

ZOMBIES! Resolution and Comments

For everyone who attended my workshop on Wednesday – thank you! It was a privilege to work with you. I’m including what would have been our final bit: using your model to make a prediction – which is really the whole point of building scientific models!

First, let’s revisit Facts, Assumptions, and Need-to-Knows, and Representations for our model. The objective was:

“Build a model that predicts how fast zombification spreads through a population.”

Facts:

Zombies only affect Humans.

There are three non-overlapping sub-populations: Humans (who are susceptible but not yet Zombies), Zombies (the undead), and Removed (dead from all causes, and maybe-dead Zombies).

People become infected when a Human encounters a Zombie.

People can die of natural causes, or become a Zombie.

Zombies come from two sources:

direct contact with a Human, or
resurrection of a Removed person.

Zombies can be Removed if a Human removes their head. (This was not in the film clip, but I gave this piece of information later.)

Assumptions:

Everyone is born susceptible/no one is born a Zombie.

Zombies do not attack other zombies.

** Once a Zombie, there is no recovery.

** There is no delay between infection and symptoms (called a “latency period” in disease models).

(The stars ** mean that we can change these assumptions later and see whether/how they affect our model.)

Need-to-know:

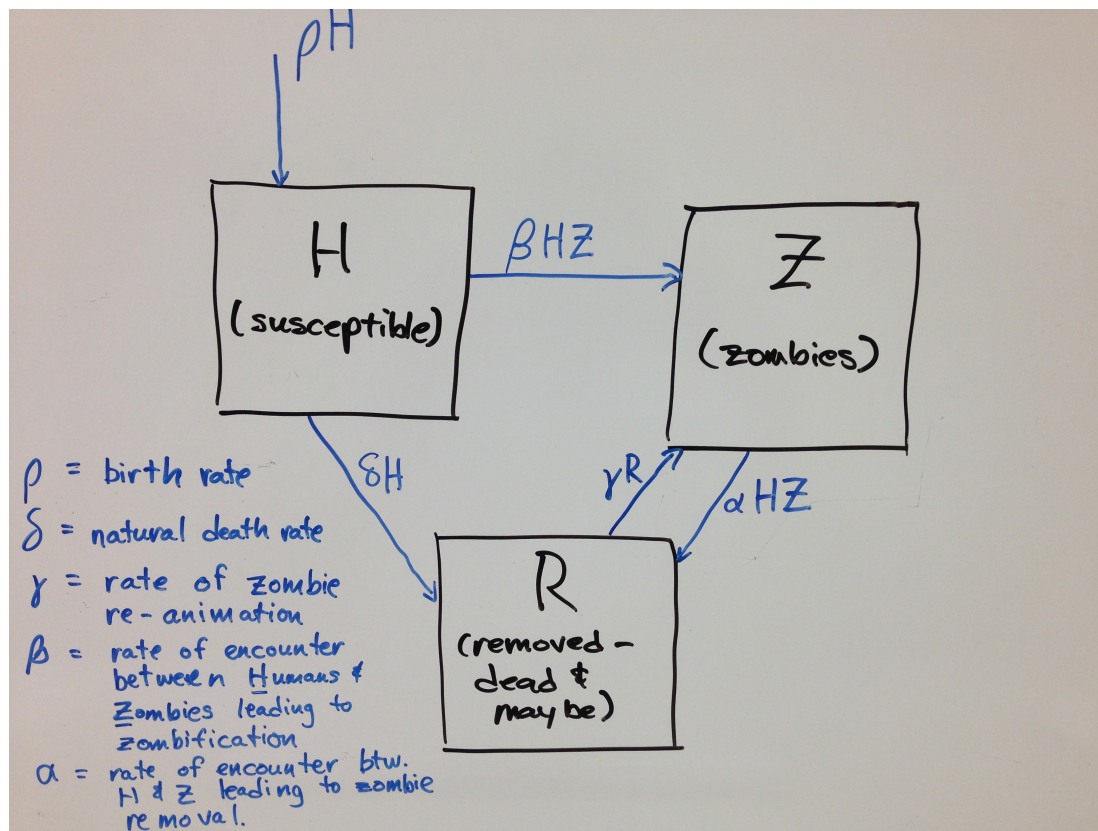
What is the rate of zombification in this population? Put another way, we can ask, is there any hope for Humans?

Representations:

We invested most of our time on our representations. Below is a picture of one way to represent this system, but note that as with ALL models, there are many equally-valid and accurate ways to represent the same information! Which representation we choose would

be based on the target audience for our model – for example, kids, peers, interested non-experts, or other experts. In our case, I emphasized the *mechanistic* (describing-how) model representation.

