Dynamic Model of the Zombie Apocalypse

General Zombie Information

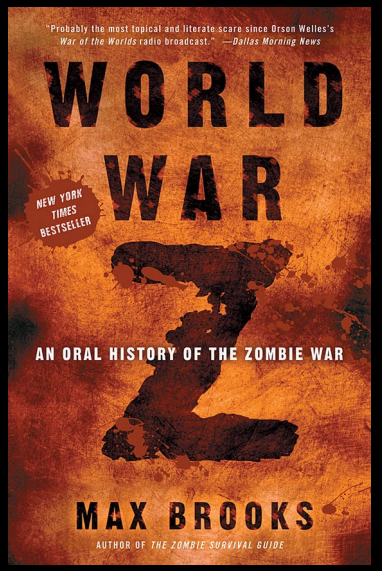
- In standard zombie literature, humans become infected with the zombie virus through body fluid contact
- An infected person loses all higher thinking ability and desires only to consume living flesh, which further spreads the virus through bites
- Delivery methods, incubation time, and zombie behavior do vary among universes, and these differences are what we explored in this project

Inspiration

- Our work was inspired by a previous publication, entitled “When Zombies Attack!: Mathematical Modelling of an Outbreak of Zombie Infection” by Munz, et al. (2009)
- In this work, the researchers made some generalizing assumptions that limit their model to only the most basic model of zombie attack
- We expand on this work by considering different models outside of the most mainstream scenario

Basic Model (World War Z)

- Our most basic model is based off of the rules laid down in Max Brooks' *World War Z*, a popular zombie horror novel
- In this model, zombies are slow movers who spread their disease only through bodily fluid
- Infected people undergo an incubation period of about two days before they succumb to the disease and become a zombie



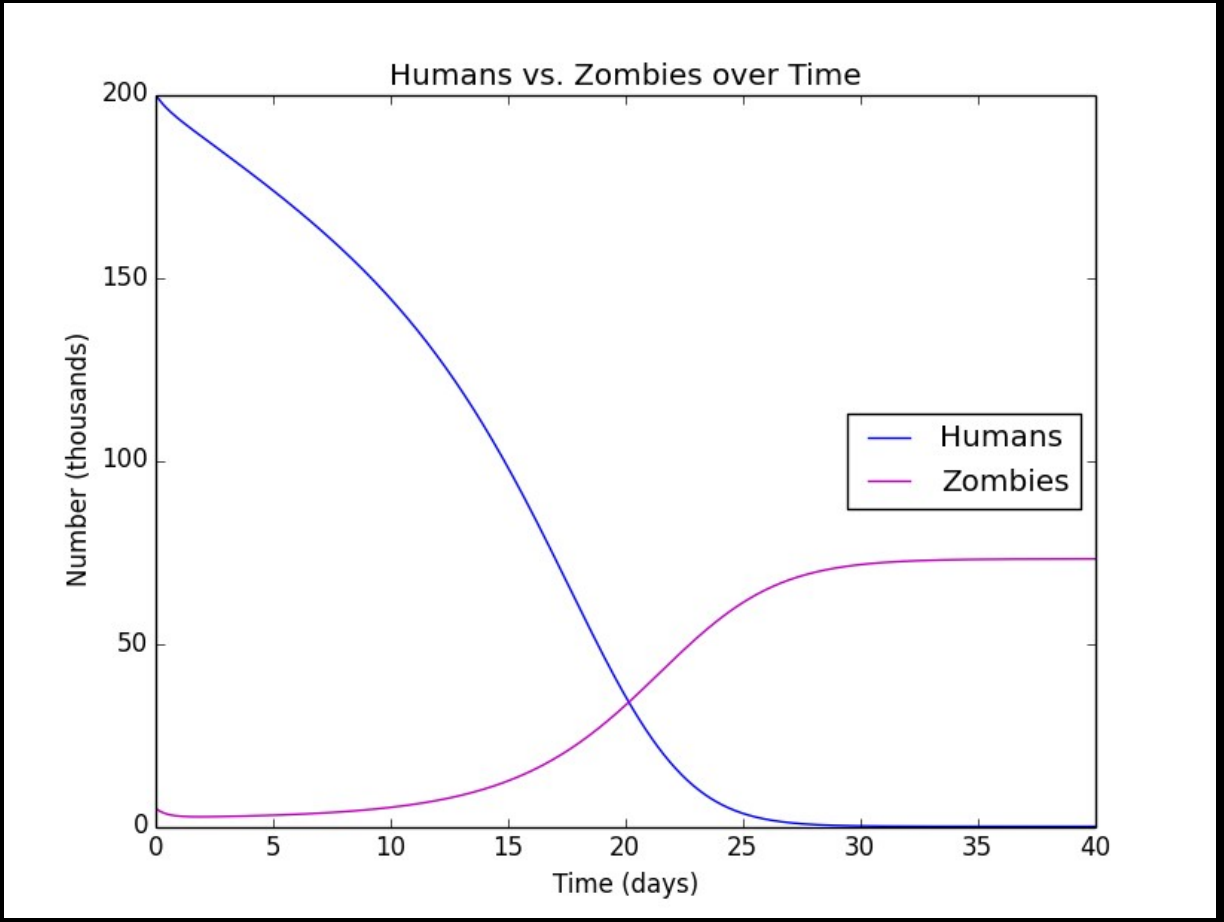
World War Z (ctd.)

