The following laboratory worksheets are an open educational resource adapted to be used with the Operation Outbreak(OO) simulation. Information on use of OO can be found at operationoutbreak.org. All posters in this file should be printed and posted in the learning space during the OO simulation. This resource and details on how to use it can be found at merlot.org (author: Melissa Poua)

Operation Outbreak

Epidemiology Review

Teacher's note: before printing, review and modify areas highlighted in yellow

Words in blue can be found in posters, glossaries and other printouts.

1 Objectives

After attending the laboratory the student should demonstrate achievement of at least 70% in written and practical examinations focusing on the following objectives.

1. Define epidemiology, surveillance and related definitions.
2. Use mathematics to measure statistics such as mortality, morbidity and incidence.
3. Outline the steps in an outbreak investigation.
4. Work collaboratively with student peers in a social simulation.
5. Effectively communicate scientific findings.

2 Procedure

Simulation:

1. Download the Operation Outbreak app and make sure Bluetooth is enabled.
2. Meet in the classroom for initial instructions.
3. Discuss pathogen, interventions and limitations.
4. Determine roles of laboratory, nurse, scientific communicator.
5. Complete questions on laboratory report—due at the end of class.

Assessment:

1. Log into classroom platform to review simulation data. (video of your simulation will be provided by Operation Outbreak)
2. Answer follow up questions.

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Name_____ Date_____

Operation Outbreak

LABORATORY EXERCISE

Epidemiology lesson

1. Predict (to be completed BEFORE starting the simulation):
   Your classroom is undergoing a simulation of exposure to a measles-like virus. This virus is highly contagious (measured by proximity on the Operation Outbreak app).
   a. If 2 of the 45 members of the group carry the pathogen, how many do you think will become ill?

   b. How many classmates do you think you will be in contact with over the next XX minutes?

   c. Will you stay "well"?

   d. Record your ID name for the outbreak here.

2. Investigate:
   Explore the classroom space and answer the following questions:
   1. What is our case definition of an infected person? How are cases characterized?

   2. What is the etiological agent used in the simulation?

   3. What kind of laboratory support is provided?

3. Define the following terms as they relate to the spread of disease. There are definition glossaries around the classroom.

   a. Endemic
   b. Epidemic
   c. Pandemic
   d. Incubation period
   e. Morbidity rate
   f. Mortality rate
   g. Nosocomial infections
   h. Reservoir
   i. Cluster

4. Define the following types of transmission of pathogenic microbes. (Ask a Clinical Year student for an example of each mode of transmission). I used this portion of the worksheet to encourage the younger students to ask older students for their expertise. If not you may want to bring books OR supply a few microbiology textbooks for students to look up this information as it is not all available in the posters or glossaries

Mode of transmission	Definition	Example of pathogen
Fomite		
Droplet		
Zoonoses		
Oral/fecal		
Vector		
Close Contact		

Which route of transmission best fits today's simulation?

5. What control measures are being implemented? Are there any additional measures that would be helpful?

4. Assess: Visit the online classroom, post- simulation to view our dashboard and answer final questions.
    a. Examples of assessment questions:
        i. What do you think went well with this simulation? Did you learn anything new?
        ii. What suggestions do you have to improve this simulation?
        iii. Review your predictions on page one. Compare them to the simulation review video. How accurate were you about the number of contacts you had and your health?
        iv. Students may calculate specific statistics such as
            1. Total population
            2. Mortality rate vs morbidity rate
            3. Vaccination rate
            4. Discussion of "prevalence"

This page for scientific communicator only (alternately, you might provide a whiteboard or other venue for them to disseminate this information)

Name_____ Date_____

You have been designated as scientific communicator. Write an 80-word (maximum) "tweet" to the public that describes your current "outbreak" and includes all of the information that they need to know.

Operation Outbreak

Virology Review

Teacher's note: before printing, review and modify areas highlighted in yellow

Words in blue can be found in posters, glossaries and other printouts.

1 Objectives

After attending the laboratory the student should demonstrate achievement of at least 70% in written and practical examinations focusing on the following objectives.

1. State the structural properties unique to the *Paramyxoviridae* family.
2. Work collaboratively with student peers in a social setting.
3. Explore a sample surveillance database tool.
4. Discuss the statistical requirements needed for effective vaccination and control measures.
5. List members of the *Paramyxoviridae* family and the clinical conditions associated with each.

2 Procedure

Simulation:

1. Download the Operation Outbreak app and make sure Bluetooth is enabled.
2. Meet in the classroom for initial instructions.
3. Discuss pathogen, interventions and limitations.
4. Determine roles of laboratory, nurse, scientific communicator.
5. Complete questions on laboratory report—due at the end of class.

Assessment:

1. Log into classroom platform to review simulation data. (video of your simulation will be provided by Operation Outbreak)
2. Answer follow up questions.

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Name_____ Date_____

Operation Outbreak

LABORATORY EXERCISE

Virology lesson

1. **Predict** (to be completed BEFORE starting the simulation):
   Your classroom is undergoing a simulation of exposure to a measles-like virus. This virus is highly contagious (measured by proximity on the Operation Outbreak app).
   a. If 2 of the 45 members of the group carry the pathogen, how many do you think will become ill?

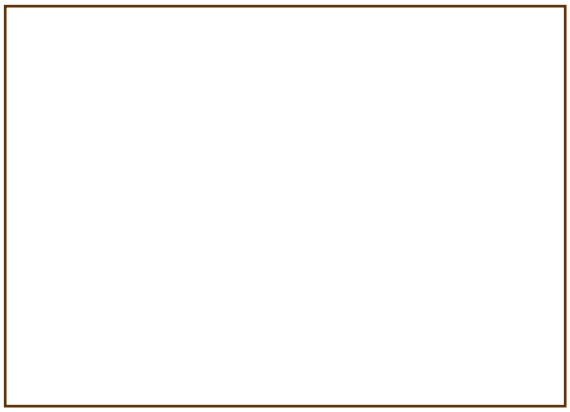
   b. How many classmates do you think you will be in contact with over the next XX minutes?

   c. Will you stay "well"?

   d. Record your ID name for the outbreak here.

2. **Investigate:**
   Explore the classroom space and answer the following questions:
   a. What is our case definition of an infected person? How are cases characterized?

   b. Our "outbreak" is defined as a "measles-like" virus. For the purpose of this investigation, we will study Rubeola (Measles) virus. Diagram and label the structure of the virus here: Include labels indicating type of nucleic material (DNA/RNA/ss/ds), if it is enveloped, key proteins. You can find answers to these questions around the classroom and hallway.



c. Describe the transmission of measles here. How is it spread? What mitigation measures would be best implemented?

d. List the symptoms of measles here. Include a timeline of when these symptoms would occur and possible complications.

e. List diagnostics tests used to identify measles in the lab.

3. **Describe:**
   a. Explain briefly how R_0 relates to infectious disease. Describe the difference between infection risk in measles (with a R_0 of 12-18) and a virus with a R_0 of 2.

   b. What is needed to provide *herd immunity* in terms of R_0 and how could that be achieved?

   c. Look at the example of an infectious disease model posted in the hallway. How would the following factors affect spread of disease: (teacher's note: this knowledge is not expressly spelled out but must be inferred by the student)

      Age range of population?

      Asymptomatic transmission?

      Population concentration?

4. **Create:**
   Find a person infected with our measles-like virus and write a brief summary of your " measles" case and fill out the following sample case report. Points will be awarded for accuracy of details. Details must match clinical picture for full credit. You may "embellish" your case details to give a more complete clinical story. The patient may be yourself if you are "infected" in the outbreak simulation.