I also added some variable names for the different rates, just as you all assigned variable names to different parameters in your ping-pong models. So, in this representation, there are variables H , Z , and S which represent the population sizes¹; rates α , β , γ , δ , ρ , that describe how fast individuals enter or leave different populations; boxes that “enclose” each population; and arrows that indicate how an individual can get from one population to another. I used Greek letters for the rates only because it’s a lot harder to mix up a rate with a population that way.



Just as described in Facts, one of two things can happen when a Human encounters a Zombie. Either:

1) The Human wins by removing the Zombie’s head, and the Zombie moves to Removed. This happens at a rate αHZ .

OR:

2) The Zombie wins, infects the Human, and the Human becomes a Zombie. This is βHZ .

By the way, this kind of interaction is called *mass action*, and it is found in a LOT of biological and physical models. For example, predator-prey relationships are mass-action relationships because prey don’t (usually!) just die of fright when they merely SEE a

¹ Actually densities, but for our purposes, we will not worry about this.

predator – the predator and prey have to bump into each other and the predator must kill, handle, and consume the prey. For those of you who teach cellular and molecular biology, enzyme models are also mass-action models: enzyme and substrate must come into contact with one another for the reaction to occur. Particle-collision problems in physics are mass-action problems. So, one neat thing about using models is that we can use the same terms over and over again, depending on how components interact, and science (might) begin to look a lot less random to learners.

Those of you with strong math backgrounds will notice that you can write the system of ordinary differential equations (ODEs) or difference equations from our picture and, using freely available software, can solve the system for the equilibrium. (That wasn't our purpose, but I use this method to teach ODEs in a non-intimidating way, and it would work beautifully for students co-enrolled in pre-calculus, or calc AB or BC. I haven't tried difference equations with middle-school kids who have had Algebra, but I have taught the difference-equation/no calculus approach to college students with little math background.)

But now you should be able to make a broad prediction for our Need-to-Know:

“Is there any hope for humans?”

As you look at the model, what do you think? Use heuristic #9, Think yourself into the problem. Use your model to look at how individuals move, or not, between populations. What's your best guess? Use your model to support your claim.²

Comments:

I chose this model because I knew it would be both accessible and challenging to professionals like you. It has a pretty clear prediction that does not require us to set up and solve the system of ODEs to see. The purpose for that was to illustrate how one model representation could be broadly applicable to kids of many ages, from late elementary through high school.

² A reasonable prediction is that Zombies will eventually win, and that first Humans, then Removed, will decline to zero. Individuals from either Removed or Human populations flow into the Zombie population, but the only way out of the Zombie population is when a zombie's head is removed by a Human. As Humans decline, there are fewer of them to remove Zombie heads, so the Zombie population grows faster and faster. This is also what happens during epidemics of influenza or other infectious diseases: the Infected population grows rapidly as the Susceptible population declines to close to zero. The epidemic dissipates only when there are too few Susceptibles to sustain the infection any more, either because almost all individuals are Infected or Removed (recovered or dead). In biology, we call this a “sink” or an “absorbing state.” Interestingly, most diseases will dissipate even when Susceptibles are still greater than zero. This is a “threshold effect,” and in disease ecology there is an actual term, called *herd immunity*, that describes what proportion of a population can still be Susceptible to a disease – not have it – but the disease won't spread. All of these scenarios can be modeled!

This particular model also has a lot of possible representations: the box-and-arrow diagram (sometimes called a *compartment model*), the system of ODEs (or, for non-calculus students, a system of difference equations). We can even draw a time-series graph, with time on the X-axis and three different curves – one each for H, Z, and R – on the Y-axis as dependent variables. I mentioned that I also emphasize what I call “plain language,” or the verbal explanations and arguments that go along with models. All of these different representations of this one model are multiple ways for both students to succeed, and for you to assess their mastery of concepts and of scientific practices.

As I mentioned at the end of our time together, we (Dr. Diane Ebert-May and I) have submitted a grant proposal to do what we did during the workshop on a longer, sustained, systematic scale in a professional-learning experience. Beginning next summer, in-service and pre-service teachers (undergrad MSU teachers-in-training) will learn about how to build scientific models, and a set of high-impact tools for teaching and supporting scientific modeling to your own students. As pre- and in-service teacher teams, you’ll make a plan to build scientific modeling into your existing curriculum, implement it, assess it, and improve it. If funded, the grant provides the 3.5-day professional learning workshop at KBS, support during your implementation, and a stipend.

If you are interested, please email me. I’ll collect addresses and keep you posted about the status. We hope to hear about this by mid-May.

Go forth and MODEL IT!

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