Air quality and bioaerosols

Bioaerosols are airborne particles that are biological in origin.

Formed from any process that generates enough energy to separate small biological particles from a larger substance, such as wind, water, air, or other biological materials.

Plants, soil, water, and animals (including humans) all serve as sources of bioaerosols.

Bioaerosols are subsequently present in most places where any of these sources are found.

Bioaerosols are everywhere.

Bioaerosols have a direct effect on our world on a daily basis, causing many health and welfare effects.

Historically-significant events involving bioaerosols

Irish Potato Famine

Caused by the fungus, *Phytophthora infestans*, which devastated Ireland in the middle of the 19th century.

Over a period of three years, *P. infestans* decimated the potato crop of Ireland, leading to a famine that claimed the lives of an estimated 500,000-1,000,000 people.

Another 2,000,000 people left the country.

The fungus was carried by ships and wind from southern England to Ireland.

The fungus multiplied on the potato plants, causing its leaves to rot and wither, and was then transported by the wind to surrounding plants.

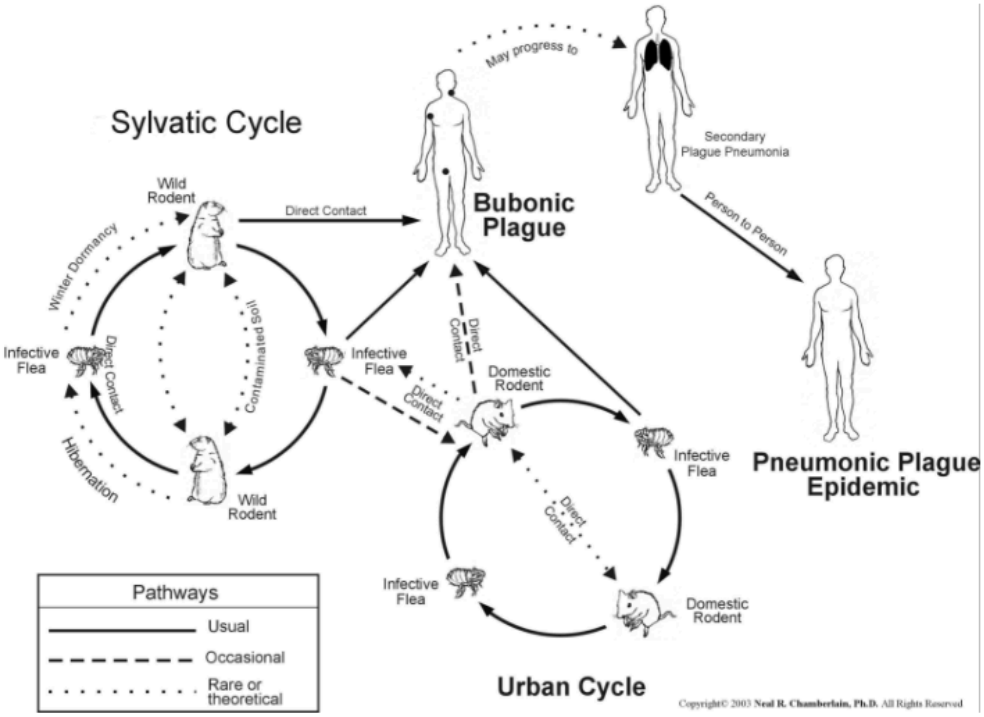
Plague

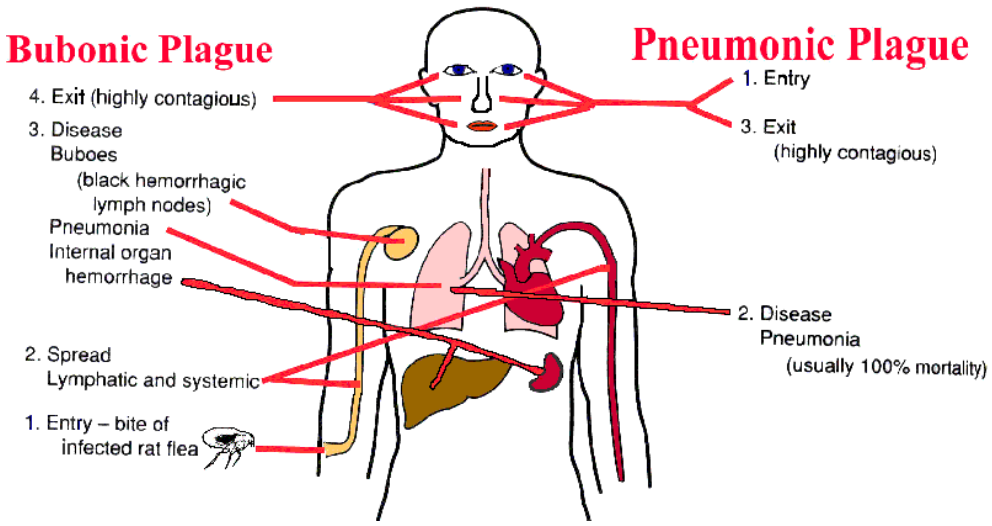
Plague or black death is an infection of rodents caused by *Yersinia pestis* and is accidentally transmitted to humans by the bite of infected fleas.

