**Contact Function Lab**

**(1)** Pathogen transmission always requires a ***contact*** between two organisms (or a virus and an organism), but different types of contacts lead to transmission in different disease systems. For each disease system below, identify which two organisms contact, and determine the relevant **transmission mode** for that type of contact. *(12 points – 15 minutes)*

There are several transmission modes that are considered **horizontal transmission** within one generation (usually between unrelated individuals):

*Close-contact transmission*

(1) **ordinary direct contact transmission** (not via sexual transmission)

(2) **sexual transmission**

*Indirect transmission (another species - vector/intermediate host - is required for transmission)*

(3) **vectorborne transmission**

(4) **trophic transmission**

*Environmental transmission (time or space separate the infectious and susceptible hosts)*

(5) **active environmental transmission** (pathogen in environment seeks out host)

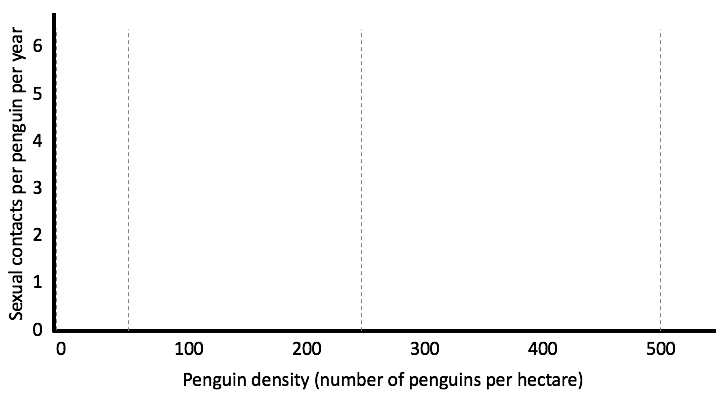
(6) **passive environmental transmission** (fomites, passive spores in soil, etc.)

There can also be **vertical transmission** from parent to offspring across generations.

|  |  |  |
| --- | --- | --- |
| **Disease System** | **Who Contacts Whom?** | **Transmission Mode(s)** |
| EX: Human cold virus | Infectious human  Susceptible human | Ordinary direct contact transmission |
| *Pseudogymnoascus destructans*, the white-nose syndrome fungus | (1)  (2) | (1)  (2) |
| Zika virus (focus on when the virus infects humans) | (1)  (2)  (3) | (1)  (2)  (3) |
| *Euhaplorchis californiensis* (focus on when the trematode infects the bird) | (1) | (1) |

All epidemiological models contain a **contact rate function,** which describes how the number of transmission-relevant contacts that each susceptible host makes changes with host density (hosts per unit area). It is easiest to work with contact rate functions for pathogens with close-contact transmission, because we can usually focus only on contacts between hosts, ignoring the movement, mortality, and contacts made by individual parasite/pathogen stages or vectors.

**(2)** Plot a hypothesized contact rate function for *Herpes penguinamori*, an imaginary sexually-transmitted virus that infects imaginary Queen Penguins. Female Queen Penguins lay eggs twice per year (November and March), and males and females care for the young from November-February and March-June. Males and females always form monogamous pairs, with no extra-pair mating in November or March. However, for reasons that science cannot yet explain, males and females always switch partners between November and March, so each penguin has 2 partners per year, on average, and they mate with each partner a single time. On the graph below, draw one point each for the average number of sexual contacts (and thus opportunities for *Herpes penguinamori* transmission) that you would expect an individual Queen Penguin to make if it were living in one of four populations in Antarctica: (1) a sad lonely rock where a single lost penguin lives all alone, (2) a population with 50 penguins per hectare, (3) a population with 250 penguins per hectare, and (4) a population with 500 penguins per hectare. You can assume that populations 2-4 are roughly 50% male and 50% female. *(4 points – 7 minutes)*



**(3)** If you drew a line connecting the points in the above graph, what shape would you say best describes the contact function? *(1 point – 2 minutes)*