- H = Humans, yet to be exposed to the virus
- I = Infected population, not yet zombies
- Z = Zombies
- R = Individuals removed from the system entirely

Governing Equations:

- $H' = H(\alpha-\beta) - \chi HZ$
- $I' = \chi HZ - \delta I - \varepsilon IH/(Z+1)$
- $Z' = \delta I - \phi HZ$
- $R' = \beta H + \varepsilon IH/(Z+1) + \phi HZ$

World War Z Plot



The Walking Dead

- Another popular series in zombie fiction is *The Walking Dead*, which is a T.V. show, comic, and video game
- The rules are similar to those in *World War Z*, in that zombies still move slowly and spread the disease through fluid contact
- This is different from *World War Z* in that all humans are passive carriers of the zombie virus
- When a person dies in this universe, they will turn into a zombie unless dispatched by those around them

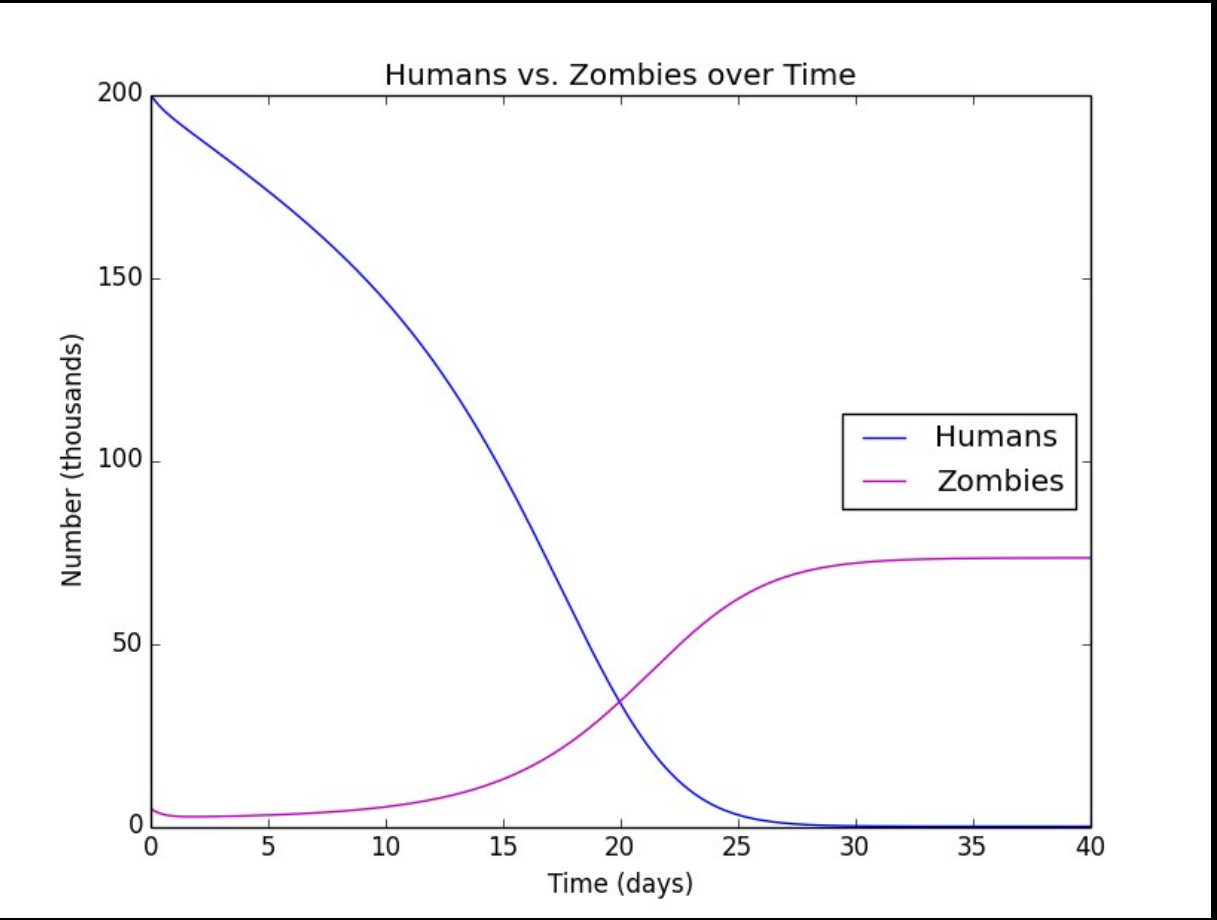
The Walking Dead (ctd.)

