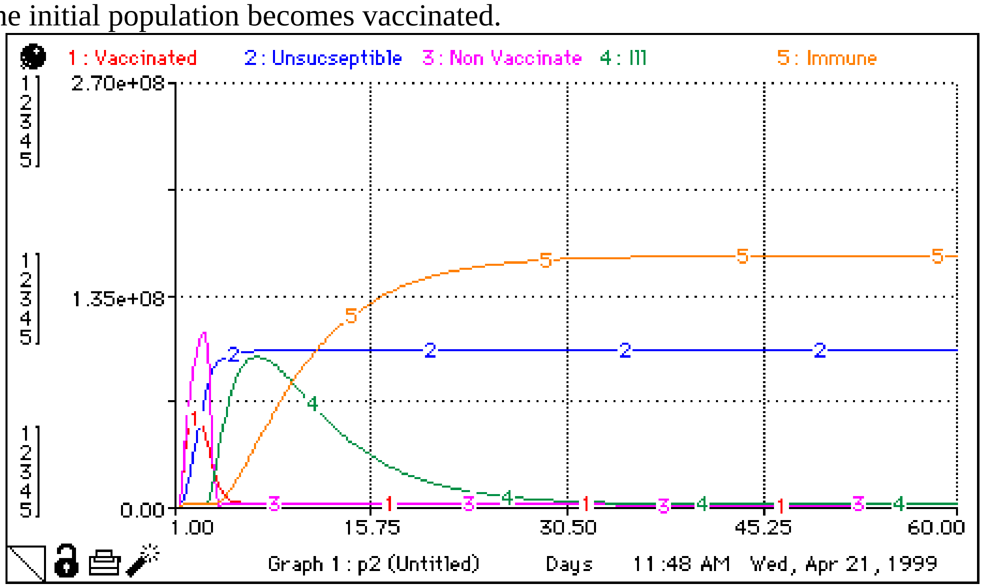
<u>Vaccine Percentage</u> The following graphs show how the model will change if the percentage of people who become vaccinated is reduced or increased because of lack of or raised awareness. In the original model, the vaccination percantage is 25%.

This graph shows what will happen if the vaccination percentage is 0%, meaning that no people became vaccinated.



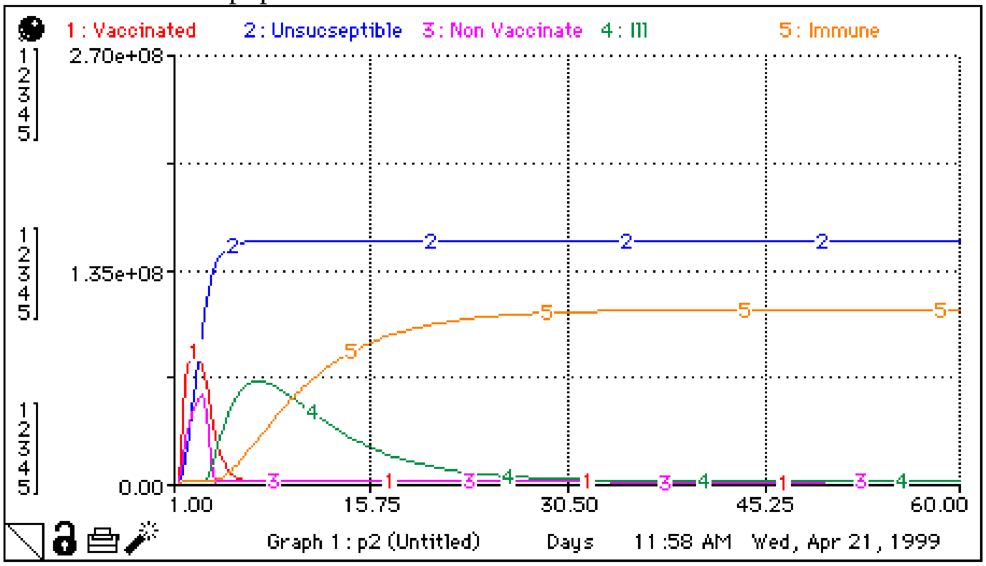
The Nonvaccinated population increases greatly and the Vaccinated and Unsusceptible populations are zero because all people are unvaccinated until infected.

This graph shows what will happen if the vaccination percentage is 50%, meaning that half of the initial population becomes vaccinated.



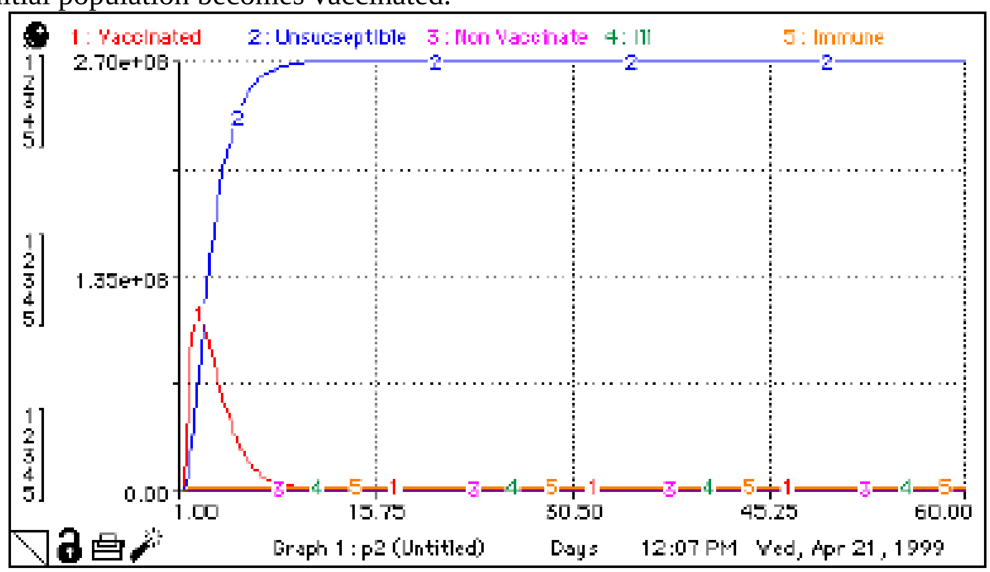
The Nonvaccinated population is smaller than the that of the original model, and the Vaccinated and Unsusceptible populations are greater than previous. The Infected, Ill, and Immune populations are smaller than in the original because less people are suseceptible to the virus.

This graph shows what will happen if the vaccination percentage is 75%, meaning that three quarters of the initial population becomes vaccinated.



The Nonvaccinated population is much lower than previously, and the Vaccinated and Unsusceptible populations are far greater. Less people are allowed to be infected, so the Ill, Infected, and Immune populations are lower than that of the original model.

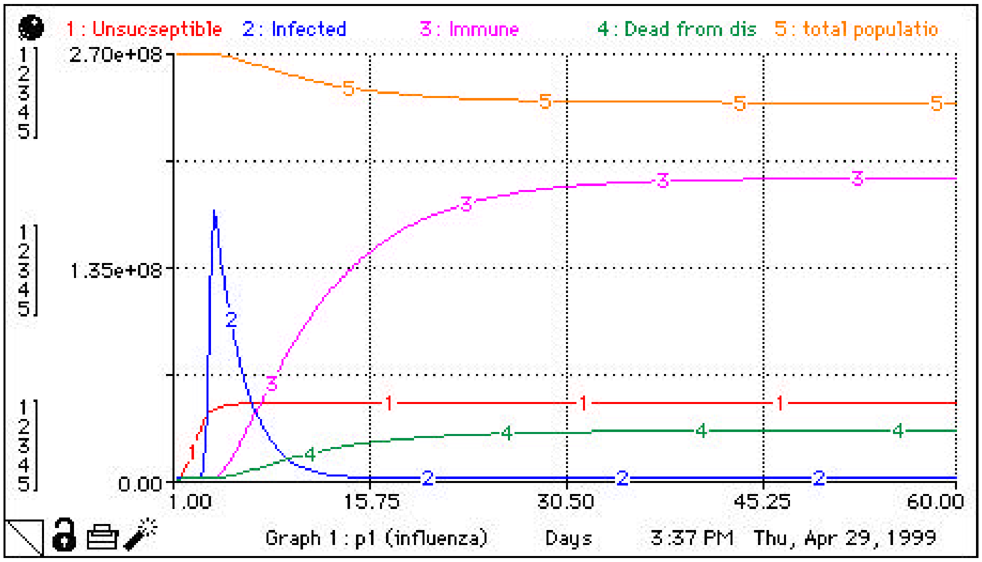
This graph show what will happen if the vaccinated percantage is 100%, meaning that all of the initial population becomes vaccinated.