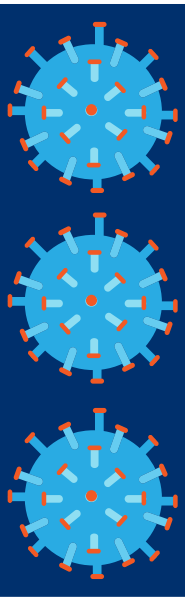
   a. Case write-up (Write 3 to 4 sentences include how infection was acquired, symptoms and lab tests performed). Then complete the table on the next page.

Sample Measles-"like" virus Case Report (for classroom purposes only, this table is a teaching tool and not for medical use)				
Patient Demographics				
Patient name:		Age: □days □weeks □months □years		Gender:
Signs and Symptoms				
Rash: □ yes □no □unknown	Date of onset:	Duration: _____ of days	Origin on body:	Direction of spread
Fever: □yes □no □unknown	Date of onset:	Temperature taken:	Was temp >38.3C?	If not taken, skin was: □hot □warm □normal
Cough □yes □no □unknown	Conjunctivitis: □yes □no □unknown	Koplik's spots □yes □no □unknown	Other symptoms? Describe	
Laboratory Tests (note to student: these must make clinical sense for full points) you may need to add some future or past dates for the clinical picture to be complete)				
Specimen obtained for lab testing. List specimen type here:	Serology performed: IgM	Specimen date: / /	Test results: □P □N □I □E □X	Key: P= positive
	IgG (acute)	/ /	□P □N □I □E □X	N= negative
	IgG (convalescent)	/ /	□P □N □I □E □X	I= Indeterminate E= pending X= not done
Virus test done? □ yes □no □unknown	If yes, list specimen type:	Note: Send to CDC for genotyping	Date sent: / /	
Other tests done? List here:				
Vaccination status				
Received one or more doses of vaccine? □yes □no □unknown	Number of doses and dates: Dose 1: / /	Dose 2: / /	Dose 3: / /	
If unvaccinated choose all that apply:	Reason not vaccinated: □Personal beliefs exemption □Permanent medical exemption □Temporary medical exemption □Underage for vaccine □MD diagnosis of previous disease □Delay in starting series □Other: please list			
Contact investigation				
List spread setting (e.g. school, daycare, etc.)	List travel history:	Possible number of exposures:	Inform patient that follow-up call for contact tracing will be initiated.	

5. **Assess**: Visit the online classroom, post- simulation to view our dashboard and answer final questions.
    a. Examples of assessment questions:
        i. What do you think went well with this simulation? Did you learn anything new?
        ii. What suggestions do you have to improve this simulation?
        iii. Review your predictions on page one. Compare them to the simulation review video. How accurate were you about the number of contacts you had and your health?
        iv. Students may calculate specific statistics such as
            1. Total population
            2. Mortality rate vs morbidity rate
            3. Vaccination rate
            4. Discussion of "prevalence"
        v. Students may answer a sample measles question or two (structure, symptoms etc.) to prepare for upcoming virology exams

"Measles-like virus" IS HIGHLY CONTAGIOUS

Vaccination is the only defense against this disease.



Facts about "measles-like virus"

- ✔ Measles- like virus that travels by direct contact or through the air.
- ✔ You can catch measles-like virus by walking into a room where someone with the virus has been (even after they've left).

Unvaccinated children are most at risk

Before 1963 (when the vaccine became available) measles, a virus similar to "measles-like virus" killed **2.6 million** people worldwide each year.

2016 Vaccination programs cut that to **89,000**.

Measles-like virus is similar to measles. Measles remains a leading cause of death among children worldwide. Most U.S. cases are imported from other countries.

Treatment

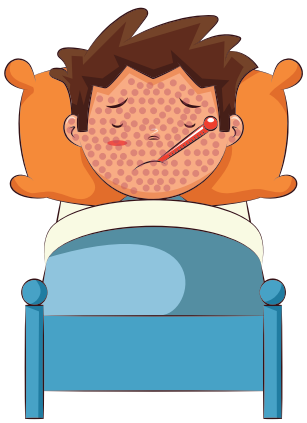
Bed rest and plenty of fluids. Doctors can treat only the symptoms, not the illness, with:

- ✔ Medicines to bring down fever and boost vitamin A levels, and
- ✔ Antibiotics if you get an infection.

Be Wise — Immunize

- 2 shots (at 12-15 months and at 4-6 years) give almost full protection against the virus.
- Getting the vaccine is much safer than getting sick.

Talk to your doctor if you have questions about measles-like virus.



Symptoms and complications

Symptoms can last up to 10 days

- High fever, cough, runny nose
- Red, watery eyes
- Small white spots in the mouth
- Tell-tale rash 3-5 days after symptoms begin

Complications can send 1 in 4 to the hospital

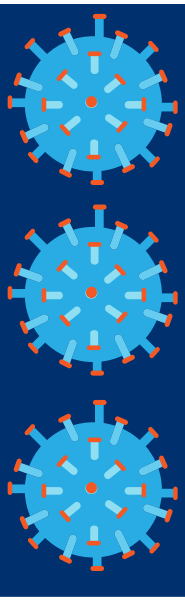
- Diarrhea, vomiting, eye infections, and bronchitis
- Pneumonia, swelling of the brain, blindness, even death

INSERT VACCINE QR CODE FROM OPERATION OUTBREAK HERE BEFORE PRINTING

Sources: Centers for Disease Control and Prevention, World Health Organization

EL "CASI-SARAMPIÓN" ES ALTAMENTE CONTAGIOSO

La vacunación es la única defensa contra esta enfermedad.



¿Qué es el casi-sarampión?

- ✔ El casi- sarampión es un virus que viaja o se contagia por contacto directo o por el aire.
- ✔ Usted puede contagiarse con casi-sarampión al ingresar a una habitación donde ha estado alguien con el virus (incluso después de que se hayan ido).

Los niños no vacunados corren mayor riesgo

Antes de 1963 (cuando la vacuna estuvo disponible) el sarampión, un virus parecido al casi-sarampión mató a **2,6 millones** de personas en todo el mundo cada año.

Los programas de vacunación del año **2016** redujeron eso a **89,000 mil**.

El casi-sarampión se parece a sarampión. El sarampión sigue siendo una de las principales causas de muerte entre los niños en todo el mundo. La mayoría de los casos en EE. UU. se importan de otros países.

Tratamiento

Reposo en cama y abundante cantidad de líquidos.

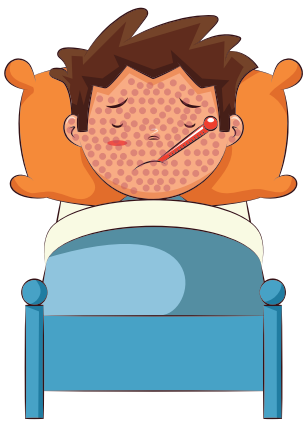
Los médicos solo pueden tratar los síntomas, no la enfermedad, con lo siguiente:

- ✔ Medicamentos para bajar la fiebre y aumentar los niveles de vitamina A, y
- ✔ Antibióticos si tiene una infección.

Be Wise — Immunize

- 2 inyecciones (a los 12-15 meses y a los 4-6 años) brindan una protección casi total contra el sarampión.
- Ponerse la vacuna es mucho más seguro que enfermarse.

Hable con su médico si tiene preguntas sobre el casi-sarampión.



Síntomas y complicaciones

Los síntomas pueden durar hasta 10 días.