- H = Humans, not directly exposed to the virus but active carriers
- I = Infected population, not yet zombies
- Z = Zombies
- R = Individuals removed from the system entirely

Governing equations:

- $H' = H(\alpha-\beta-\chi) - \delta HZ$
- $I' = \delta HZ - \varepsilon IH/(Z+1) - \phi I$
- $Z' = \phi I - \gamma ZH + \chi H$
- $R' = \beta H + \varepsilon IH/(Z+1) + \gamma ZH$

The Walking Dead Plot



The Walking Dead with Cure

- In this case, we examined *The Walking Dead* scenario under the assumption that a cure exists and that it is spread to non-cured individuals
- The cure works by making the body immune to both active (bite-based) and passive (in all people) forms of the infection
- The cure is spread by all cured individuals, but retarded by high concentrations of zombies

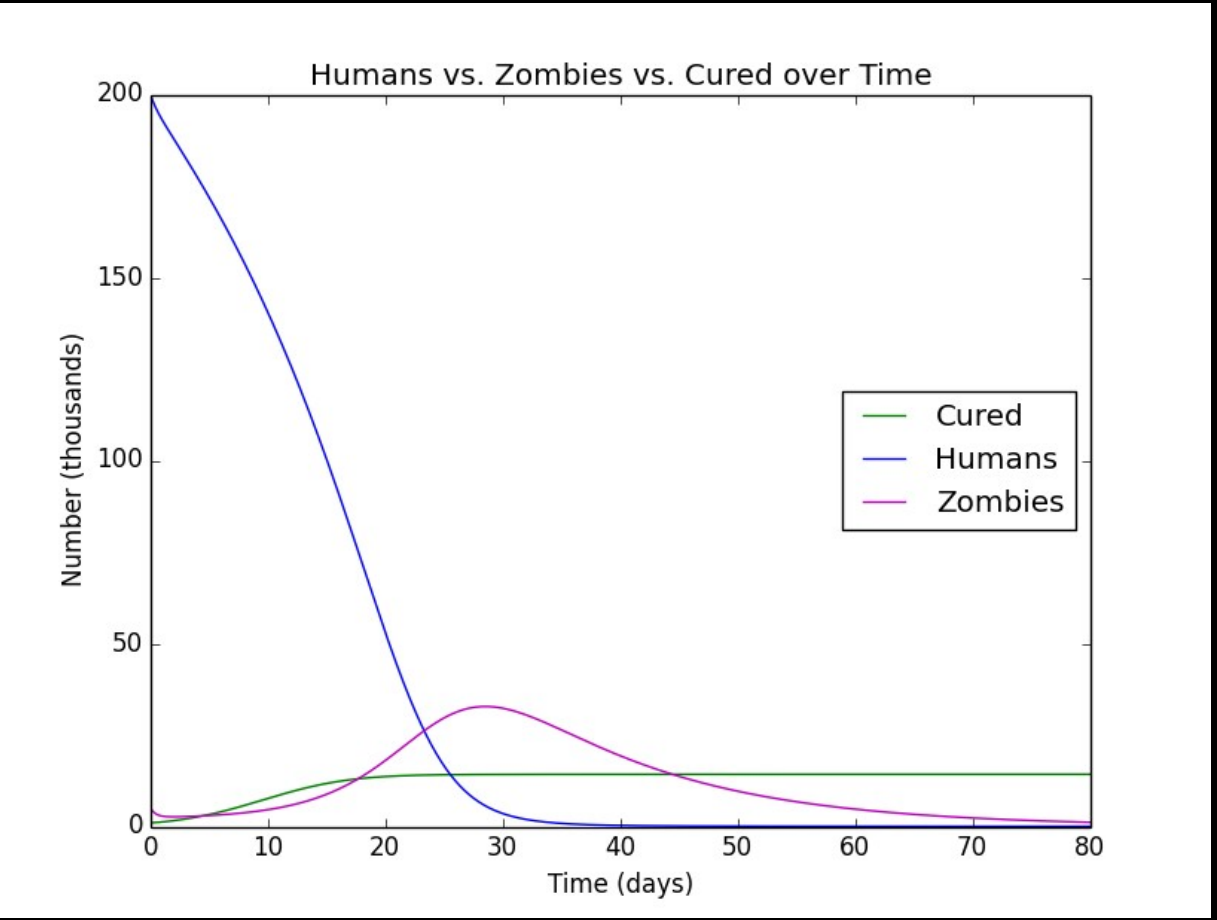
T.W.D. with Cure (ctd.)

- H = Humans, not directly exposed to the virus but active carriers
- I = Infected population, not yet zombies
- Z = Zombies
- S = Cured humans who can no longer become zombies
- R = Individuals removed from the system entirely

Governing equations:

- $H' = H(\alpha-\beta-\chi) - \delta HZ - \eta SH/(Z+1)$
- $I' = \delta HZ - \varepsilon I(H+S)/(Z+1) - \phi I$
- $Z' = \phi I - \gamma ZH + \chi H$
- $S' = \eta SH/(Z+1) – S(\beta+\chi) + \alpha S$
- $R' = \beta H + \varepsilon IH + \gamma ZH + S(\beta+\chi)$

T.W.D. with Cure Plot



28 Days Later

- A classic and somewhat controversial addition to zombie cannon is the film *28 Days Later*
- It popularized the notion of a fast zombie
- Fast zombies are living humans infected with a disease, and thus require nourishment
- They are largely unable to find food, and starve over time