The Nonvaccinated, Infected, Ill, and Immune populations are all very low because few people are becoming infected. The Vaccinated and Unsusceptible populations are very high, because of the fact that every one is becoming vaccinated.

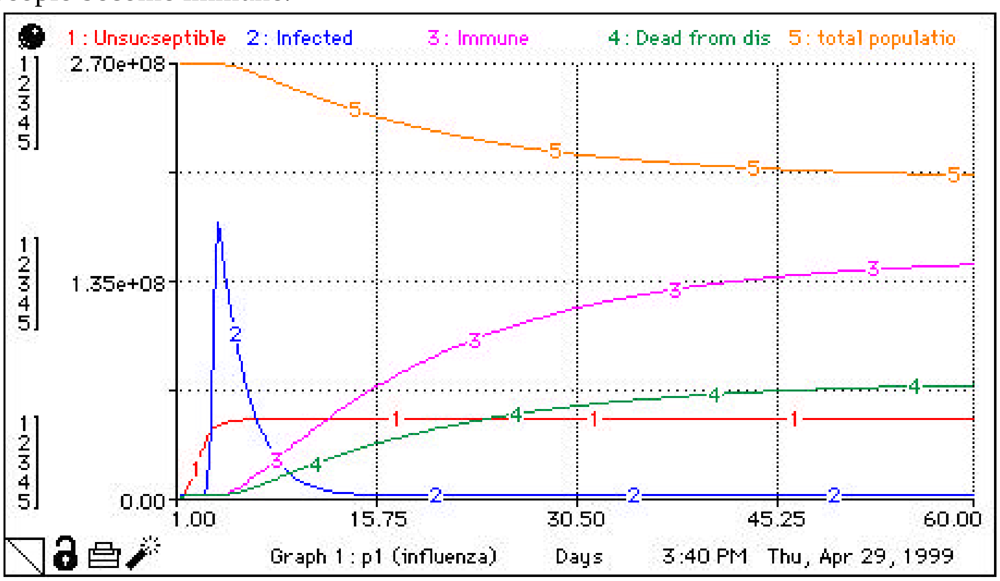
Immunity Percentage   The following graphs show how the model will change if the percentage of people that develop immunity towards the virus is changed because of the rapid speed of virus mutation. The immunity percentage is 99% in the original model.

This graph shows what would happen if the immunity percentage is 75%, meaning that three quarters of the ill people become immune in the proccess of recovery.



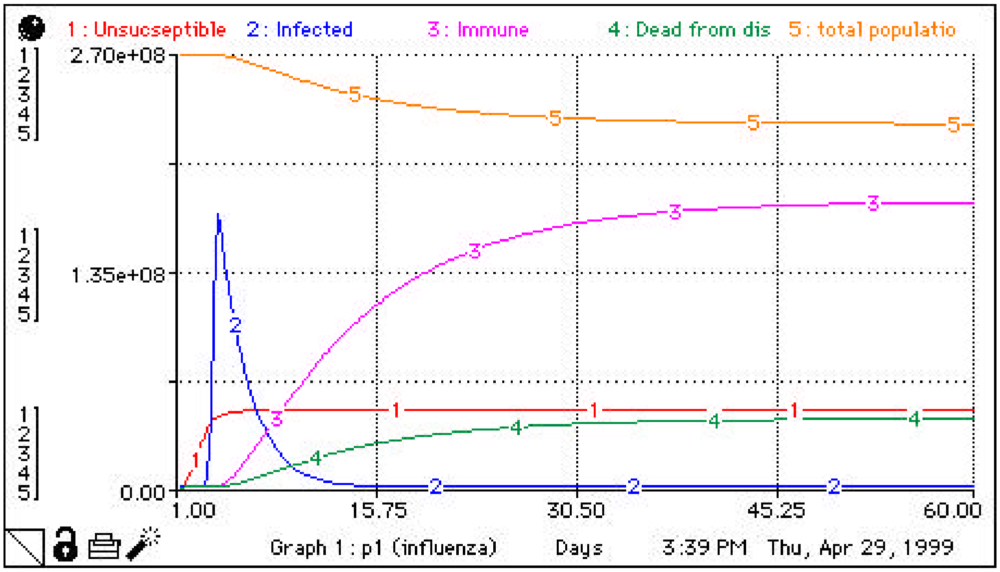
The model shows few changes, but it takes a slightly larger amount of time for the Immune population to level, and the value at which balance is reached is lower than that of the original model. This is because more people don't become immune, and are re-infected, causing the Ill and Dead populations to rise.

This graph shows what will happen if the immunity percentage is 50%, meaning that half the ill people become immune.



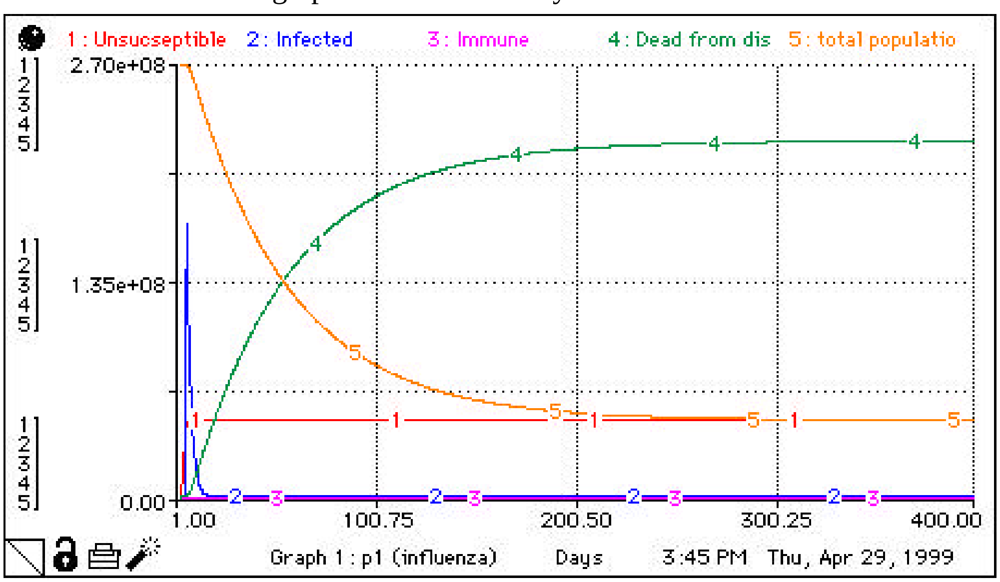
The Immune population takes longer to become level and reaches a balance at a lower level, while the Ill and Dead from Disease populations rise.

This graph shows what will happen if the immunity percentage is 25%, meaning that a quarter of the ill people become immune.



The Immune population rises slower and reaches a lower level and the Ill and Dead from Disease populations rise.

