**MODELLING DISEASE SPREAD (35 MARKS)**

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| Assessment Type: | Science Inquiry |
| Outcome: | Outcome 1: Science Inquiry practical  Outcome 2: Infectious diseases |
| Unit Content: | Unit 4 Infectious diseases  The spread of a specific disease involves a range of interrelated factors, including growth of pathogen population, density of host population and mode of transmission. |

**TASK**

An investigation to explore the effects of two transmission factors (variables) on the transmission of a disease.

**PROCEDURE**

Access the web link and familiarise yourself with the simulator before starting your investigation

<http://www.learner.org/courses/envsci/interactives/disease/disease.html?initLesson=1>

Choose one of the diseases available on the simulator. Perform your own investigation.

**Submit the following:**

**RESULTS**

Present your findings using a maximum of 3 data tables and 3 graphs.

**DISCUSSION**

Clear statement of the results of the simulations

Scientific explanations for each set of results

**RESEARCH QUESTION**

After the discussion of data, develop a research question in order to produce a hypothesis for **further research (based on what you have already simulated – extend your investigation in one area)**

**CONCLUSION**

Of the diseases studied in this course, select evidence from real populations that supports your simulation data.

**What you need to do**

Refer to this assessment brief and the mark scheme to complete the task.

**This task is worth 5% of your course mark**

**Use the simulator below to investigate a particular transmissible Australian disease.**

**1)** Familiarise yourself with the simulator

**2)** Research a disease that may or may not occur in Western Australia/Australia and its ‘virulence’ factors. Run the simulator using ‘base-line’ parameters to observe transmission.

**3)** Use the website simulation below to investigate the effect of 2 different factors on the transmission rate of the chosen disease and compare with the ‘base-line’ results.

**Tables:**

* There is no need to include a prediction
* You should include an ‘average’ row for each table (average of 3 simulations)

**Graphs:**

* Only graph the averages
* Use ‘contagion rate’ as your dependent variable (more accurate and easier to interpret especially if one of the variables you are testing is ‘density of population’).
* Your independent variable will be the transmission factor you are investigating.

**Simulation website**

<http://www.learner.org/courses/envsci/interactives/disease/disease.html?initLesson=1>

<https://bit.ly/2LmRIOr>

Investigate 2 of the variables below, known to affect disease transmission

* length of time an individual is contagious
* disease transmission rate
* population density
* population mixing
* vaccination rate

**MARK SCHEME**

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| --- | --- | --- |
| **RESULTS** | Marks | Your mark |
| * Data collection   *Sufficient data correctly presented in the 3 tables* | 6 |  |
| * Representation of data   *Correct representation of collected data in graph form* | 9 |  |
| **DISCUSSION** |  |  |
| * Clear statement of the results of the simulations | 6 | Sim.1 =  Sim. 2 =  Sim. 3 = |
| * Scientific explanation for each set of results provided | 6 | Sim.1 =  Sim. 2 =  Sim. 3 = |
| * Developed a research question for a hypothesis for further research | 2 |  |
| **CONCLUSION**  *Of the diseases studied in this course, select evidence from real populations that support your simulation data* | 6 |  |
| **Total** | 35 |  |

**Interactive Labs**

[[](http://www.learner.org/courses/envsci/interactives/disease/disease.html)  
OPEN SIMULATOR](http://www.learner.org/courses/envsci/interactives/disease/disease.html)

**Disease Lab**

Overview - Introduction

[HELP](http://www.learner.org/courses/envsci/interactives/disease/disease_help.php) – To familiarise you with the simulator

**Lesson 1 -** [The Virgin Field](http://www.learner.org/courses/envsci/interactives/disease/virgin_field_1.php)

[- Step 1](http://www.learner.org/courses/envsci/interactives/disease/virgin_field_1.php)

[- Step 2](http://www.learner.org/courses/envsci/interactives/disease/virgin_field_2.php)

[- For Your Consideration](http://www.learner.org/courses/envsci/interactives/disease/virgin_field_fyc.php)

**Lesson 2 -** [Vaccination](http://www.learner.org/courses/envsci/interactives/disease/vaccination_1.php)

[- Step 1](http://www.learner.org/courses/envsci/interactives/disease/vaccination_1.php)

[- Step 2](http://www.learner.org/courses/envsci/interactives/disease/vaccination_2.php)