- Fiebre alta, tos, secreción nasal
- Ojos rojos y llorosos
- Pequeñas manchas blancas en la boca
- Síntomas de sarpullido 3-5 días después de que comienzan los síntomas

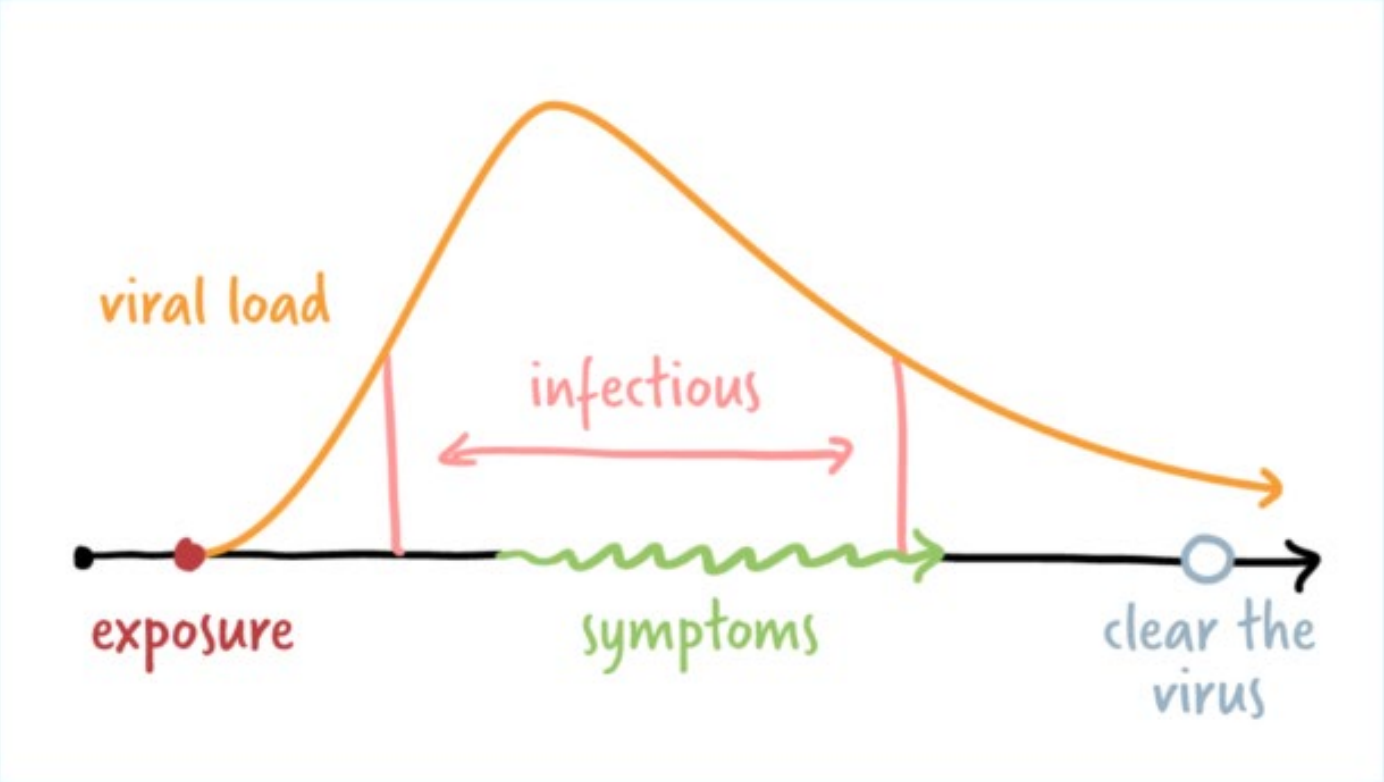
Las complicaciones pueden enviar a 1 de 4 al hospital

- Diarrea, vómitos, infecciones en los ojos y bronquitis
- Neumonía, hinchazón del cerebro, ceguera e incluso la muerte

INSERT VACCINE QR CODE FROM OPERATION OUTBREAK HERE BEFORE PRINTING

Sources: Centers for Disease Control and Prevention, World Health Organization

Example of An Infectious Disease Model



Source: Charting an Omicron Infection (New York Times)
https://www.nytimes.com/interactive/2022/01/22/science/charting-omicron-infection.html

Molecule of the Month: Measles Virus Proteins

Six proteins in measles virus work together to infect cells.

Measles is one of the most infectious viruses: 9 out of 10 people exposed to an infected person will contract the disease. Infection by the virus most often leads to an uncomfortable rash and then clears up, but some people have more serious or even deadly complications. Fortunately, there is an effective vaccine that protects against infection. The disease has not been eradicated, however, because the vaccine is not widely available in many parts of the world, and a growing number of people refuse vaccination.

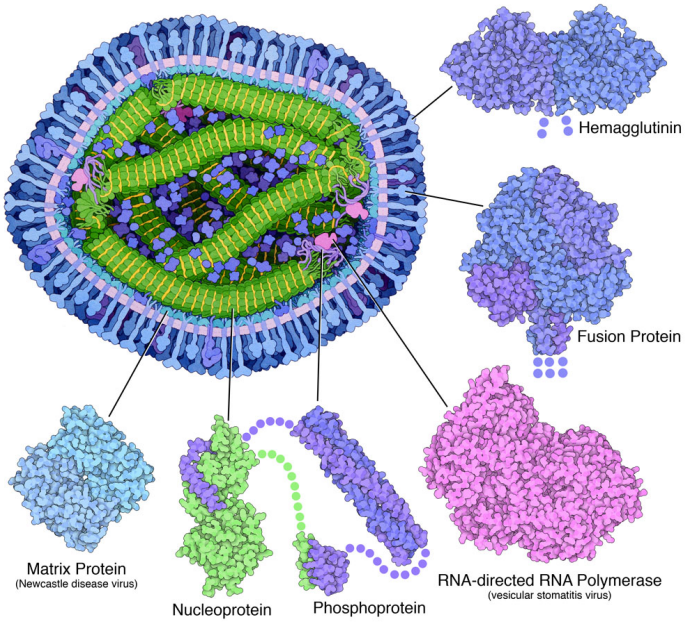


Illustration of a cross section through measles virus and structures for each of the viral proteins. Portions of the proteins that have not been determined are shown with dots.

Download high quality TIFF image

Measles Proteins

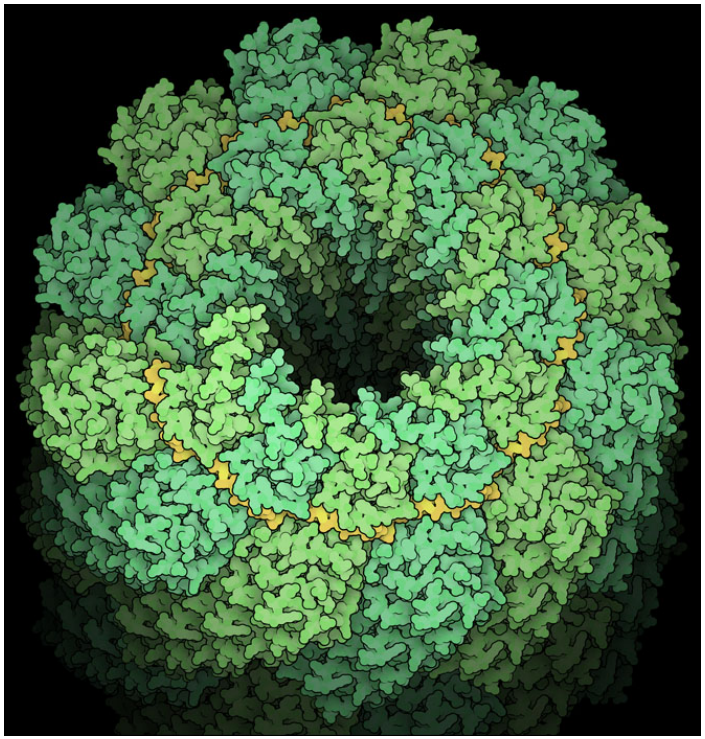
The measles virus genome encodes six proteins, which are enough to choreograph its highly infectious life cycle. Three are involved in management of the genome. The genome is composed of RNA, so a special polymerase is made by the virus that makes new copies of RNA using RNA as a template (a related polymerase from a different virus is shown here, PDB entry 5a22). The RNA is encapsidated by the nucleoprotein, with six nucleotides bound to each protein subunit. The phosphoprotein has several flexible tails that tether the polymerase to the nucleoprotein, chaperoning the process of replication and transcription. Structures are available for the ordered regions of nucleoprotein and phosphoprotein (PDB entries 5e4v, 3zdo, 1t6o), but the remaining regions are thought to form a flexible, random tangle.