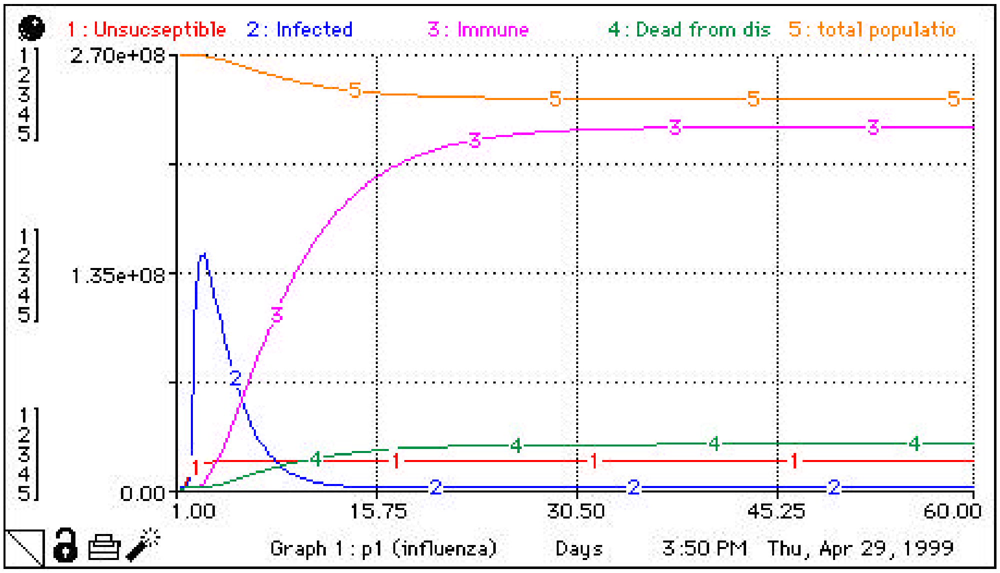
This graph shows what will happen if the immunity percentage is 0%, meaning that no ill people become immune. This graph is run for 400 days.



The Immune population stays at zero because no one is becoming immune, and all of the ill people become reinfected until, eventually, everyone dies from the disease except for the unsusceptible people.

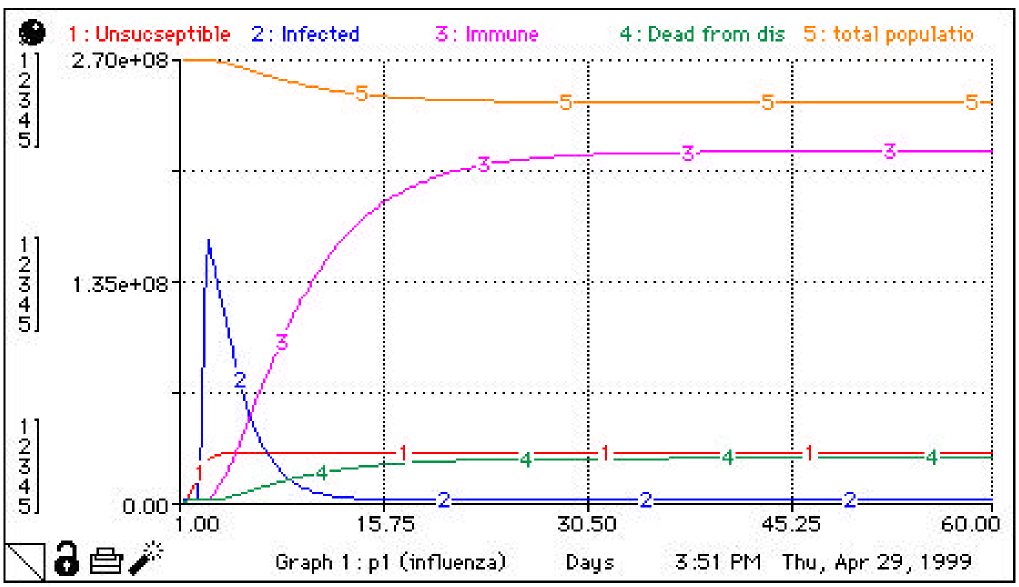
Contacts The following graphs show how the model will change if the average number of contacts is changed. The number of contacts is 75 people per day in the original model.

This graph shows what will happen if the number of contacts is 300, meaning that every person in the United States comes in contact with an average number of 300 people.



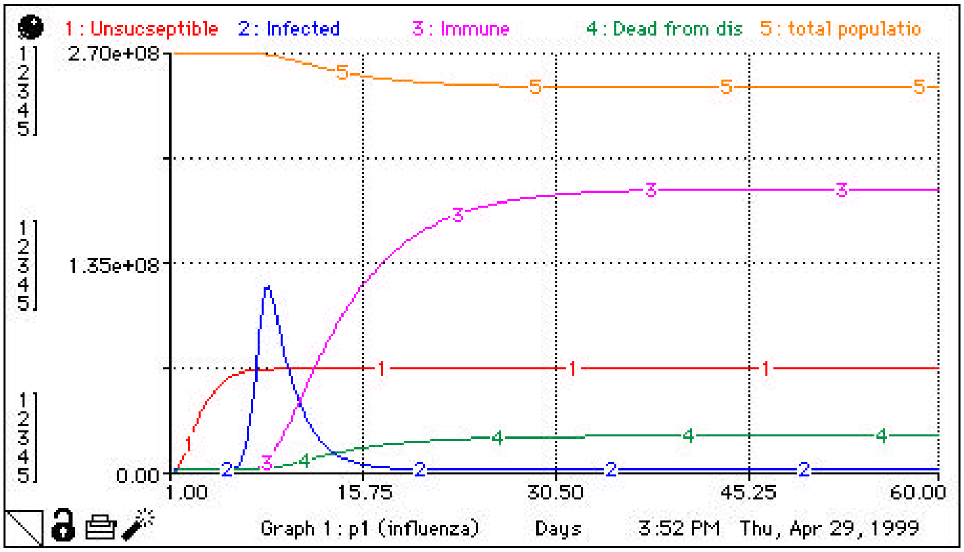
The Immune population rises because more people are becoming infected and later becoming immune. Because the Immune population is high, the Unsusceptible population is lower. The Dead from Disease population also rises due to a larger amount of infected people.

This graph shows what will happen if the number of contacts is 150.



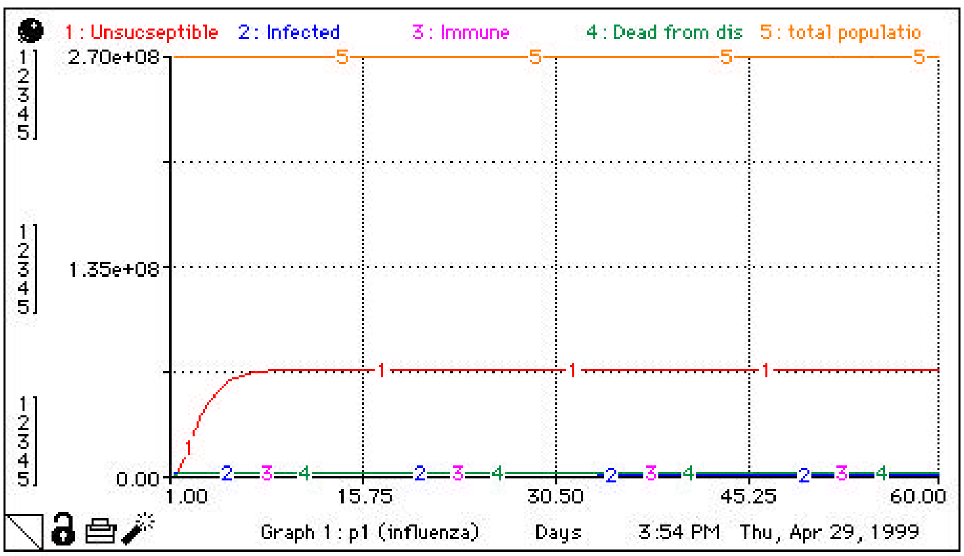
The Immune and Dead from Disease populations are lower than previous and the Unsusceptible population is larger.

This graph shows what will happen if the number of contacts is 30.



The Immune population is much lower than previous, the Dead from Disease population is slightly lower than before, and the Unsusceptible population is higher.