[- Step 3](http://www.learner.org/courses/envsci/interactives/disease/vaccination_3.php)

[- For Your Consideration](http://www.learner.org/courses/envsci/interactives/disease/vaccination_fyc.php)

**Lesson 3 -** [Pandemic](http://www.learner.org/courses/envsci/interactives/disease/pandemic_1.php)

[- Step 1](http://www.learner.org/courses/envsci/interactives/disease/pandemic_1.php)

[- For Your Consideration](http://www.learner.org/courses/envsci/interactives/disease/pandemic_fyc.php)

**1) Overview**

Human and animal diseases are often caused by viruses or bacteria. Over the past two hundred or so years, vaccines have eradicated some of these diseases. Others have returned to haunt humans with new and ever-mutating strains, or revived when vaccination programs were interrupted. Communicable diseases may spread in different ways: through blood, air, feces/urine, food, or water. The World Health Organization (WHO) and the Center for Disease Control (CDC) keep constant watch over the most potentially dangerous diseases and the most likely threats to various world populations.

New diseases (such as MRSA) and the possibility of a pandemic avian flu have also raised international concerns about health. As populations grow (see the [Demographics lab](http://www.learner.org/courses/envsci/interactives/demographics/index.php)), especially when packed densely as in urban areas, there is increased risk of disease transmission. This lab will let you explore various diseases: Kold, a caricature of the common cold; Impfluenza, which resembles influenza; Neasles, with the high transmission rate of measles; and Red Death, a fast-spreading epidemic with a high mortality rate.

What factors come into play in the spread of these diseases? And what can we do to counter them?

[Word document icon](http://www.learner.org/courses/envsci/interactives/disease/data_table_disease.doc)Download the Data Table to keep a record of your data.

**HELP – Explanations to help you use the simulator**

**Tools of the Simulator**

**Simulator Controls**

Simulator control buttons

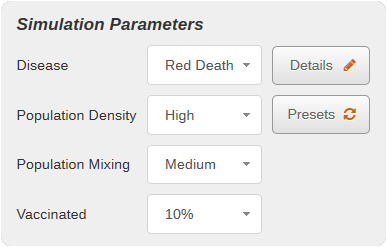
**Reset** - Returns the simulator to Day 0.

**Pause** - Interrupt a Run.

**Step** - Advance the simulator one day.

**Run** - Run the simulator to day 100.

**Simulation Parameters**



**Disease** - A pull-down menu that lists diseases to explore: Kold, Impfluenza, Neasles, and Red Death. Though the disease names are evocative of real diseases, they are simplified caricatures, hence the cartoon names.

**Details** - The Details button allows you to examine and change the parameters of the current disease. ([See below](http://www.learner.org/courses/envsci/interactives/disease/disease_help.php#disease_details).)

**Presets** - The Pre-sets button restores pull-down selections to the defaults for the current Lesson.

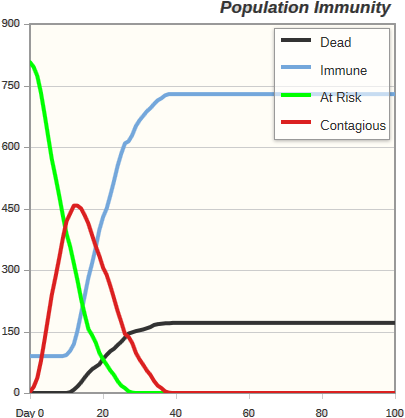
**Population Density** - A pull-down menu to select how crowded and populated the population display area will be. There are three options: Low for 200 initial population, Medium for 600, and High for 900.

**Population Mixing** - A pull-down menu to select how often contagious people infect others at a distance, beyond their immediate neighbours. There are four options for Population Mixing:

* None—contagion only passes to immediate neighbors
* Low—rare distance interactions
* Medium—moderate interaction in the community
* High—contagion can pass throughout the community

**Vaccinated** - If available for the current Lesson, Vaccination is a pull-down menu to select what percentage of the population is already immune to the disease on day 0, when simulation begins.

**Population Immunity Graph**



This graph shows the simulator progress over time. The y-axis is population and the x-axis is the day. Four lines appear on the graph. You can mouse over (or tap) a point on the line to get a tooltip giving the line's value at that point. On the graph legend, you can click a line's name to turn the line on or off.