Surface Proteins

The virus is enveloped by a lipid membrane with two types of proteins that coordinate how the virus finds cells and enters them. The hemagglutinin protein (PDB entry 2zb5) binds to receptor proteins on the cell surface, and the fusion protein (PDB entry 5yxw) fuses the viral membrane to the cell membrane, releasing the viral genetic material into the cell. The hemagglutinin protein is the major target of our immune system, and the widely-used vaccines employ weakened forms of the virus that stimulate the immune system to make antibodies against the protein.

The Matrix

The matrix protein is involved in budding of new viruses from an infected cell, and ensuring that the viral RNA is included. As is often the case with biology, there are two conflicting models of how this occurs, based on the results of different experimental studies. The model shown here places matrix on the inner surface of the membrane, where it assists with bending the membrane and also interacts with the helical nucleocapsid. An alternative model proposes that tubes of matrix surround the nucleocapsid, which then associate with the membrane. The matrix protein structure shown here (PDB entry 4g1g) is from a related virus.



Measles Nucleocapsid

The measles nucleoprotein forms a large helical complex with RNA, as seen in PDB entry 4uft. It is thought to chaperone the process of replication and transcription by providing a ready site for binding of the polymerase/phosphoprotein complex while a new RNA chain is being built. The structure includes the stable core domain of the nucleoprotein and a strand of RNA, but the flexible tail of nucleoprotein was removed in this study.

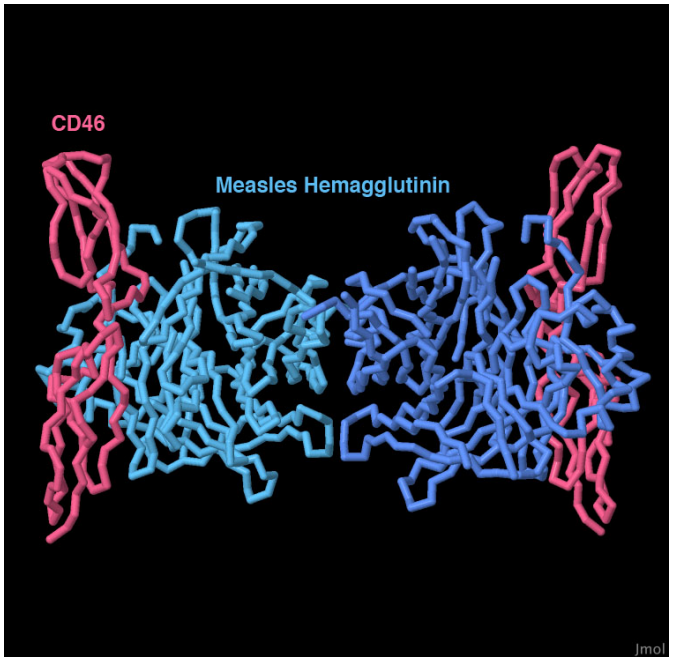
Measles nucleoprotein (green) and RNA (yellow).

Download high quality TIFF image

Exploring the Structure

Image | JSmol

Measles Hemagglutinin and Cellular Receptors



Measles hemagglutinin is known to bind to three different proteins found on the surface of our cells. Structures have been determined for each: CD46 (PDB entry 3inb, shown here in the image), SLAM (PDB entry 3alz) and nectin-4 (PDB entry 4gjt). In all three, two copies of the receptor protein (red) bind on opposite sides of a dimeric hemagglutinin molecule (blue). To explore all three structures in more detail, click on the image for an interactive JSmol.

Topics for Further Discussion

1. Researchers are developing drugs to block several of these measles proteins. Try searching for “measles inhibitor” in the main RCSB PDB site to see a few of them.

2. The phosphoprotein complex structures shown here were determined by studying chimeric proteins, where portions of two proteins are fused together—you can use the “Protein Feature View” to help sort out which parts belong to each protein.

Related PDB-101 Resources

- Browse Viruses
- Browse Immune System

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March 2019, David Goodsell

http://doi.org/10.2210/rcsb_pdb/mom_2019_3

Case Definition: Measles-like virus

Measles (Measles virus)

Clinical criteria

Any person with demonstratable symptoms (classic symptoms: fever AND maculo-papular rash AND at least one of the following three:
- Cough
- Coryza (inflamed mucus membranes)
- Conjunctivitis (inflammation in the eyes)

Laboratory criteria

A positive diagnostic test

Laboratory results need to be interpreted according to the vaccination status. If recently vaccinated, investigate for wild virus.

Epidemiological criteria

An epidemiological link by human to human transmission

Case classification

A. **Possible case**
Any person meeting the clinical criteria
B. **Probable case**
Any person meeting the clinical criteria and with an epidemiological link
C. **Confirmed case**
Any person not recently vaccinated and meeting the clinical and the laboratory criteria

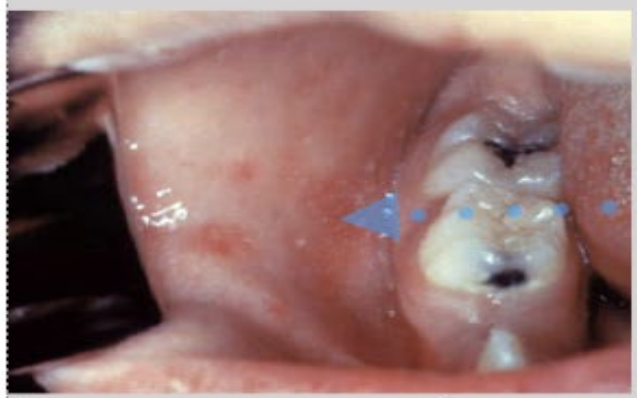
Number of:

Possible cases **Probable cases** **Confirmed cases**

Measles-"like" virus

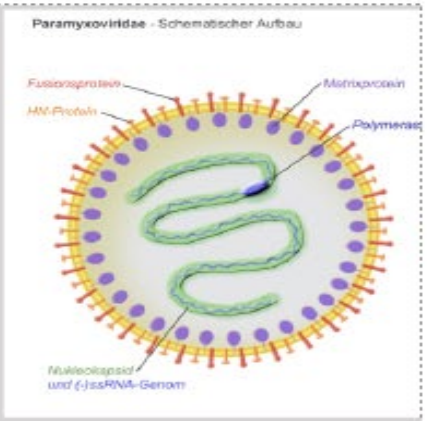
Report all cases to your local RN/authorities