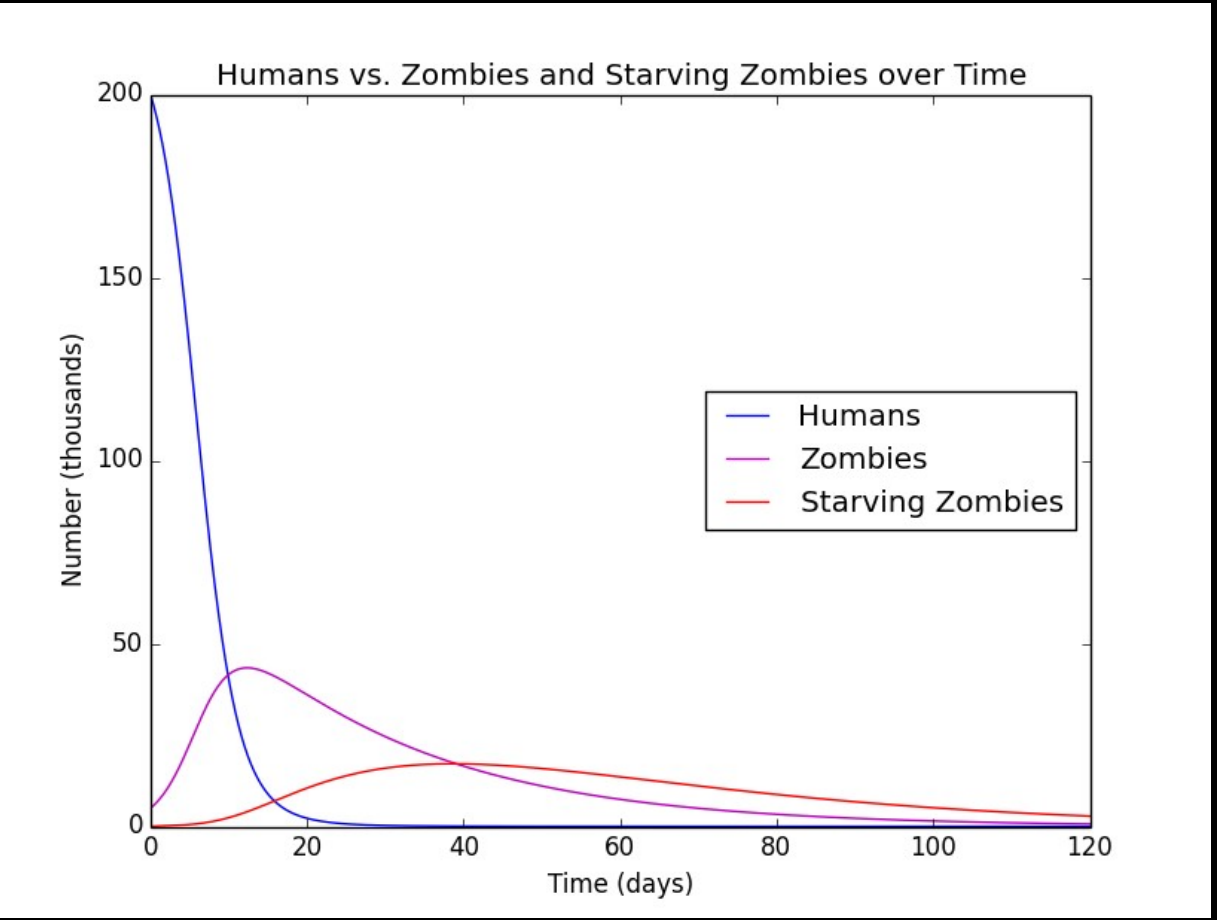
28 Days Later (ctd.)

- H = population of those not exposed to virus
- Z = fast, “healthy” zombies exhibiting no signs of starvation
- D = starved zombies; significantly less effective
- R = removed individuals; all humans and zombies who have been killed

Governing equations:

- $H' = -\alpha HZ$
- $Z' = \alpha HZ - \beta HZ - \chi Z$
- $D' = \chi Z - \delta Z - \varepsilon HD$
- $R' = \beta HZ + \varepsilon HD + \delta Z$

28 Days Later Plot



I Am Legend

- The final work of fiction we examined is the movie *I Am Legend*
- In this story, a modified measles virus goes airborne and infects the entire human population
- 90% of infected people succumb to the disease and die, 9% recover and turn into zombies, and 1% recover and go on to live regular human lives