**Contagious** - The number of people who are sick and contagious.

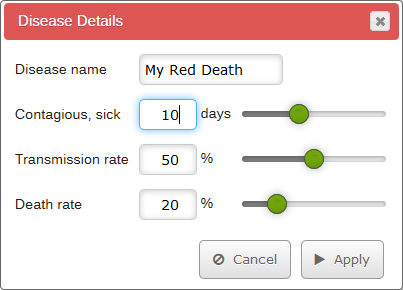
**Immune** - People who were either vaccinated on day 0, or got sick and got better. Immune people cannot catch or transmit the disease.

**At Risk** - People who can still get sick if exposed.

**Dead** - People who have died as a result of the disease.

**Disease Details**

Click the Details button to the right of the Disease pull-down to open the Disease Details dialog.



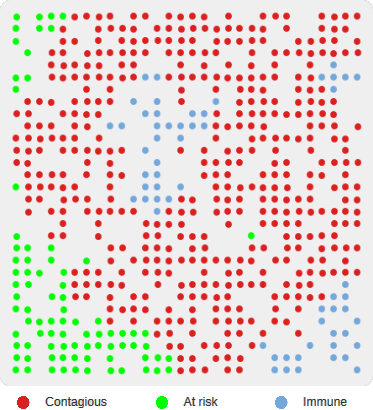
**Disease Name** - The name for your custom disease if you make any changes. The dialog won't change the preset 4 diseases, but rather add your new disease to the pull-down list.

**Contagious, sick** - Use the slider or text entry box to set the number of days a sick individual will remain sick and be contagious to others. There is no incubation period.

**Transmission rate** - This is the probability that an “at-risk” person (not immune) will catch a disease when exposed to it. Exposure comes from either a sick neighbor or a long-range interaction from a sick non-neighbor (population mixing). This probability is per day, so if a neighbor is sick for 5 days, the person has 5 chances at this rate to catch the disease. Use the slider or text entry box to set the rate.

**Death rate** - Use the slider or text entry box to set the probability that an individual will die as a result of the illness. Death happens on the last day of illness—a sick person either gets well (and immune) or dies after the set number of sick days.

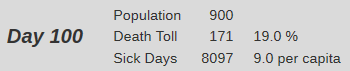
**Population Display**



Each dot represents an individual. The color legend is at the bottom of the display. Contagious is red, Immune is blue, and At Risk is green. The dead are removed from the field as they expire. Immune dots do not wiggle, to show that they are not involved in disease propagation.

**Vital Statistics**

Above the population display:



**Day** - Current day in the simulator's 100-day Run.

**Population** - The starting number of people within the scenario.

**Sick Days** - The total number of sick days taken for the entire population. The number per capita is the number of sick days divided by the population.

**Death Toll** - The total number of people in the population who have died as a result of the disease. The percentage next to Death Toll tells you the percentage of the total population that died of the disease. Note that dead individuals are removed from the population display.

**Lesson 1: The Virgin Field > Step 1** (This was started by Mr. Edwards)

Most diseases begin with what is called "the virgin field"—a scenario in which humans have no natural or man-made immunity to the disease. To see the progress of a disease in a particular community, start by predicting how many sick days will be reported when you run the Kold disease through a medium-sized population, and **record your prediction in the** [**data table**](http://www.learner.org/courses/envsci/interactives/disease/data_table_disease.doc). In this first run-through, we'll assume that the population does not move around the field; they interact with their neighbors, but the contagion cannot travel long distances. (Population Mixing remains set to None.)

Make sure the Lesson is set to Virgin Field and **Run the simulator to 100 days three times, recording data in your table**. Note that a Kold lasts 5 days (see the Details button next to Kold). So the number of Kold cases is roughly the simulated number of sick days divided by 5. Then answer the following:

1. Do you get the exact same results each time? How do the results compare to each other and to your prediction?
2. What factors might contribute to susceptibility to the disease?