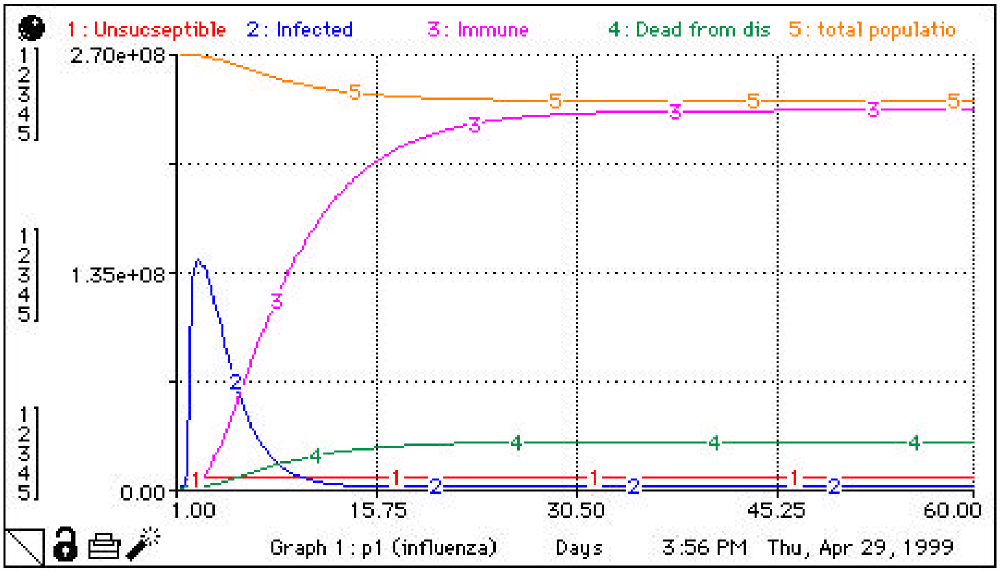
This graph shows what will happen if the number of contacts is zero.



There is no Immune or Dead from Disease population because no one is being infected except for the initially infected person. The Unsusceptible population does, however, rise to a large value because Vaccinated people are still becoming unsusceptible.

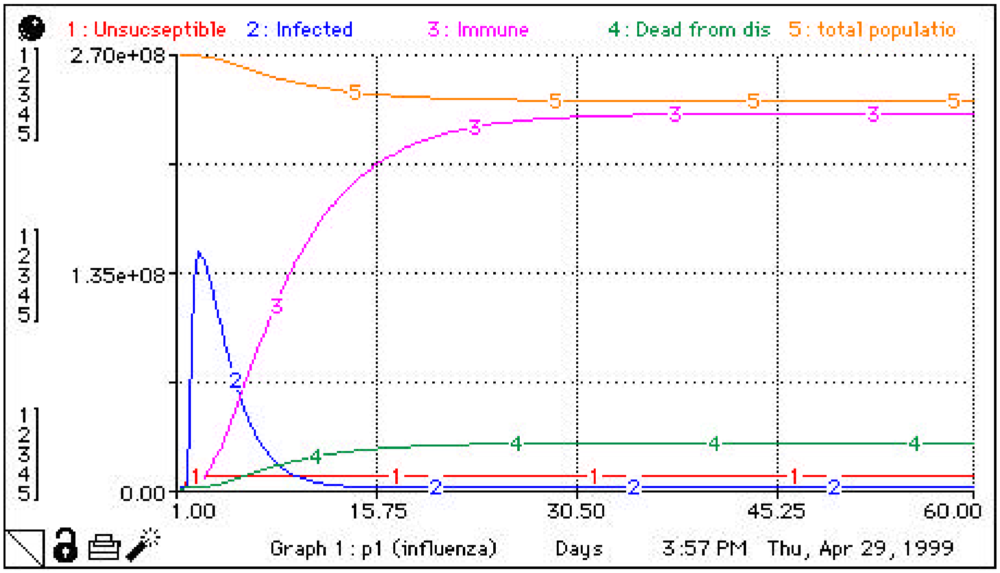
Probability of Contraction   The following graphs show how the model will change if the probability of contraction is changed for reasons such as there being a more evolved strain of influenza. The probability of contraction is an assumed value of 10% in the original model.

This graph shows what will happen if the probability of contraction is 100%, meaning that whenever someone comes in contact with an infected person, they will contract the virus.



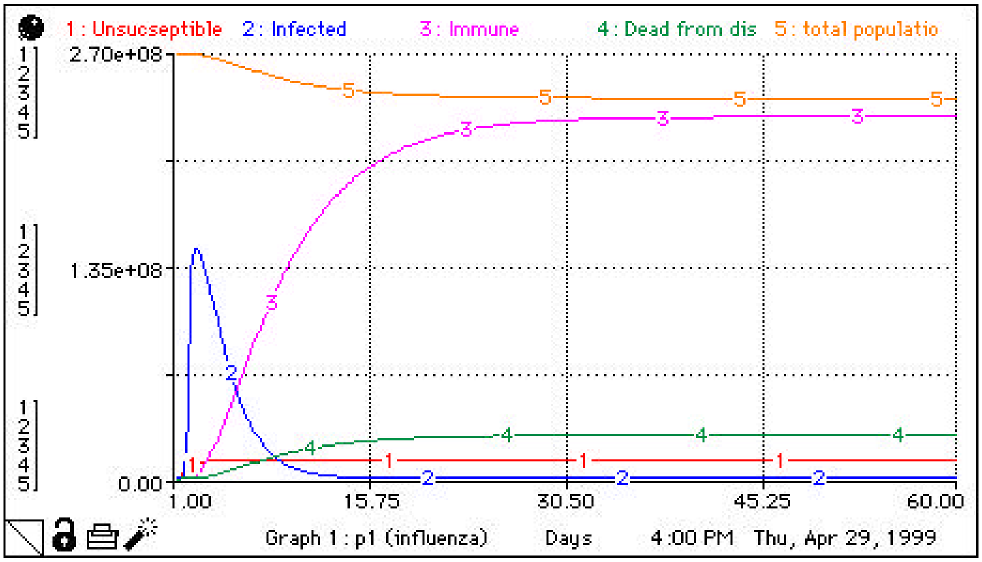
The Immune and Dead from Disease populations are much higher than that of the original model and the Immune population reaches a level much sooner because more people are being infected at a faster pace. Because of this, the Unsusceptible population is very low.

This graph shows what will happen if the probability of contraction is 75%.



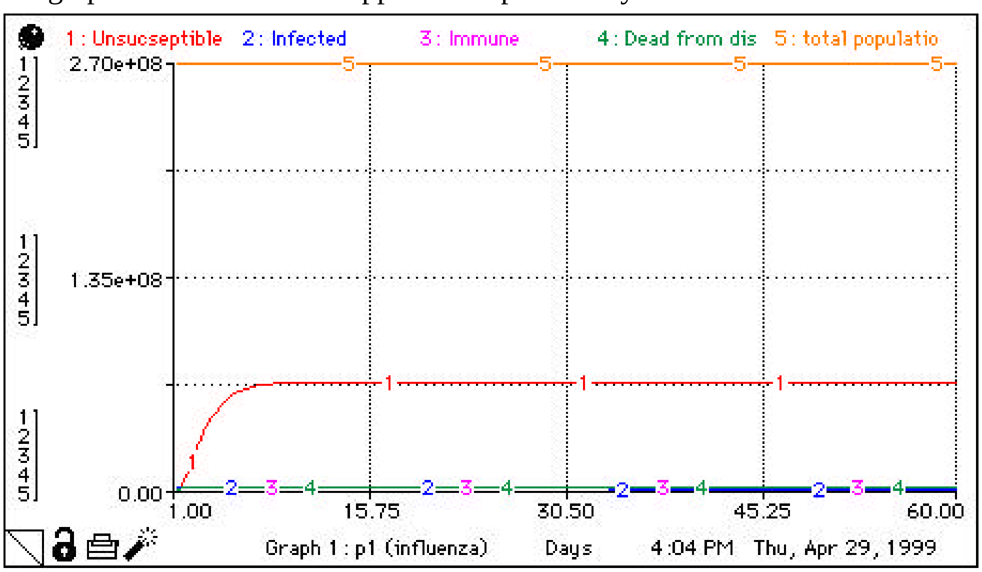
The Immune population is slightly lower and reaches a level at a later time and the Dead from Disease population is slightly lower. The Unsusceptible population is higher.