90% Rate of Infectivity
Airborne precautions
Isolate suspected cases
Room contains airborne virions
Up to 4 hours after patient leaves



Rubeoloa - ssRNA
Paramyxoviridae

INFECTIVITY *BEGINS*



10 day incubation

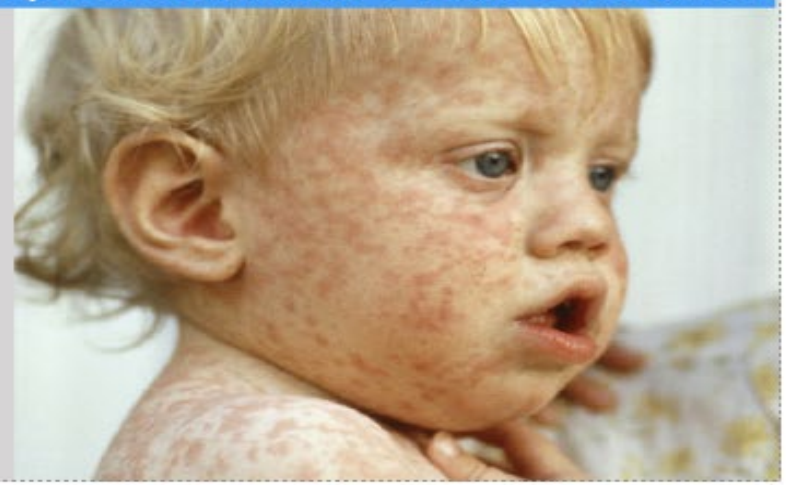
Coryza
Fever (T ≥ 40c)
Conjunctivitis

2-3 days later

Koplik spots

3-5 days later

Macular, patchy rash
Exanthema classically starts behind ears
Then spreads down, neck -> trunk -> extremities



Mortality=1/1000
Complications include
2° Pneumonia &
Subacute sclerosing
panencephalitis (SSPE)

DX=Serum IgM/IgG, Nasopharyngeal Swab PCR

TX= supportive ± vitamin A in malnourished/hospitalized

Post Exposure PPx, within 72 hours suspected exposure

Non-immune, age> 6 months=MMR vaccine

High risk, non immune=Measles IG + later MMR
High risk features=age< 6 months, immunocomprised state

HOW TO WEAR A FACE MASK

Proper face mask usage is important to prevent the spread of illness. This includes proper techniques for wearing the mask, taking it on and off, and storing it.

HOW TO PROPERLY PUT YOUR MASK ON

1

Wash your hands with soap and water or use an alcohol-based hand sanitizer before touching the mask.

2

If your mask has ear loops, use the ear loops to secure behind your ears.

3

If your mask has ties, bring the mask to nose level and tie the top straps across the upper part of your head, above the ears. Bring the mask over your mouth and under your chin. Once it is secure, tie the lower straps behind your neck.

4

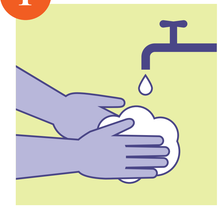
Mold or pinch the area around your nose so the mask fits securely. Make sure it covers both your nose and chin.

Helpful Tips

- **Do no**t touch the front of the mask.
- **Do not** forget to cover your chin.
- **Do wear it securely over your nose**, from the bridge of your nose to below your chin.
- **Do make sure it is fastened securely** and **fits snugly** on both sides, with **no gaps**.

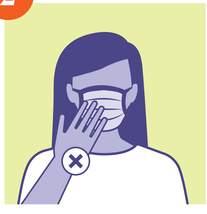
HOW TO REMOVE A FACE MASK

1



Wash your hands thoroughly with soap and water or use an alcohol-based hand sanitizer.

2



Do not touch the front of the mask.

3

Use the ear loops to remove the mask. If your mask has ties, untie the bottom string first, then the top, and use the ties to pull the mask away from your face.

4

Properly dispose of your mask if necessary, or store it safely. Clean your hands.

Helpful Tips

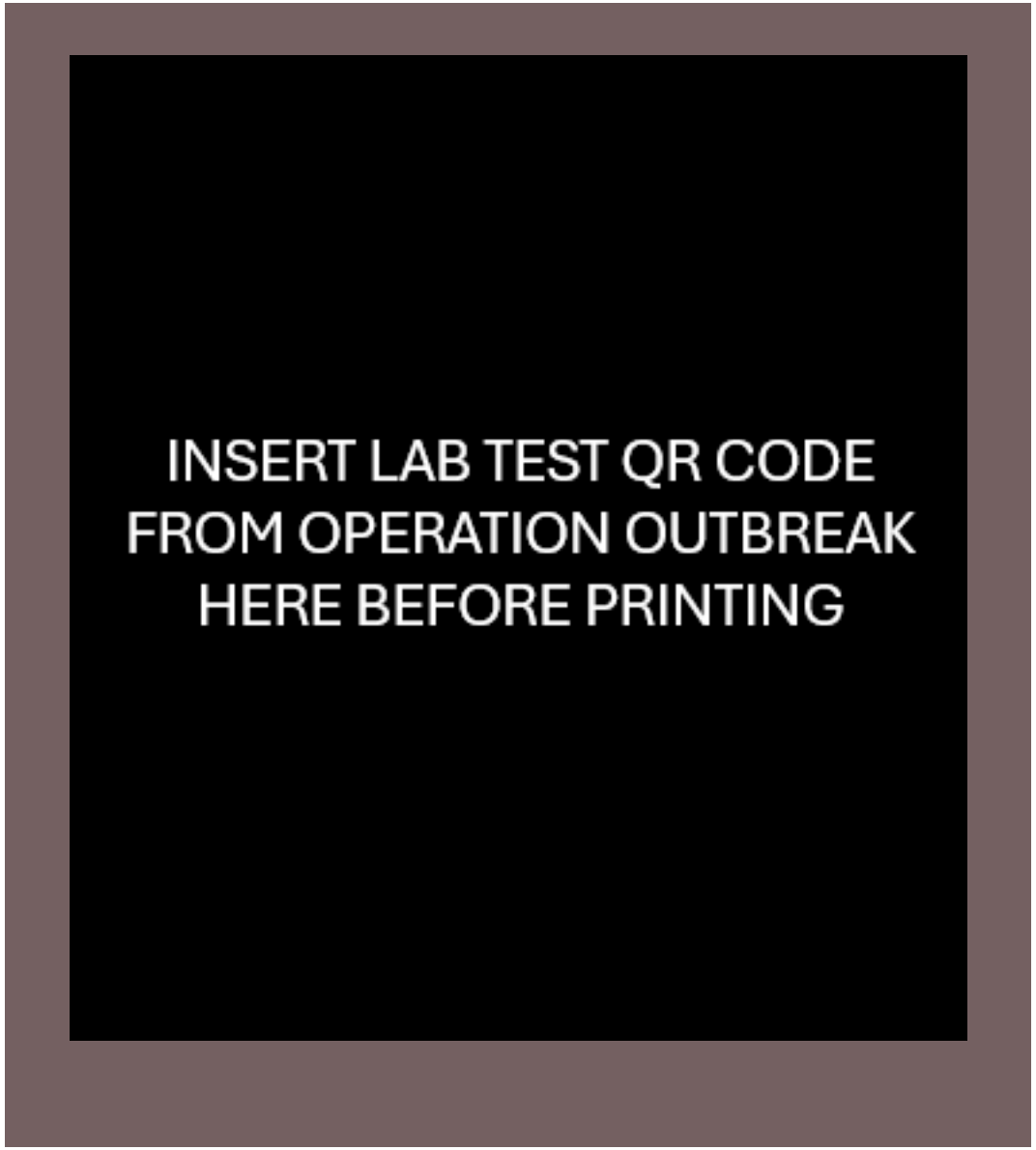
- **Wash** and dry **cloth masks daily**.
- **Store masks** in a **clean, dry location**, like a paper bag. They should be carefully folded so that the outer surface faces inward.