**LESSON 1: Transmission of ‘Kold’ disease**

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| **Lesson 1:**  **Step 1** | Population Number | Starting Number of Contagious People | Sick Days Reported | Contagious | Contagion Rate (per capita) (no. of sick days per pop. no.) |
| Prediction | 600 | 3 |  |  |  |
| Simulation Run 1 | 600 | 3 |  |  |  |
| Simulation Run 2 | 600 | 3 |  |  |  |
| Simulation Run 3 | 600 | 3 |  |  |  |

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| **Responses to Questions: Step 1** |
| **Q1)** various  **Q2)**  Distribution of initial cases? (Close together or widely separated)  Location of initial cases within the population (edge of population, or middle of population)  **Your susceptibility appears directly related to the number of ‘close’ neighbours you have.**  1) Distribution of initial cases (Close together or widely separated)  **close:** 1004, 1735, 1512  **separated:** 787, 1587, 852, 977, 1192  2) Location of initial cases within the population (edge of population, or middle of population)  **edge:**  **middle:**  3) Both factors:  **close together and in the middle:**  **close and on the edge:** 112, 267  **separated and in the middle:**  **separated and on the edge of population:**  **Notes:**  If the original cases have a greater number of gaps around them the disease does not spread as far.  If the original cases are close together, the immunity acquired by individuals surrounding one infected case will prevent the spread from the other original cases from going too far.  Original cases that are ‘completely surrounded’ by ‘at risk’ individuals seems to result in a large spread.  Cases surrounded by only 2 or 3 ‘at risk’ individuals and/or are on the edge of the population do not spread the disease very far.  **Your susceptibility appears directly related to the number of ‘close’ neighbours you have.** |

**The Virgin Field > Step 2**

Unlike some of the other interactive labs, this model has some randomness built in to reflect the real spread of a disease, which is a matter of probabilities. Despite this variability, you can get a sense for what effect each factor has on disease spread.

Before running the simulator, predict whether the sick days per capita will be higher or lower with **low population density**. **Record your prediction in the data table** and then run the simulator to 100 days three times, **recording the data each time**. **Make a prediction for high population density, record it in the data table**, and run the simulator three times, **recording that data in the table**. Answer the following:

1. What could be done to prevent the spread of disease in a low population density?
2. What kinds of challenges would high population density present?

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| **Lesson 1:**  **Step 2** | Population Number | Population Density | Starting Number of Contagious People | Sick Days Reported | Contagious | Contagion Rate |
| Prediction 1 (low) | 200 | low | 3 |  |  |  |
| Simulation Run 1 | 200 | low | 3 | 42 | 6 (day 4) | 0.2 |
| Simulation Run 2 | 200 | low | 3 |  |  |  |
| Simulation Run 3 | 200 | low | 3 |  |  |  |
| Prediction 2 (high) | 900 | high | 3 |  |  |  |
| Simulation Run 1 | 900 | high | 3 | 4342 |  | 4.8 |
| Simulation Run 2 | 900 | high | 3 |  |  |  |
| Simulation Run 3 | 900 | high | 3 |  |  |  |
| **Responses to Questions: Step 2** | | | | | | |
| **Q1)**  **Q2)**  **Notes:** | | | | | | |

**The Virgin Field > For Your Consideration**

Population mixing in a contagious area is analogous to increasing population density. Both increased density and increased movement of people bring more contagious people into contact with susceptible people, thus increasing the spread of disease. The rate of spread also has a lot to do with the nature of the disease: how long a sick person is contagious, the method of transmission (air, water, food, bodily fluids), the transmission rate (i.e. the chance that any particular encounter will transmit the disease), and the death rate due to the disease (Kold is nonlethal).

Disease spread is considered epidemic if it exceeds the norm, which differs depending on the disease in question. Less lethal diseases will have higher transmission rates without a sense of emergency (such as the common cold or the common flu) while a small increase above the norm in diseases such as tuberculosis, polio, HIV, Ebola, or other such highly lethal or disabling viruses, results in a state of emergency. In addition, there are major differences between bacterial and viral illnesses. Antibiotics work for bacterial disease, and sometimes vaccines can be developed for viral disease. There isn't always a quick fix to an illness, however, since both bacteria and viruses mutate and alter their genetic makeup, making previous treatments non-effective.