This graph shows what will happen if the probability of contraction is 50%.



The Immune and Dead from Disease populations are lower and and Unsusceptible population is higher.

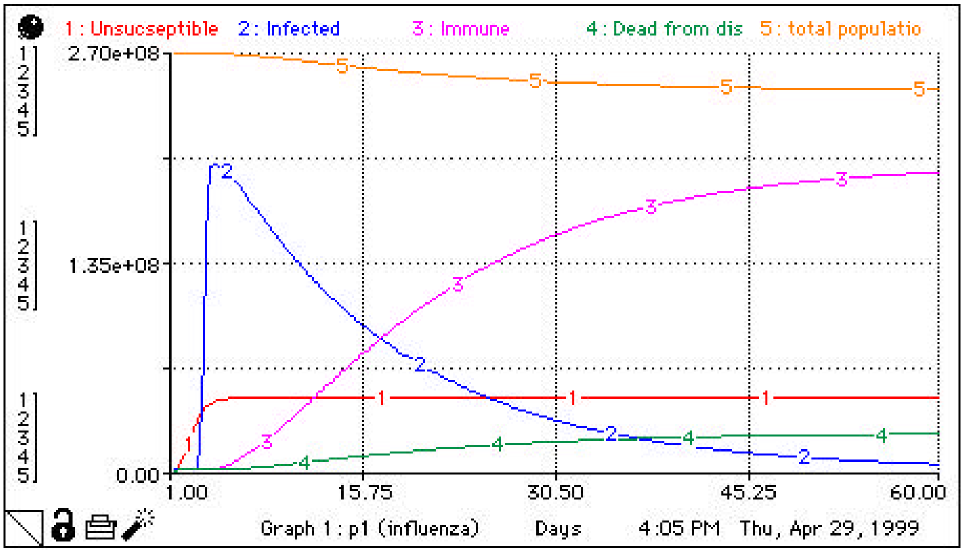
This graph shows what will happen if the probability of contraction is 0%.



The same results as shown when the number of contacts is zero appear.

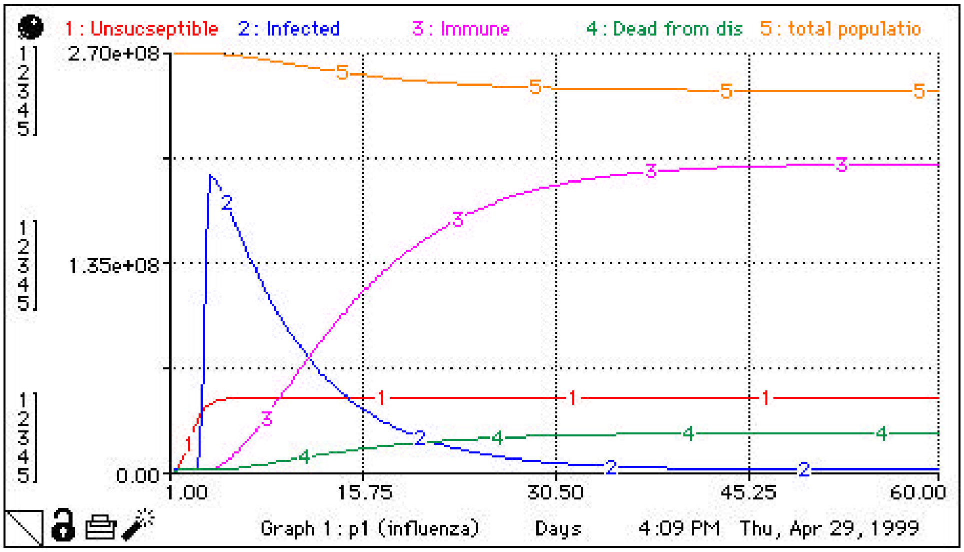
Incubation Period The following graphs show how the model will change if the incubation period changes because of possible variation in strains of the influenza virus. The incubation period is two days in the original model.

This graph shows what will happen if the incubation period is fourteen days, meaning that it takes two weeks for an infected person to show symtoms.



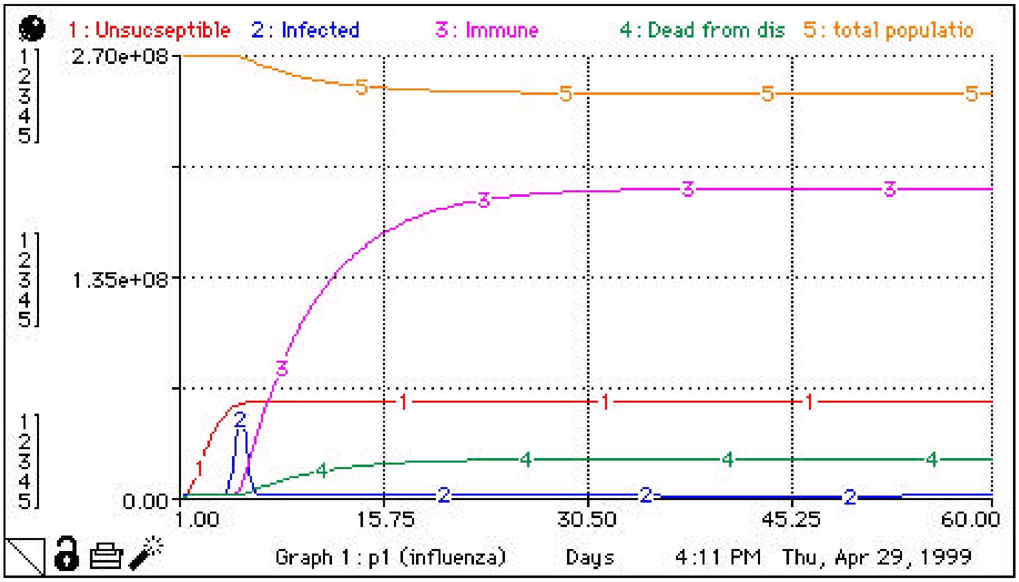
The Infected population rises because people are staying in the Infected stock for a longer period of time. Because it takes longer for infected people to become ill and immune, the Immune population grows at a slower rate than in the original model. With the large amount of infected people infecting larger amounts of uninfected people, more people die so that the Dead from Disease population rises and the total population lowers.

This graph shows what will happen if the incubation period is seven days.



The Infected, Immune, and Dead from Disease populations are slightly lower and the total population is higher.

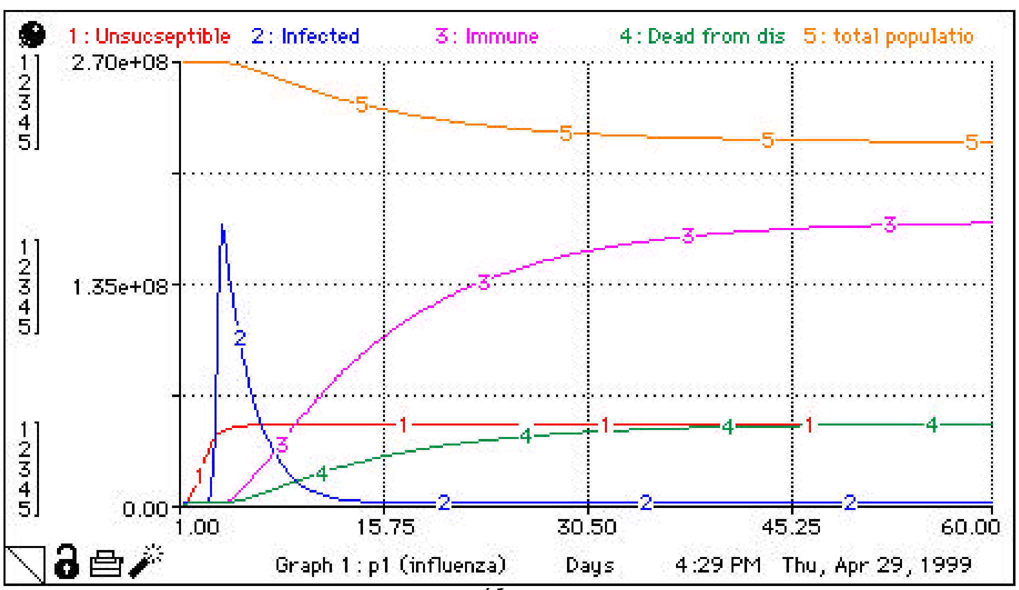
This graph shows what will happen if the incubation period is one tenth of a day.