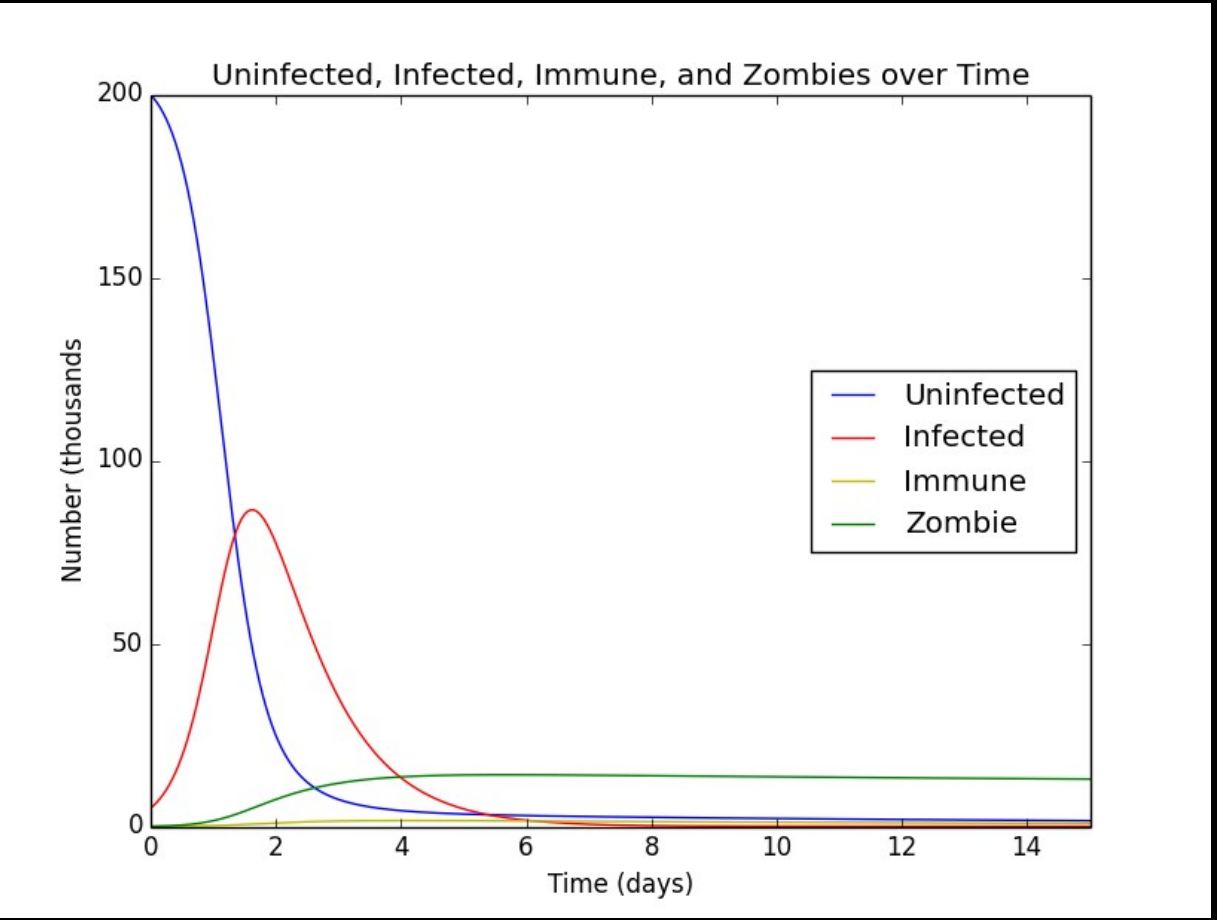
I Am Legend (ctd.)

- H = humans not exposed to the virus
- I = humans exposed to the virus and carrying it
- C = those who have been exposed to the virus and have recovered completely, now immune to the disease
- Z = zombies
- R = dead individuals

Governing equations:

- $H' = H(\alpha - \beta) - \chi HI - \delta HZ$
- $I' = \chi HI - \varepsilon I - \phi I - \gamma I - \eta IZ$
- $C' = \varepsilon I + C(\alpha - \beta) - \delta CZ$
- $Z' = \phi I - \varphi ZH$
- $R' = \delta(H + C)Z + \eta IZ + \gamma I + \varphi ZH + \beta(H+C)$

I Am Legend Plot



I Am Legend with Cure

- The final case we considered is the *I Am Legend* universe where a cure is discovered
- The cure is spread by immune individuals and makes immune those in the uninfected, infected, and (at a slower rate) zombie class
- It is retarded by high concentrations of zombies