**Lesson 2: Vaccination > Step 1**

In this lesson we look at “Impfluenza”. Start by examining the disease propagation in a virgin field. First, click the Details button on Impfluenza and Kold to compare the differences between the two diseases. Based on these differences and what you know about Kold, predict the sick days per capita and death rate for Impfluenza at medium population and medium mixing. **Record your prediction in your data table.**

In the simulator, select Lesson Vaccination, then set Vaccinated to None to provide the virgin field effect. Population Density and Mixing should both be Medium. **Then run the simulator to 100 days three times.** Answer the following:

1. Was your prediction correct? If not, why not?
2. Notice that Impfluenza, unlike Kold, has a death rate. How many people die, on average, when you run the simulator on the virgin field?
3. How does a death toll change precautionary factors? What kinds of precautions might you take with Impfluenza that you might not have taken with Kold?
4. Would you consider Impfluenza's death toll to warrant a “state of emergency”? How high would the numbers have to be for this to happen?

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| **Lesson 2:**  **Step 1** | Population Number | Population Density | Starting Number of Contagious People | Sick Days Reported | Contagious | Dead |
| Prediction (medium/medium) |  |  |  |  |  |  |
| Simulation Run 1 |  |  |  |  |  |  |
| Simulation Run 2 |  |  |  |  |  |  |
| Simulation Run 3 |  |  |  |  |  |  |
| **Responses to Questions: Step 1** | | | | | | |
| **Q1)**  **Q2)**  **Q3)**  **Q4)**  **Notes:** | | | | | | |

**Vaccination > Step 2**

In this step we vaccinate a certain percentage of the population against Impfluenza. This represents a real-life scenario, where the country vaccinates a certain portion of its population against the expected influenza strains for that year.

Select Lesson Vaccination. **Predict and record** the sick days per capita and death toll % at medium population and medium mixing, with 50% of the population vaccinated. Run the simulator three times and **record your data**. Repeat with 90% vaccinated. **Compare your results to the table in Lesson 2 Step 1**.

Then change the parameters to high population and high mixing. **Predict** what will happen at 50% and 90% vaccination, and run the simulator three times with each, **recording your data** for each run. Answer the following:

1. For the first set of parameters (medium/medium), how does the vaccine reduce sick days? How large a percentage of the population would have to be immunized in order to bring the sick days per capita *reliably* below 0.1 per capita?
2. How does using vaccination compare to changing the mixing or population density?

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| **Lesson 2:**  **Step 2** | Population Mixing | Population Density | Starting Number of Contagious People | Percentage of Population Affected | Sick Days Reported | Contagious |
| Prediction 1 (medium/medium) |  |  |  |  |  |  |
| Simulation Run 1 |  |  |  |  |  |  |
| Simulation Run 2 |  |  |  |  |  |  |
| Simulation Run 3 |  |  |  |  |  |  |
| Predication 2 (high/high) |  |  |  |  |  |  |
| Simulation Run 1 |  |  |  |  |  |  |
| Simulation Run 2 |  |  |  |  |  |  |
| Simulation Run 3 |  |  |  |  |  |  |
| **Responses to Questions: Step 2** | | | | | | |
| **Q1)**  **Q2)** | | | | | | |
| **Notes:** | | | | | | |
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**Vaccination > Step 3**

In the United States in recent years, there has been increasing public resistance to vaccination, especially against measles and influenza. The reasons are complex, including religious objections, health care access and costs, a lack of public confidence in the annual influenza vaccine, and an assumption that “vanquished” diseases such as polio and measles are no longer a threat. But these diseases have not been eradicated. People die of them every year. By keeping vaccination rates high, we've enjoyed “herd immunity”, where a high proportion of immune individuals block disease propagation. This protects weaker, more susceptible members of society who cannot be vaccinated, such as infants in the case of measles. Lower vaccination rates reduce our herd immunity.

In this step, using Neasles to stand in for measles, **explore on your own** **(using the simulator)** to see why it is that Neasles requires a high vaccination rate to prevent deaths. Then answer the following:

1. What is it about Neasles that requires a high vaccination rate to prevent deaths?
2. Although more people die of influenza each year, they are largely the elderly and infirm, while measles is more likely to kill infants. Does this affect the popular will to control the two diseases?

Many families do not have health insurance or the means to pay for a vaccine. Would it be in the best interest of the overall population to provide free immunization to those who cannot afford it? What are some counter-arguments to doing so?