All of the populations show similar trends, but reach their asymptotes at a much earlier time.

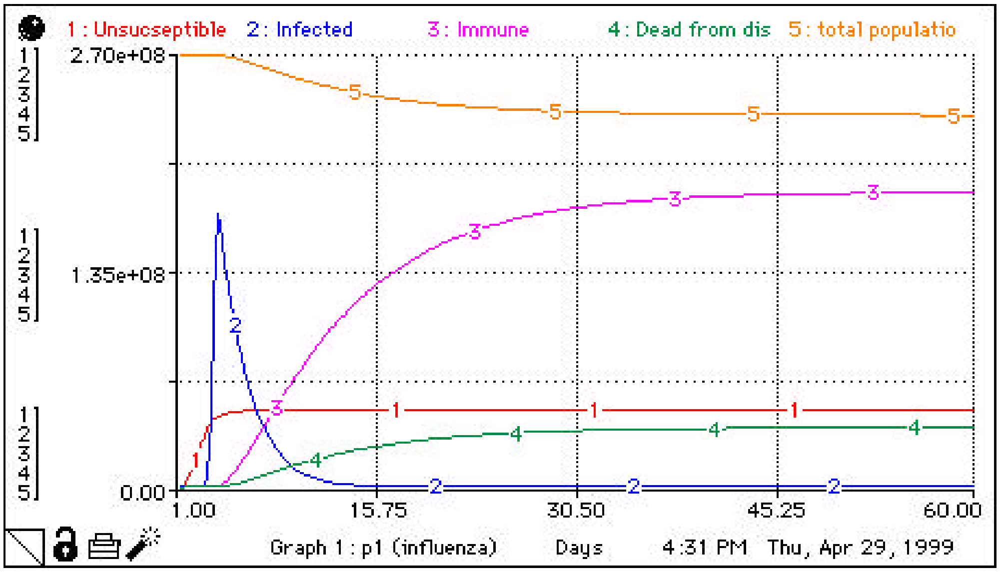
<u>Recovery Time</u> The following graphs show how the model will change if the recovery time is changed because of possible variation in the influenza virus. The recovery time is an average of six days in the original model.

This graph shows what will happen if the recovery time is fourteen days, meaning that it takes two weeks to recover from the influenza virus.



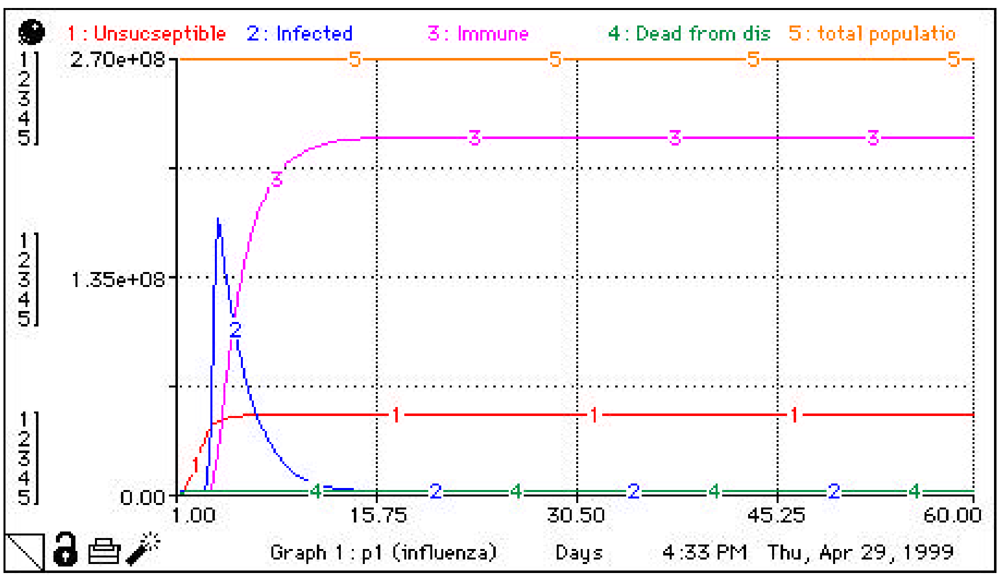
The Immune population grows slower and reaches a balance at a lower level because more people are staying ill and more are dying. The Dead from Disease population increases greatly because of this, and the total population decreases.

This graph shows what will happen if the recovery time is ten days.



The Immune population and the total population are higher and the Dead from Disease population is lower.

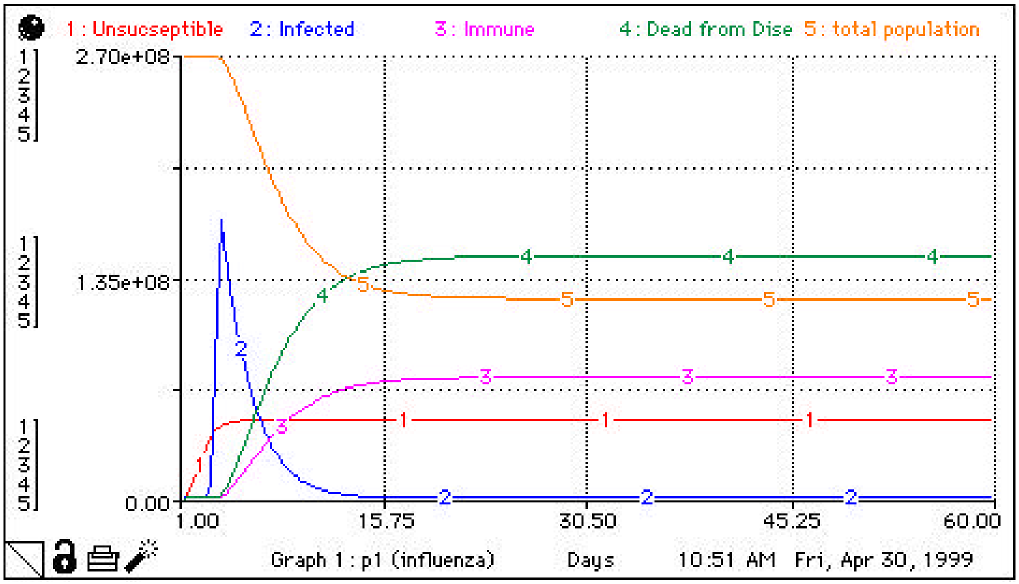
This graph shows what will happen if the recovery time is one tenth of a day.



The Dead from Disease population is very low because people are recovoring so quickly that few are dying. Because few are dead, the Immune population and total population are high.