INSERT MASK QR CODE FROM OPERATION OUTBREAK HERE BEFORE PRINTING

Sources:
cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html
cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-to-wear-cloth-face-coverings.html

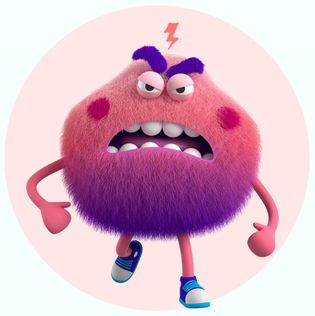
Laboratory Area

Laboratory Area

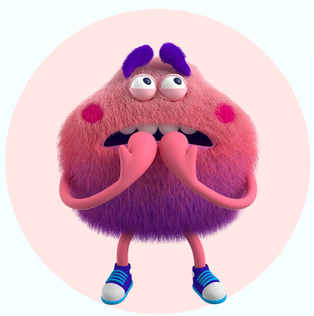


How do you feel today?

Name your emotions with the Feelings Monster in Reflect.

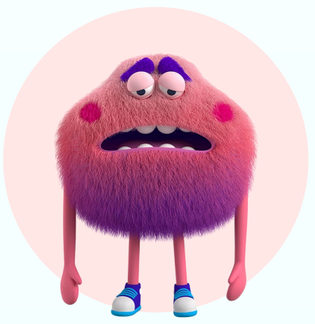


Angry



Anxious

Ashamed



Hopeless

Lonely

Concerned

Disappointed

Hurt

Jealous

Stressed

Annoyed

Bored

Calm

Confused

Tired

Curious

Confident

Excited

Focused

Happy

Ambitious

Determined

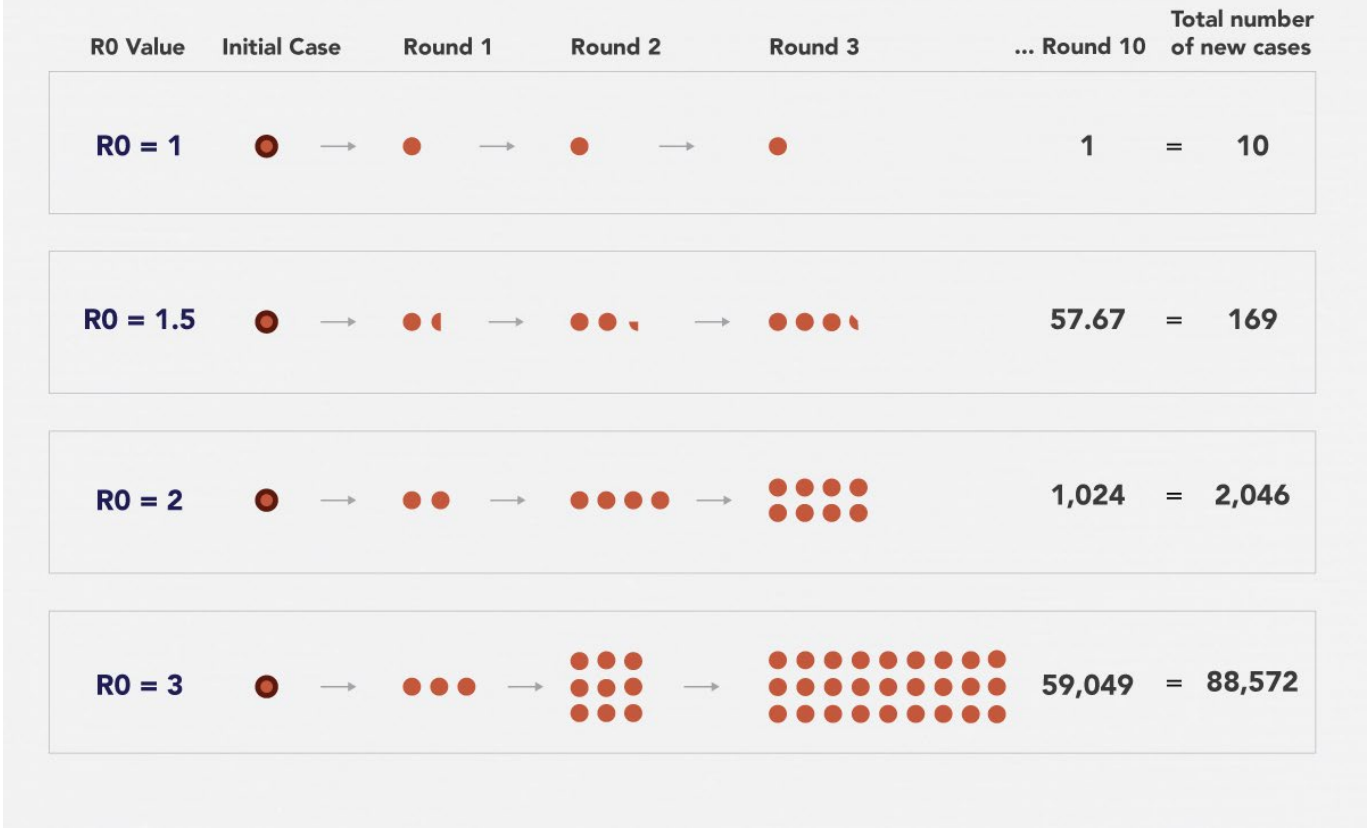
Grateful

Included

Proud

Comparing Different R0 Values

R0 (pronounced "R-naught") is the basic reproduction number of infectious agents. It is the average number of people every infected person will transmit the virus to, assuming a completely susceptible population. For example, if R0 = 2, then one case would create two new cases, and each new case would create another two cases. The visual below illustrates this exponential growth across a few different R0 values.



A Primer on R0 for infectious diseases. (2020, April 21) Retrieved from https://www.mastersindatascience.org/resources/r0-infectious-diseases/

Maths in a minute: "R nought" and herd immunity

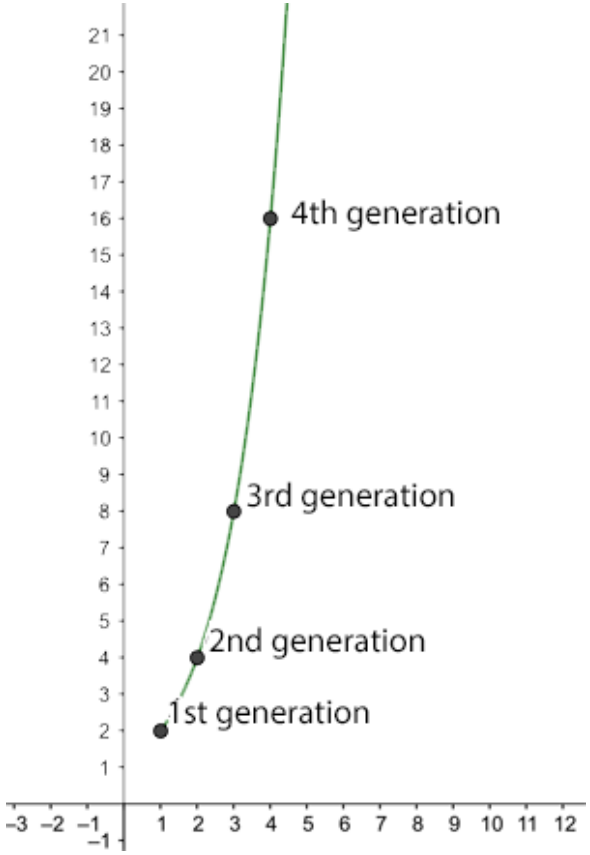
Submitted by Marianne on 2 April, 2020

Two things many of us will have heard about over the last few weeks are the concept of herd immunity and a number called R_0 (which people say as "R nought").