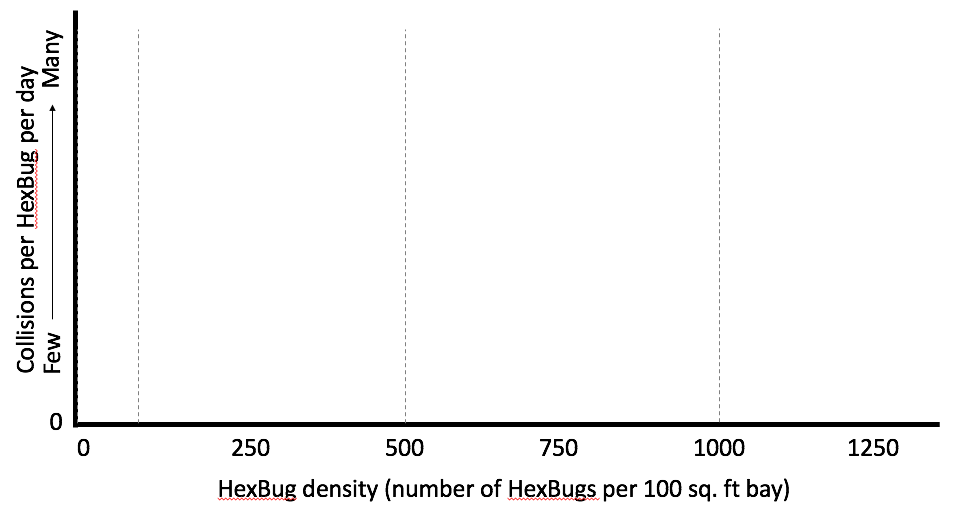
A. A linear, increasing function

B. A constant

C. A nonlinear, increasing function

D. A linear, decreasing function

**(4)** Skynet has been successful, and robots control the earth. You are a T-8000 logistics robot tasked with monitoring the performance of HexBugs (robot scavengers that collect metal dust and other debris to be processed into new machines). Recently, however, you’ve noticed that many of these HexBugs are becoming corrupted with a Robo Pox virus, which you suspect was cunningly released by John Connor, right before his death. The virus seems to transmit from HexBug to HexBug following collisions. In one factory, HexBugs work in four different bays (100 square feet) with different rates of metal dust accumulation, so some bays have been assigned just a few HexBugs, while others have been assigned many HexBugs. On the graph below, draw one point each for the average number of collisions (and thus opportunities for Robo Pox virus transmission) that you would expect an individual HexBug to make if it were working in one of four bays: (1) an empty bay where one lonely HexBug got lost and can’t find its way home, (2) a bay with 10 HexBugs (0.1 per square foot), (3) a bay with 100 HexBugs (1 per square foot), and (4) a bay with 1000 HexBugs (10 per square foot). Note: you don’t have enough information to know exactly how many collisions there will be, but you can hypothesize what the qualitative relationship will be. *(4 points – 7 minutes)*



**(5)** If you drew a line connecting the points in the above graph, what shape would you say best describes the contact function? *(1 point – 2 minutes)*

A. A linear, increasing function

B. A constant

C. A nonlinear, increasing function

D. A linear, decreasing function

**(6)** Let’s test your HexBug contact rate hypothesis. Each group of 4 people has a lunch tray that can serve as a bay microcosm and up to 10 HexBugs. For each density assigned to your group, perform one 30 second trial where you release the HexBugs on the tray and record how many contacts a single focal HexBug makes during that time. You can pick any HexBug as your focal robot, but you should probably pick one that is easy to distinguish from the others. When you are done, have one person add your group data to the Google Sheet. *(6 points – 12 minutes)*

|  |  |
| --- | --- |
| Group | Densities |
| 1 | 1,3,5,7,9,10 |
| 2 | 2,3,4,5,6,8 |
| 3 | 1,3,5,7,9,10 |
| 4 | 2,3,4,5,6,8 |
| 5 | 1,3,5,7,9,10 |
| 6 | 2,3,4,5,6,8 |
| 7 | 1,2,4,6,7,8 |
| 8 | 1,2,4,6,7,8 |

|  |  |
| --- | --- |
| HexBug Density | Number of contacts (30 secs) |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