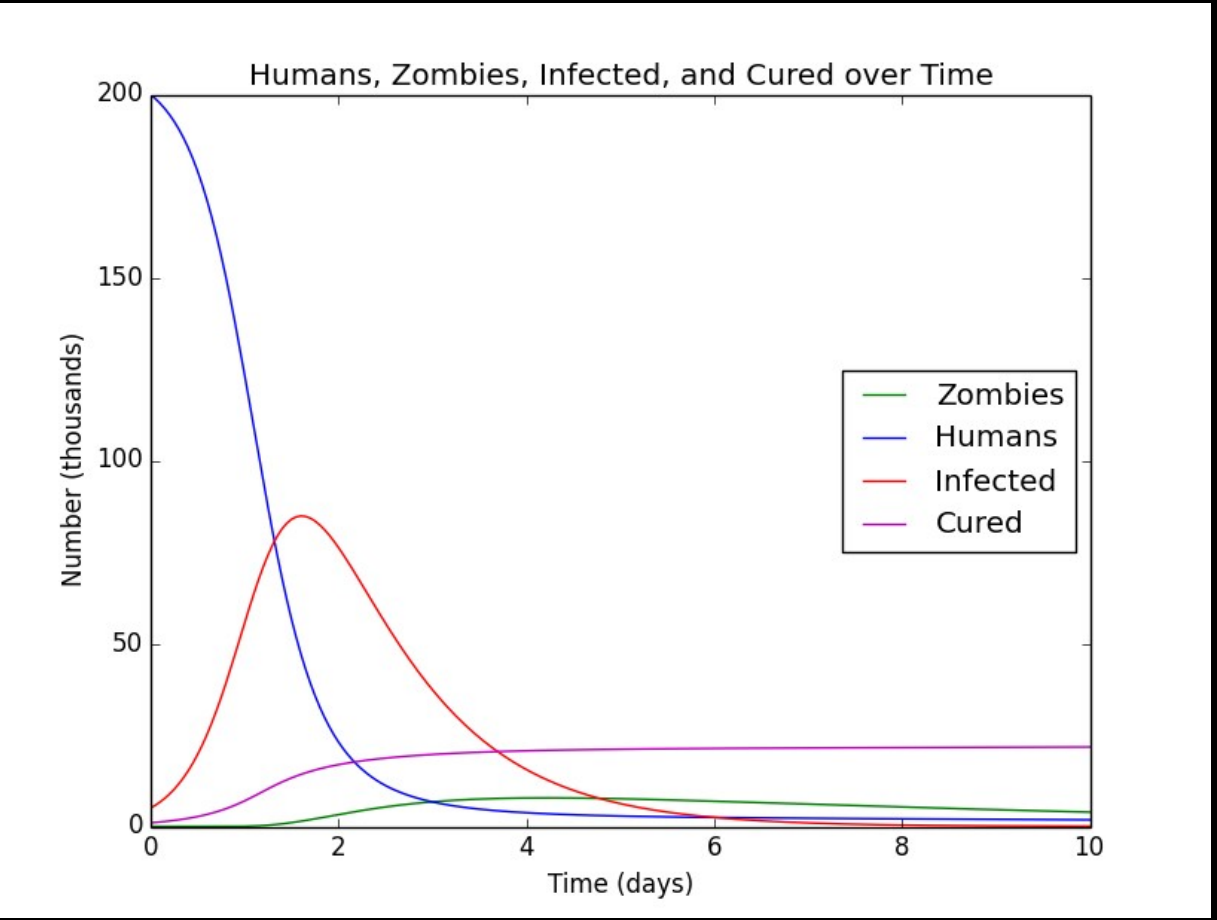
I Am Legend with Cure (ctd.)

- H = humans not exposed to the virus
- I = humans exposed to the virus and carrying it
- C = those who are naturally immune to the virus or have been treated with the manmade cure
- Z = zombies
- R = dead individuals

Governing equations:

- $H' = H(\alpha - \beta) - \chi HI - \delta HZ - \mu HC/(Z+1)$
- $I' = \chi HI - \varepsilon I - \phi I - \gamma I - \eta IZ - \mu IC/(Z+1)$
- $C' = \varepsilon I + C(\alpha - \beta) - \delta CZ + \mu C(H+I)/(Z+1) + \pi CZ$
- $Z' = \phi I - \varphi ZH - \pi CZ$
- $R' = \delta(H + C)Z + \eta IZ + \gamma I + \varphi ZH + \beta(H+C)$

I Am Legend with Cure Plot



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