The basic reproduction number

Given an infectious disease, such as COVID-19, R_0 is the *basic reproduction number* of the disease: the average number of people an infected person goes on to infect, given that everyone in the population is susceptible to the disease. For COVID-19 this is currently estimated to lie between 2 and 2.5. For seasonal strains of flu, it lies between 0.9 and 2.1. And for measles it is a whopping 12 to 18.

You can see how a large enough R_0 leads to a rapid spread of the disease. For example, if R_0 is equal to 2 then a single infected person generates the following growth of new infections:



1st generation: 2 new infections
2nd generation: 4 new infections
3rd generation: 8 new infections
4th generation: 16 new infections.

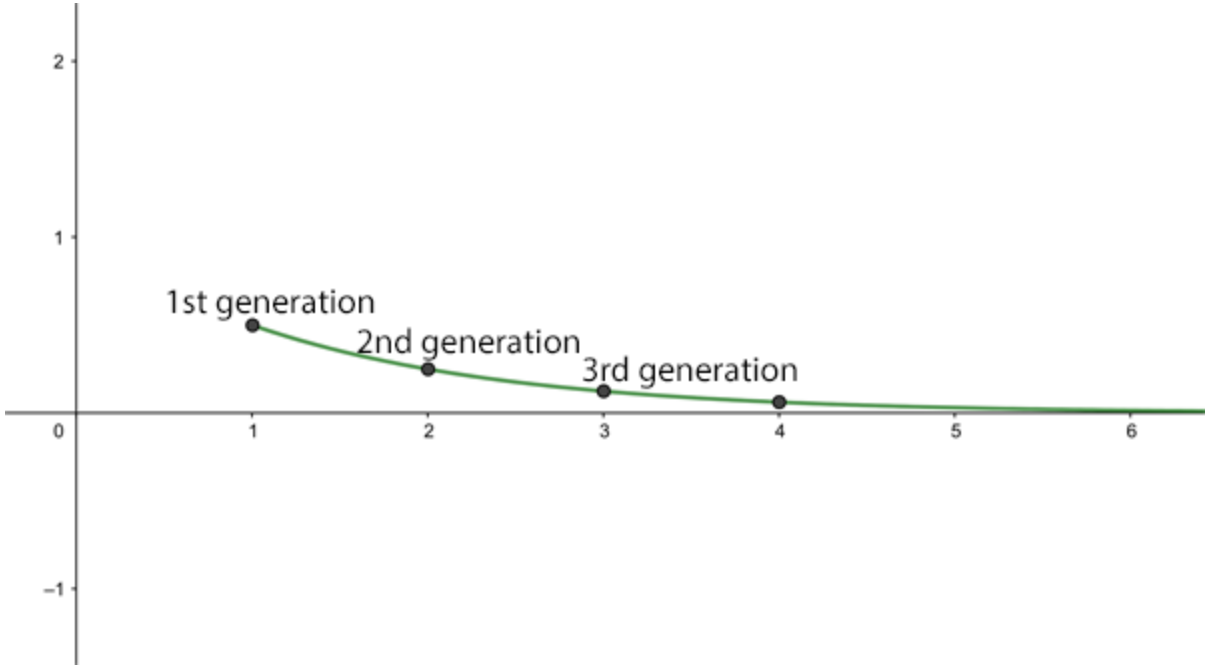
The number of new infections after *n* generations for R_0=2.

Generally, there are 2^n new infections in the nth round of new infections. Assuming a person is only infectious for a week, at this rate the entire world population (7.8 billion) would be infected after slightly over 32 weeks.

When the basic reproduction number R_0 is less than 1 a very different picture emerges. As an illustration, imagine we have $R_0 = 0.5$. Now obviously, an infected person can't go on to infect half a person, but remember that this is an average: it means that 10 people can be assumed to go on to infect 5 others, or that 100 people can be assumed to go on to infect 50 others. As before let's assume there is 1 infected person to start with, then the number of new infections behaves like this:

1st generation: 0.5 new infections
2nd generation: 0.25 new infections
3rd generation: 0.125 new infections
4th generation: 0.0625 new infections.

Generally, there are $(0.5)^n$ new infections in the nth round of infections. This number becomes smaller and smaller as the number n of generations becomes larger. A dead end for the disease.



The average number of new infections after *n* generations for R_0=0.5.

What if $R_0 = 1$? In this case the disease will be *endemic*: always present in the population, but not an epidemic.

The effective reproduction number

So, given that the R_0 of measles, or some strains of seasonal flu, is greater than 1, how come the whole world hasn't been infected with these diseases a long time ago? The reason is that R_0 is the average number of people an infected person goes on to infect, given that *everyone in the population is susceptible*. In real life, this might be the case if someone who has become infected with a disease elsewhere enters a part of the world where the disease has never been seen before, so people don't have immunity and there isn't a vaccine to protect them. An R_0 of 2 then means that, at the beginning, the number of infected people will grow wildly, as we've described above.

However, once a person has recovered from the disease they will (hopefully) gain some immunity. This means that after a while we're not dealing with a totally susceptible population anymore. Indeed, there may be other reasons why some people in the population aren't susceptible: they may be immune for other reasons, or if there's a vaccine, they may have received it, or they may be isolated from the rest of the population.

In most real life situations we should be looking at the *effective reproduction number* of the disease, sometimes denoted by R: the average number an infected person goes on to infect in a population where *some people are immune* (or some other interventions are in place). Of course R_0 and R are related. Writing s for the proportion of the population that is susceptible to catching the disease, we have

$$R = sR_0.$$

As an example, if only half the population is susceptible, so $s = 0.5$, we have $R = 0.5R_0$. In this case, if R_0 is less than or equal to 2, then R is less than or equal to 1 and the disease won't turn into an epidemic. The ideal aim of any intervention, be it vaccination or social distancing, is to get the effective reproduction number down to under 1.

Herd immunity

What does all this have to do with herd immunity? The general idea behind herd immunity is that in a population where many people are immune a disease can't take hold and grow into an epidemic, thereby protecting people who aren't immune. The population (perhaps unfortunately called a herd) protects vulnerable individuals.