**(7)** Download the class data from the Google Sheet and use Excel or another program to make a quick graph of the number of contacts per HexBug versus HexBug density. Below, draw a rough version of that graph, including axis scales, axis labels, and the general shape of the contact rate function (i.e., draw in a line or curve, rather than each point). (*12 points –* *10 minutes*)

**(8)** What shape would you say best describes the contact function that you sketched above?

*(1 point – 2 minutes)*

A. A linear, increasing function

B. A constant

C. A nonlinear, increasing function

D. A linear, decreasing function

**(9)** Based on your data, how many contacts would you expect a HexBug to make, on average, if there were 16 (Groups 5-8) or 18 (Groups 1-4) HexBugs per tray? Explain how you made your prediction. *(6 points – 5 minutes)*

**(10)** Test your prediction! Join another group of four people and combine your HexBugs to test one more density. This time, perform three replicates of the same density treatment. When you are done, have one person add your group data to the Google Sheet. *(9 points – 5 minutes)*

|  |  |
| --- | --- |
| Groups | Density |
| 1+2 | 18 |
| 3+4 | 18 |
| 5+6 | 16 |
| 7+8 | 16 |

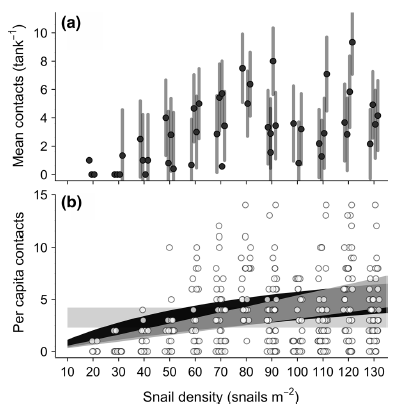
|  |  |  |
| --- | --- | --- |
| HexBug Density | Replicate | Number of contacts (30 secs) |
|  | 1 |  |
|  | 2 |  |
|  | 3 |  |

**(11)** Compare your observations in Question 10 to your prediction in Question 9. Were you right? Why or why not? *(5 points – 5 minutes)*

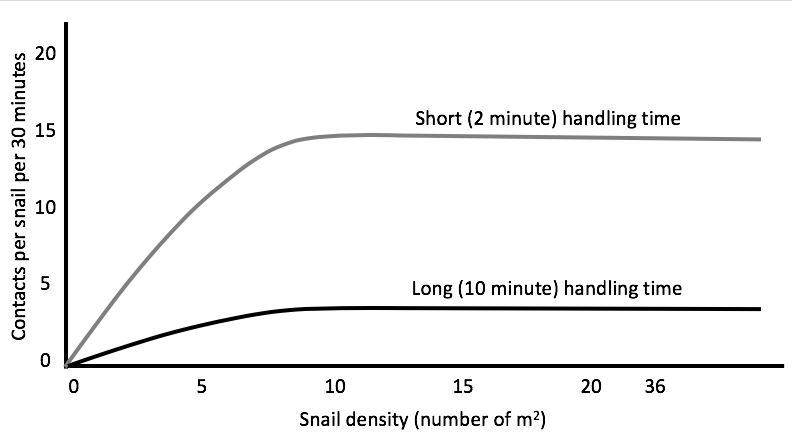
Most epidemiological models assume that contact rate functions come in one of two flavors. In **density-dependent (DD) transmission** models, contact rates are assumed to increase linearly and infinitely with host density. In **frequency-dependent (FD) transmission** models, contact rates are assumed to be constant—they don’t change with host density. The choice to use the DD versus FD contact/transmission functions to model horizontally-transmitted parasites has historically depended on the mode of parasite transmission. This table gives a list of historical preferences and a non-exhaustive list of relevant references:

|  |  |  |
| --- | --- | --- |
| **Transmission Mode** | **Transmission Function** | **References** |
| Ordinary direct transmission (e.g., HexBug Robo Pox virus) | DD | Begon et al. (2002) |
| Sexual transmission (e.g., Queen Penguin herpes) | FD | Begon et al. (2002); Thrall et al. (1993); Antonovics et al. (1995) |
| Vectorborne transmission | FD | Thrall et al. (1993); Antonovics et al. (1995) |
| Trophic transmission | DD (pred-prey models) | Holling (1959, 1965) |
| Active environmental transmission | DD | Fenton et al. (2002) |
| Passive environmental transmission | DD | Fenton et al. (2002) |