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| **Lesson 2:**  **Step 3** |  |  |  |  |  |  |
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| **Responses to Questions: Step 3** | | | | | | |
| **Q1)**  **Q2)** | | | | | | |
| **Notes:** | | | | | | |
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**Vaccination > For Your Consideration**

Vaccinating a population has a similar effect to changing the population density. An immune person is no longer a vehicle for transmitting the disease, thus lowering the effective density of the population. Since we can't control population density in most cases, vaccination is one of the best means to prevent the spread of disease, not just to the vaccinated individuals, but to the population as a whole. Stopping or slowing the mixing of people, via quarantine, or closing businesses and schools, is also an option, with similar net effect. Although the common cold doesn't have a vaccine available, you may choose to return to the simulator and experiment with the possibilities of immunizing a percentage of your population to Kold.

There are four main types of vaccine: those containing a killed pathogen, those containing live strains of a pathogen, those containing toxoids (the compounds produced by a pathogen that cause a human reaction, as opposed to injecting with the microorganism), and those containing subunits of the pathogen (such as antigens or other proteins that create part of the physical makeup of the microorganism). Newer genetically targeted vaccines are being developed, but although preliminary tests look very positive, the constantly mutating genetic makeup of the more dangerous diseases prevents us from distributing a vaccine without caution.

**Lesson 3: Pandemic**

What if we were to face an outbreak of a disease such as bird flu? In 1918-1919, the world experienced a pandemic unlike anything seen since the Black Plague of the mid-14th century in Europe. The Spanish Flu, or La Grippe, killed between 20 and 40 million people worldwide. In America alone, 28% of the population was infected with the virus, the vast majority of whom where between the ages of 20 and 40. There was no method in place at that time to deal with a pandemic with such a high transmission rate as well as a high death rate. The disease struck a virgin field.

In this lesson, imagine a new disease for which there is no vaccine and the death rate might be very high. Examine the details of Red Death andpredict how many sick days per capita and the death toll of this new disease in low population and low mixing. **Record the prediction** in your table. To see if you're correct, set Vaccinated to None, run the simulation three times, and record your data.

What if you had a high population and high mixing? **Record your prediction**, change the population and mixing settings to high, and run the simulator three times. **Record your data** and compare with your prediction.

1. Would either of these scenarios be considered epidemic? Why or why not?
2. What practical, precautionary measure would you suggest for each situation?

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| **Lesson 3:**  **Step 1** | Population Mixing | Population Density | Percent Vaccinated | Starting Number of Contagious People | Sick Days Reported | Contagious | Immune | Dead |
| Prediction 1 (low/low) |  |  |  |  |  |  |  |  |
| Simulation Run 1 |  |  |  |  |  |  |  |  |
| Simulation Run 2 |  |  |  |  |  |  |  |  |
| Simulation Run 3 |  |  |  |  |  |  |  |  |
| Prediction 2 (high/high) |  |  |  |  |  |  |  |  |
| Simulation Run 1 |  |  |  |  |  |  |  |  |
| Simulation Run 2 |  |  |  |  |  |  |  |  |
| Simulation Run 3 |  |  |  |  |  |  |  |  |
| **Responses to Questions:** | | | | | | | | |
| **Q1)**  **Q2)** | | | | | | | | |
| **Notes:** | | | | | | | | |
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**Counter-Virus > For Your Consideration**

Diseases travel through populations in fairly predictable ways. Population density, or population mixing with the same effect as changing density, is one of the key controlling factors of disease transmission.

If you haven't already done so, you should complete the [Demographics lab](http://www.learner.org/courses/envsci/interactives/demographics/index.php) and consider how exponential population growth in certain developing countries might affect disease propagation and how this might be countered.

Diseases like HIV, hepatitis, and avian influenza are currently spreading rapidly in developing countries. Ebola outbreaks also recur. Controlled diseases such as polio have had outbreaks in Syrian refugee camps. On average, the CDC maintains a list of 12 diseases that are epidemic or pandemic and highly lethal. Although the list rarely changes and a majority of the diseases are found in sub-Saharan Africa, a threat continues to the world as a whole. Differences in health care, the availability of clean water (or water in general), and socio-political agendas often define how quickly disease spreads and to what extent those afflicted may find care and respite. Consider the following:

1. In addition to the efforts of the CDC and WHO, what might be done to either contain virulent disease or prevent its onset?
2. In your opinion, what is the greatest viral or bacterial threat to your local population and what precautions might be taken to avoid contagion?