So how many people in a population need to be immune to have herd immunity? Imagine a disease has a basic reproduction number R_0, which is greater than 1 so an epidemic threatens. As we have seen, if the *effective* reproduction number R is less than 1, then the disease will eventually fizzle out. So to achieve herd immunity we need to somehow get the effective reproduction number R to under 1. Since $R = sR_0$, where s is the proportion of the population that is susceptible, we need

$$sR_0 < 1.$$

Rearranging, this gives

$$s < 1/R_0.$$

In other words, we need to get the proportion of susceptible people in the population to under $1/R_0$. How many people need to be immune to achieve this? If the proportion of susceptible people is s, then the proportion of people who are not susceptible, in other words immune, is $1 - s$. Now

$$s < 1/R_0$$

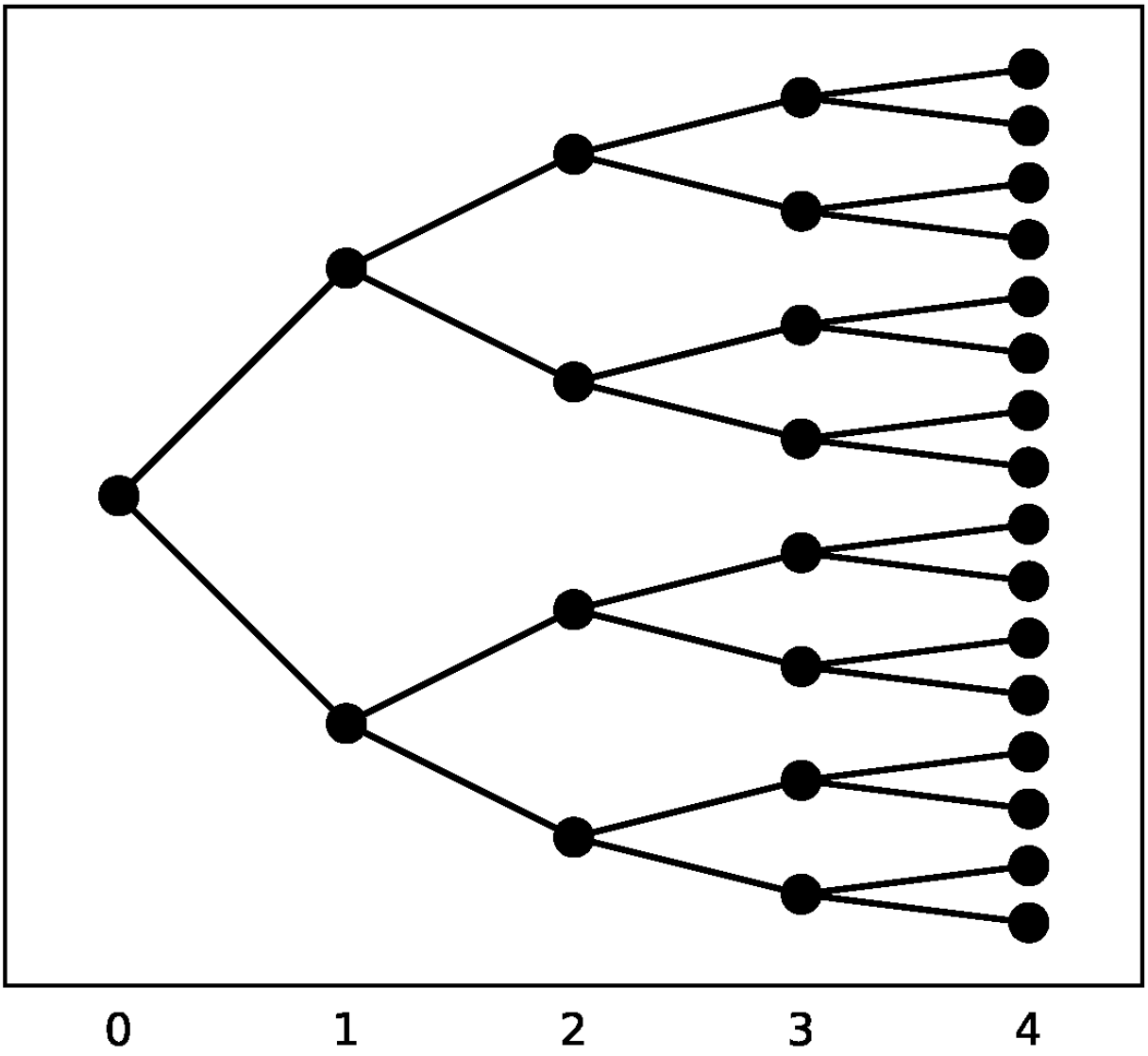
means

$$1 - s > 1 - 1/R_0.$$

So, to achieve herd immunity we need to make sure that at least a proportion of $1 - 1/R_0$ of the population is immune. For an R_0 of 2.5, the higher end of the estimates for COVID-19, this means that we need to get at least a proportion of $1 - 1/2.5 = 0.6$ of the population immune. This translates to at least 60%.

In general, our calculations above also send an important message about vaccination: it does not only protect the individual who is being vaccinated against the disease, but also those people who for some reason or other won't be vaccinated and are therefore vulnerable. Vaccination isn't just for you, it's for the whole "herd"!

This article is based on a chapter from the book Understanding numbers by the Plus Editors Rachel Thomas and Marianne Freiberger.



Okabe, Y. (2020). *A Mathematical Model of Epidemics—A Tutorial for Students,* Mathematics 2020, 8(7), 1174; https://doi.org/10.3390/math8071174

Glossary of Epidemiological Terms

Age-Adjusted Mortality Rate
A mortality rate statistically modified to eliminate the effect of different age distributions in different populations.

Agent
A factor (e.g., microorganism, chemical substance, or radiation) essential for the occurrence of a disease.

Analytic Epidemiology
Concerned with the search for health-related causes and effects using comparison groups.

Applied Epidemiology
The practical use of epidemiological methods to address public health issues.

Attack Rate
A type of incidence rate applied to a narrowly defined population during an outbreak.

Bias
Deviation of results or inferences from the truth due to systematic error.

Carrier
A person or animal without symptoms who harbors an infectious agent and can transmit it.

Case
A countable instance of a particular disease, health disorder, or condition.

Case-Control Study
An observational analytic study comparing people with a disease (cases) to those without (controls).

Cause-Specific Mortality Rate
Mortality rate from a specified cause in a population.

Cluster
A group of disease cases in a defined area or time, often unexpectedly.

Cohort
A group of individuals with shared characteristics followed over time.

Confidence Interval (CI)
A range within which the true population parameter is expected to lie, with a certain probability.

Contagious
Able to be transmitted from one person to another through close contact.

Crude Mortality Rate
Overall mortality rate from all causes in a population.

Demographic Information
Population characteristics such as age, sex, race, and occupation.

Descriptive Epidemiology
Summarizes health-related data by time, place, and person.

Epidemic
Occurrence of more cases of disease than expected in a population during a specific period.

Epidemic Curve
Graphical display of the onset of disease cases over time during an epidemic.

Epidemiologic Triad
Model including agent, host, and environment in infectious disease causation.

Epidemiology
Study of the distribution and determinants of health-related states in populations.

Herd Immunity
Resistance to the spread of disease within a population due to a high proportion of immune individuals.

Incidence Rate
Rate of new cases of a disease in a population over a specified period.

Latency Period
Time from exposure to a causal agent to the onset of symptoms.

Mean (Arithmetic)
Average of a set of numbers.

Median
Middle value in a set of ordered numbers.

Mode
Most frequently occurring value in a dataset.

Morbidity
Presence of illness or disease.

Mortality Rate
Rate of death in a population.

Pandemic
An epidemic occurring over a wide geographic area and affecting a large proportion of the population.

Point Prevalence
Number of disease cases present in a population at a specific point in time.

Prevalence
Total number of existing disease cases in a population at a given time.

Relative Risk (RR)
Ratio of the risk of disease among exposed individuals to the risk among unexposed.

Risk Factor
An exposure or characteristic that increases the likelihood of developing a disease.

Vector
An organism, typically an insect, that transmits a disease agent from one host to another.

Virulence
The degree of pathogenicity or severity of disease caused by an agent.

Zoonoses
Diseases that are transmissible from animals to humans under natural conditions.

Source: The Healthcare IT Experts Blog & CDC Glossary of Terms

(ChatGPT was used in the design of this glossary)

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If you wish, these could be cut up and posted around the learning space

Nursing Station