However, more recently, people have begun to use nonlinear contact functions more often. In these functions, contact rates increase with host density at first, but they eventually saturate at high contact rates, instead of increasing to infinity. For instance, Hopkins et al. (2018) painted individual snails with (s)nail polish, and then counted how many contacts each snail made in a small arena at different snail densities, just like you did with the HexBugs. They expected to see a DD contact function, but instead saw the nonlinear function below.



**(12)** In the snail–symbiont system in Hopkins et al. (2018), the number of contacts seemed to saturate because each snail contact takes a few minutes, and this contact “handling time” limited the number of contacts that a snail could have in a given period. For instance, if snails’ contacts take 2 minutes, on average, and snails can only have one contact at a time, then snails could only have 15 contacts in a 30 minute trial. If snails’ contacts take 10 minutes, on average, and snails can only have one contact at a time, then snails could only have 3 contacts in a 30 minute trial. Do you think snail density would have a larger effect on transmission if handling times were long or short? Is the longer handling time contact function more similar to DD or FD transmission? Explain your answer. *(4 points – 5 minutes)*



**For further reading about contact functions, you can check out this blog post and/or the snail contact paper:**

<https://parasiteecology.wordpress.com/2013/10/17/density-dependent-vs-frequency-dependent-disease-transmission/>

Hopkins, S.R., McGregor, C.M., Belden, L.K., Wojdak, J.M., 2018. Handling times and saturating transmission functions in a snail-worm symbiosis. Oecologia 188, 277–287.

**SEE HOMEWORK ON NEXT PAGE**

**Homework:**

**Part 1:** Go back to the class data that you downloaded from the HexBug experiment and perform a simulation experiment. Assume that during each trial, all of the HexBugs were susceptible and uninfected with Robo Pox virus, except for the focal HexBug, which was infected and infectious. To simplify things, also assume that each contact that the infectious HexBug made was with a unique susceptible HexBug; for instance, three recorded contacts means contacts with three unique susceptible hosts. (This assumption would be more valid in larger populations with bigger trial arenas.) Now assume that during each of those contacts, the focal HexBug had a 50% chance of infecting the susceptible HexBug. For each contact, flip a coin to simulate whether infection was successful or not: heads is successful, tails is not successful. (If you don’t want to flip a coin, you can also simulate coin flips in Excel by writing =RANDBETWEEN(0,1) in a cell and hinting enter; let’s say 1 is heads/success and 0 is tails/failure.) Write down the results of your coin flips in a new column, like in the example below. Then tally up the number of new infections (the number of heads) and write the answer in a new column. Repeat this process for the first 24 rows in the class dataset.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Group** | **HexBugDensity** | **Rep** | **Contacts** | **CoinFlips** | **NewInfections** |
| 2 | 2 | NA | 2 | HH | 2 |
| 2 | 3 | NA | 3 | HTT | 1 |

**Part 2:** In Excel or another program, make a plot of the number of new infections (Y axis) versus HexBug density (X axis). Make sure to label your axes. There should be 24 points on your graph. Print the graph out and attach it to this worksheet. *(15 points)*

**Part 3:** Pathogens can only spread through populations in epidemics if each infected individual infects more than one other individual, on average. In systems with density-dependent transmission, there is a threshold host density below which the average number of new infections per infected individual is less than one (no epidemic) and above which the average number of new infections per infected individual is greater than one (creating an epidemic). Consult the graph that you just made and determine roughly which HexBug density would be the threshold density. Explain your answer. *(15 points)*