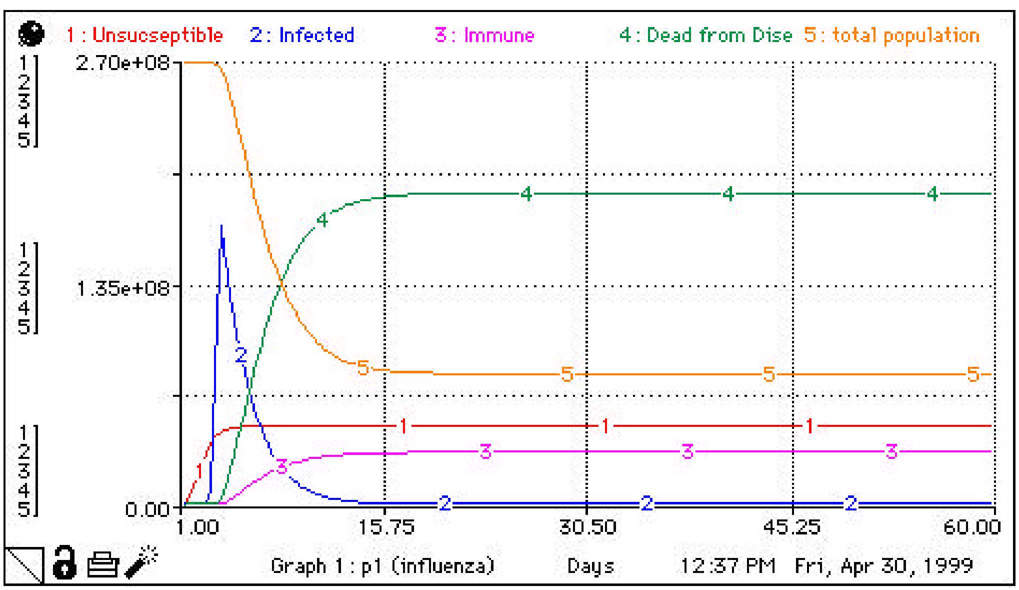
Death Rate   The following graphs show how the model will change if the death rate (death because of the influenza virus) is changed because of a possible mutated influenza strain that is more lethal. The death rate is approximately .01996 in the original model.

This graph shows what will happen if the death rate is 25%.



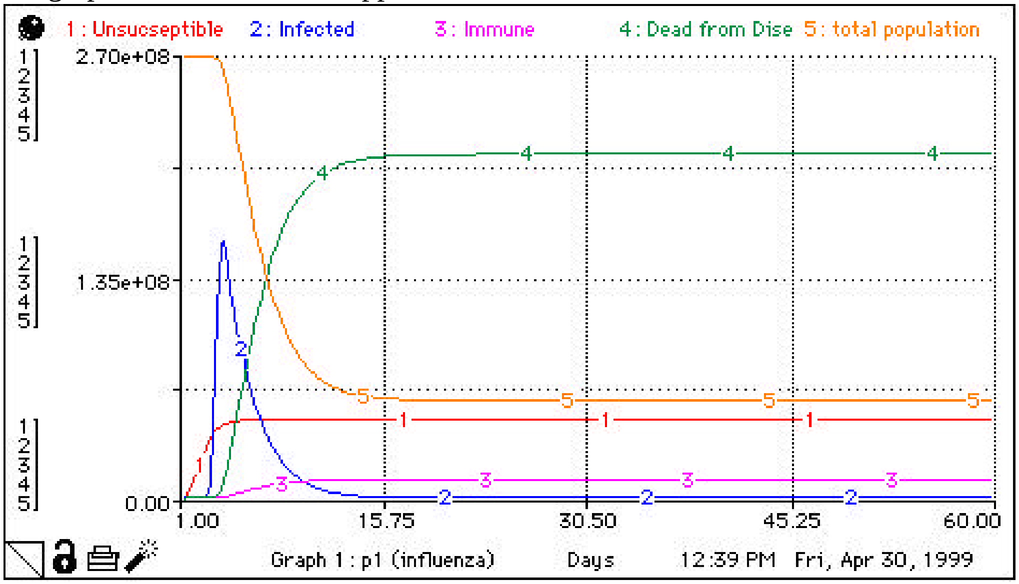
The Dead from Disease population increases drastically because several are dying, the Immune population lowers because more ill people are dying rather than becoming immune, and the total population drops because of the large number of dead people.

This graph shows what will happen if the death rate is 50%.



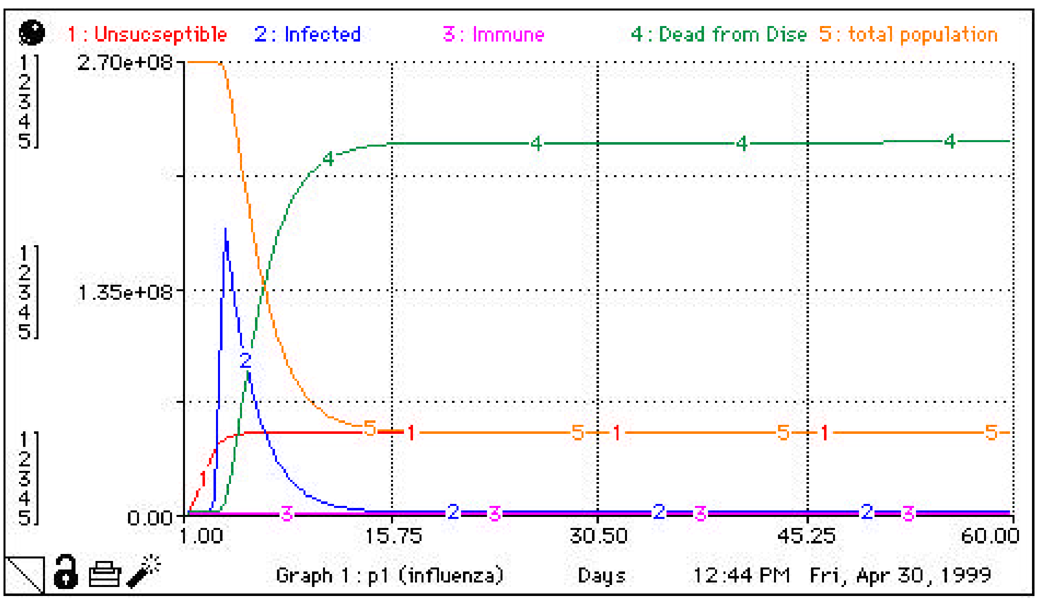
The Dead from Disease population rises and the Immune population and the total population drop.

This graph shows what will happen if the death rate is 75%.



The Dead from Disease population rises and, again, the Immune population and total population drop.

This graph shows what will happen if the death rate is 100%.



The Dead from Disease population skyrockets, the Immune population stays at zero, and the total population decreases, reaching a balance at the level of the Unsusceptible population because they are the only living people.

Conclusion and Future Plans

When run, my influenza model shows, generally, what I expected it to show. When an influenza pandemic sweeps through a population, it will have devastating effects. The influenza virus infects everyone who doesn't have a successful vaccination. All the infected people then become either immune or dead. The amount of dead people after the model has run for sixty days shows the very possible extremely destructive results of an influenza pandemic.

I believe that my influenza model presents an accurate look at how an influenza pandemic effects a population and shows how devastating an influenza virus could easily be in the United States. My model shows more severe results than even the 1918 epidemic, but it foreshadows the lethal affects that the next influenza virus is assumed to have.

To model other ideas such as the side effects of vaccination and infection, I could add separate stocks that calculate these populations. A system that models these populations would be more applicable to the interests of pharmachologists.

Source Materials

References

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Consultants For information and advice throughout the construction of this model, I spoke with Wesley Samples and Scott Guthrie.

Acknowledgements In order to find aid in the core structure of a disease related model, I consulted a manual entitled Plagues and People: A Cirricular Experiment written by the Trinity College of Vermont.

Appendices

Equations for the Model These are the equations for my final model:
Dead_from_Disease(t) = Dead_from_Disease(t - dt) + (die) * dtINIT Dead_from_Disease = 0
DOCUMENT: This stock represents the people who have died because of the influenza virus. The main reasons for death are respitory and heart failure and kidney disease . The people who die because of influenza are most often among the elderly, young, diabetic, cancer affected, and HIV infected.
INFLOWS:
die = Ill*death_rate
DOCUMENT: This represents the people that are dying because of the influenza virus.

