Name ____

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ECOL 8520

Spring 2017

FUNDAMENTALS OF DISEASE BIOLOGY II
Exam 1

How to ace this exam: (1) Read each question carefully, (2) STOP AND THINK ABOUT IT, (3) Be concise and specific (4) Use only the space provided. There are a total of 50 points possible. The points for each question are displayed – bear this in mind and utilize your time accordingly. Questions appear on both sides of the paper. Please write lucidly and legibly.

Good Luck!

Points

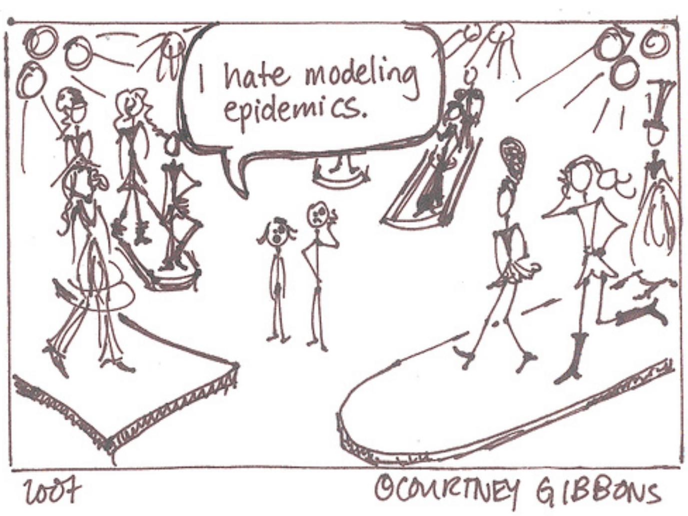
Points Page 1: ________/16

Points Page 2: ________/18

Points Page 3: ________/13

Points Page 4: ________/3

TOTAL: ________/50



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A. Multiple Choice Questions (2 pts each):

Circle the single best answer.

1) Which of the following is NOT true of R_0 in density-dependent transmission?
   a. Increases with increasing transmission rate
   b. Increases with increasing host recovery rate
   c. Decreases with increasing virulence rate
   d. Decreases with increasing host death rate
   e. All of the above

2) You know the basic reproductive number of phocine distemper virus in harbor seals is about 5, the probability of dying from it is ~60% and the annual *per capita* birth and death rates in a given population are both 0.1. What percentage of the population will need to be vaccinated in order to prevent an outbreak?
   a. 100%
   b. 95%
   c. 80%
   d. 20%
   e. 83%

3) In which country do you expect to observe the most influenza cases in July?
   A. USA
   B. Mexico
   C. Argentina
   D. Senegal
   E. China

B. True/False (2 pts):

Mark the following as being true (T) or false (F) based on the best answer to the question.

__F__ 4) R_0 will decrease in a frequency-dependent transmission system as the number of susceptibles decreases.

C. Matching (2 pts):

5) Match the general mechanism of seasonality with the correct example(s).

   A. Host exposure via contact
   B. Host susceptibility
   C. Host population size

____B____ Photoperiodism and latitudinal differences in Polio seasonality in the US
____A/C__ Measles epidemics in Niger
____C____ Seasonally-pulsed births and latitudinal trends in polio outbreaks in the US
____A____ A spike in measles cases occurs every April in London

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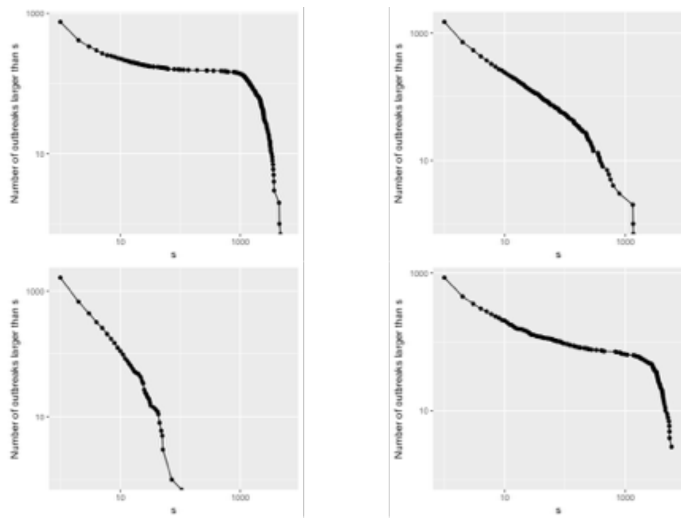
D. Short-answer Question

6) The plot below depicts the outbreak size distribution for four different values of R_0. Order them by increasing R_0. For which plot(s) is $R_0 > 1$? (6 pts)



C, B, D, A (or 3, 2, 4, 1)

A and D (or 1 and 4) are "supercritical" (R_0>1)

7) It has recently been suggested that measles determines polymicrobial herd immunity.