Ill(t) = Ill(t - dt) + (show_symptoms - die - death_4 - become_immune) * dt
INIT Ill = 0
DOCUMENT: This stock represents the infected people who are now showing symptoms of influenza. It is assumed that once people have become ill, they stay at their homes and don't risk the infection of others. Amantadine and rimantadine are to drugs perscribed to decrease the severity of influenza infection and prevent complications. Because they do not rid the body of infection, people who have taken these drugs are included in the Ill population.
INFLOWS:
show_symptoms = Infected*inverse
DOCUMENT: This flow represents the people who have been infected and are now showing symptoms and becoming ill.
OUTFLOWS:
die = Ill*death_rate
DOCUMENT: This represents the people that are dying because of the influenza virus.
death_4 = Ill*death_rate_2
DOCUMENT: This outflow represents the people dying for reasons unrelated to the influenza virus.
become_immune = Ill*immune_%*inverse_2
DOCUMENT: This represents the people who are recovering from the virus and have built up an immunity towards it.

Immune(t) = Immune(t - dt) + (become_immune - death_5) * dt
INIT Immune = 0
DOCUMENT: This stock represents people who have been infected and are now immune.
INFLOWS:
become_immune = Ill*immune_%*inverse_2
DOCUMENT: This represents the people who are recovering from the virus and have built up an immunity towards it.
OUTFLOWS:
death_5 = Immune*death_rate_2
DOCUMENT: This outflow represents the people dying for reasons unrelated to the influenza virus.

Infected(t) = Infected(t - dt) + (people_get_sick + people_get_sick_2 - show_symptoms - death_3) * dt
INIT Infected = 1
DOCUMENT: This stock represents people who are infected with the influenza virus, but aren't yet showing symptoms. People are infected by inhaling the water droplets from sneezes and coughs of infected people.
INFLOWS:
people_get_sick=Infected*fault_rate*number_of_contacts*prob_of_contraction*prob_that_person_is_uninfected
DOCUMENT: This represents the vaccinated people who are being infected with the influenza virus.
people_get_sick_2=Infected*number_of_contacts*prob_of_contraction*prob_that_pers_is_uninfected
DOCUMENT: This flow represents the non vaccinated people who are being infected with the influenza virus.
OUTFLOWS:
show_symptoms = Infected*inverse
DOCUMENT: This flow represents the people who have been infected and are now showing symptoms and becoming ill.
death_3 = death_rate_2*Infected
DOCUMENT: This outflow represents the people dying for reasons unrelated to the influenza virus.

Initial_and_New(t) = Initial_and_New(t - dt) + (new - not_vaccinated - become_vaccinated) * dt
INIT Initial_and_New = 270000000
DOCUMENT: This stock represents the initial population of the United States and new additions through births and people who haven't become immune.
INFLOWS:
new = non_immune_people+births
DOCUMENT: This inflow represents the new people who are being added to the initial and new population.
OUTFLOWS:
not_vaccinated = Initial_and_New*non_vacc_perc
DOCUMENT: This flow represents the people choosing not to become vaccinated.
become_vaccinated = Initial_and_New*vaccine_perc
DOCUMENT: This flow represents the people who are choosing to become vaccinated. The protection against the influenza virus appears one to two weeks after vaccination.

Non_Vaccinated(t) = Non_Vaccinated(t - dt) + (not_vaccinated - death - people_get_sick_2) * dt
INIT Non_Vaccinated = 0
DOCUMENT: This stock represents the people in the United States who have chosen not become vaccinated against the influenza virus and are, therefore, susceptible.
INFLOWS:
not_vaccinated = Initial_and_New*non_vacc_perc

DOCUMENT: This flow represents the people choosing not to become vaccinated.
OUTFLOWS:
death = Non_Vaccinated*death_rate_2
DOCUMENT: This outflow represents the people dying for reasons unrelated to the influenza virus.
people_get_sick_2=Infected*number_of_contacts*prob_of_contraction*prob_that_pers_is_uninfected
DOCUMENT: This flow represents the non vaccinated people who are being infected with the influenza virus.

Unsucseptible(t) = Unsucseptible(t - dt) + (success) * dt
INIT Unsucseptible = 0
DOCUMENT: This stock represents the people with whom the vaccine has worked and are now at no risk of being infected.
INFLOWS:
success = (1-fault_rate)*Vaccinated
DOCUMENT: This flow represents the vaccinated people with whom the vaccine has worked.

Vaccinated(t) = Vaccinated(t - dt) + (become_vaccinated - people_get_sick - success - death_2) * dt
INIT Vaccinated = 0
DOCUMENT: This stock represents the people in the United States who have chosen to become vaccinated. The vaccine does cause allergic reactions in 5 - !0% of vaccinated people. People suffering from these side effects are included in the Vaccinated population.
INFLOWS:
become_vaccinated = Initial_and_New*vaccine_perc
DOCUMENT: This flow represents the people who are choosing to become vaccinated. The protection against the influenza virus appears one to two weeks after vaccination.
OUTFLOWS:
people_get_sick=Infected*fault_rate*number_of_contacts*prob_of_contraction*prob_that_person_is_uninfected
DOCUMENT: This represents the vaccinated people who are being infected with the influenza virus.

success = (1-fault_rate)*Vaccinated
DOCUMENT: This flow represents the vaccinated people with whom the vaccine has worked.

death_2 = Vaccinated*death_rate_2
DOCUMENT: This outflow represents the people dying for reasons unrelated to the influenza virus.

births = birth_rate*total_population
DOCUMENT: This represents the total amount of daily births in the United States.

birth_rate = .012/365

DOCUMENT: This represents the normal daily birth rate in the United States.

death_rate = .0199753425
DOCUMENT: This represents the rate at which people die from the influenza virus.

death_rate_2 = .009/365
DOCUMENT: This represents the normal daily death rate in the United States.

fault_rate = .2
DOCUMENT: This represents the probability that the vaccine is not effective against the influenza strain. Although some vaccinated people do become infected regardless of their vaccination, those who are vaccinated usually have milder cases.

immune_% = .99
DOCUMENT: This represents the average percentage of people that build immunity towards this particular strain of influenza.

incubation_period = 2
DOCUMENT: This represents the average time it takes for the virus to show symptoms after the body has been infected (2 days).

inverse = 1/incubation_period
DOCUMENT: This represents the fraction of people who are becoming ill daily.

inverse_2 = 1/recovery_time
DOCUMENT: This represents the fraction of people who recover each day.

non_immune_people = 1-become_immune
DOCUMENT: This represents the people who haven't become immune to the particular strain of influenza virus.

non_vacc_perc = 1-vaccine_perc
DOCUMENT: This represents the average percentage of people in the United States who don't recieve vaccinations against the influenza virus.

number_of_contacts = 75
DOCUMENT: This represents the average number of people that a person comes in contact with daily.

prob_of_contraction = .1
DOCUMENT: This represents the probability that a person who has come in contact with an infected person will become infected.

prob_that_person_is_uninfected = Vaccinated/(Vaccinated+Infected)
DOCUMENT: This represents the probability that someone who a vaccinated person comes in

contact with is uninfected.

prob_that_pers_is_uninfected = Non_Vaccinated/(Non_Vaccinated+Infected)
DOCUMENT: This represents the probability that someone that a non vaccinated person comes in contact with is uninfected.

recovery_time = 6
DOCUMENT: This represents the average length of time it takes a person to recover from an influenza infection (6 days). Included in the recovery time is the recovery from side effects such as fever, malaise, and myalgia.

total_population=Ill+Immune+Infected+Non_Vaccinated+Vaccinated+Initial_and_New+Unsucseptible
DOCUMENT: This represents the total amount of living people in the United States.

vaccine_perc = .25
DOCUMENT: This represents the average percentage of people in the United States who become vaccinated against the influenza virus.