A. What does "polymicrobial herd immunity" mean? (2 pts)

Refers to situation where transmission and pathogenesis of one infectious disease is impacted by another pathogen, especially following vaccination against that pathogen.

B. What evidence was provided in support of this claim? (4 pts)

Mina et al. (2015) showed an association between measles incidence and mortality due to non-measles infectious diseases (1 pt). Further, they documented declines in mortality due to non-measles infectious diseases when the measles vaccine was rolled out in England & Wales, USA and Denmark (1 pt). The association was strongest if the 'measles shadow' lasted 30 months (1 pt). The authors also demonstrated higher odds of acquiring bacterial invasive disease within 30 months of a measles infection (1 pt).

C. What mechanism is believed to be responsible for immunomodulation by the measles virus? (2 pts)

Measles-induced amnesia thought to be due to depletion of pre-existing CD150+ memory lymphocytes and B cells.

D. What is the measles paradox? (1 pt)

The fact that measles suppresses the immune system while simultaneously engendering lifelong immunity to the measles virus.

8) Suppose we have two different outbreaks of disease in two different cities with similar population sizes. The size of the first outbreak is larger than the second. Are we able to conclude the R_0 associated with the first outbreak is greater than the second, and why? (3 pts)

No. Demographic stochasticity (1 pt) generates variability in the size of outbreaks (1 pt) for a particular value of R_0. This means that it is possible that the disease in the city with a smaller outbreak has a larger R_0 (1 pt).

9) Measles outbreaks have been monitored extensively in England & Wales for the past few hundred years.

A. What does the critical community size represent? (1 point)

Smallest population of hosts below which disease frequently goes extinct, and above which it persists.

B. After vaccination with an efficacious vaccine, would we expect any change in the critical community size? Explain your answer. (2 points)

We would expect an increase in the CCS (1 pt) because vaccination would act in the same way as reducing the effective birth rate – thus, larger population would be needed to ensure chain of transmission is unbroken inbetween epidemics (1 pt).

C. Identify and explain one potential reason for why we do not observe what we expect after the introduction of the routine immunization program in England & Wales in 1968. (2 points)

Best explanation at present is that spatial asynchrony (1pt) led to the rescue effect (1 pt), thereby expected increase in fade out frequency not observed.

10) You are presented with the following set of equations, parameters and initial conditions:

$$\frac{dS}{dt} = \mu N - \mu S - \beta S I$$

$$\frac{dI}{dt} = \beta S I - \mu I - \gamma I - \alpha I$$

$$\frac{dR}{dt} = \gamma I - \mu R$$

μ=0.3, α=0.4, β=0.2, γ=0.1, S(0)= 100, I(0)=1, and R(0)=0

a. Describe the biological meaning of each parameter. (4 pts)

μ= host per capita birth/ death rate (1 pt)

α= virulence (death rate due to pathogen) (1 pt)

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β= infection rate or transmission rate between hosts (1 pt)

1/γ= recovery rate of infected hosts (1 pt)

b. By studying the spread of an infectious disease at the start of an epidemic, derive the formula for R_0 and calculate this value for the parameters given. (4 pts)

$\frac{dI}{dt} = \beta SI - (\gamma + \mu + \alpha)$ (1 pt for correctly identifying the equation to derive these from)

Assume I =1 and S = N. Infection starts with 1 person and, by definition of R_0, everyone at the beginning of the epidemic is susceptible. (1 pt for identifying these substitutions and substituting them correctly)

$$\frac{dI}{dt} = \beta N - (\gamma + \mu + \alpha)$$

This quantity needs to be positive for the pathogen to invade (R_0>1). For this to happen, $\beta N > (\gamma + \mu + \alpha)$.

Therefore we set R_0 to $\beta N/(\gamma + \mu + \alpha)$. (1 pt for this step)

R_0= $\beta N/(\gamma + \mu + \alpha)$= (0.2*100)/(0.3 + 0.1 +0.4) = 20/0.8 = 25 (1 pt for correct R_0)

c. Derive the formula for threshold density and calculate this value for the parameters given. (3 pts)

The threshold density is when R_0 =1 so you set the above R_0 equation to 1 and solve for N.

R_0 = $\beta N/(\gamma + \mu + \alpha)$ =1 (1 pt for setting R_0=1)

$\beta N = (\gamma + \mu + \alpha)$

$N_T = (\gamma + \mu + \alpha)/\beta$ (1 pt for correct N_T formula)

$N_T = \frac{0.3+0.1+0.4}{0.2} = 0.8/0.2$= 4 (1 pt for correct threshold density value)