The disease follows urban and sylvatic cycles and is manifested in bubonic and pneumonic forms

bubo is derived from a Greek word for *groin*.

neumo is derived from a Greek word for *breath*





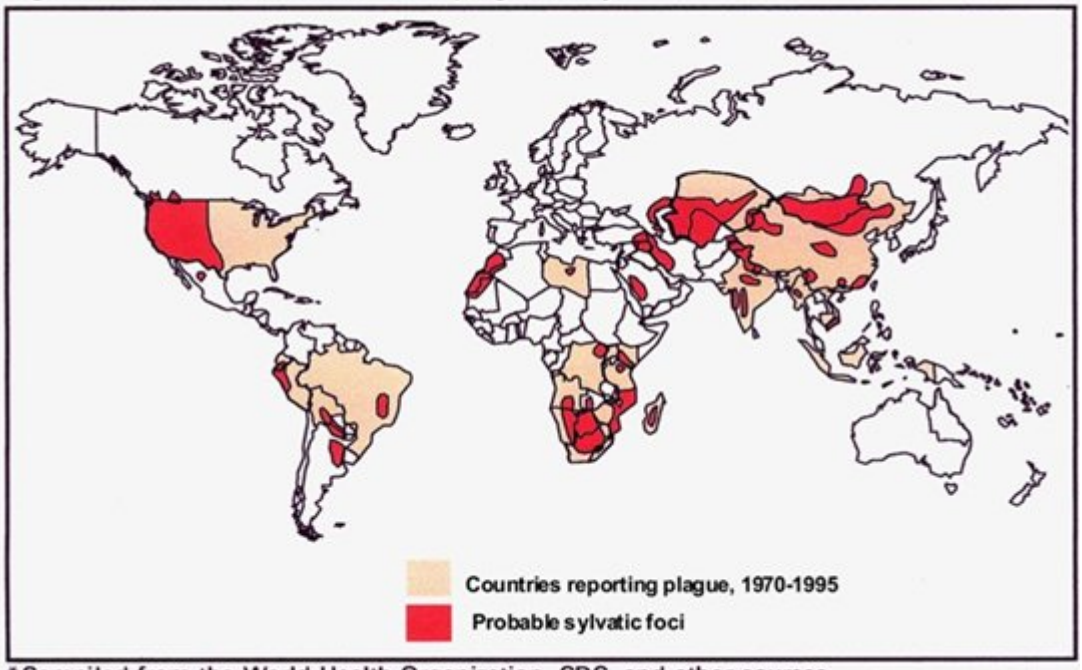
The plague was one of the great epidemic scourges of mankind, as it swept across Europe and Asia in a series of devastating pandemics during the Middle Ages (5th to 15th centuries).

> Responsible for the death of one-third of the world's population.

For largely unknown reasons, plague ceased to be an important pandemic disease.

> No major epidemics have occurred in Europe or North America in more than a century, although the pathogen is globally distributed.

Figure 2. Global distribution of the plague today *



*Compiled from the World Health Organization, CDC, and other sources.

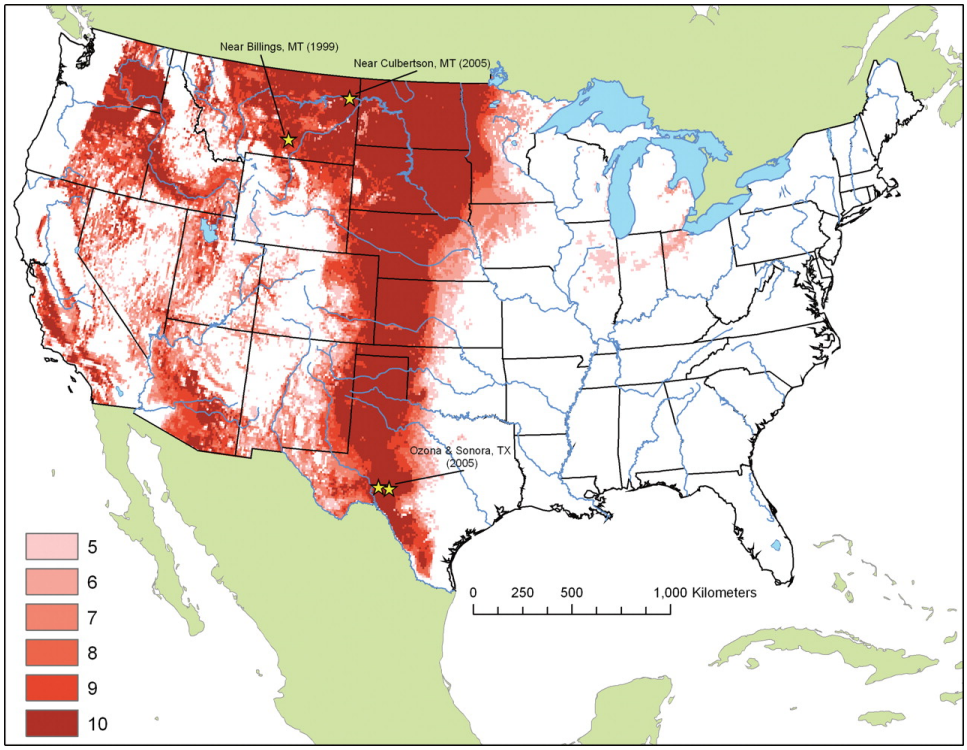
Y. pestis is currently on the list of possible agents that could be used by terrorists.

> Transmission by aerosols results in a very deadly form of this disease (pneumonic plague) that then can spread from person to person.

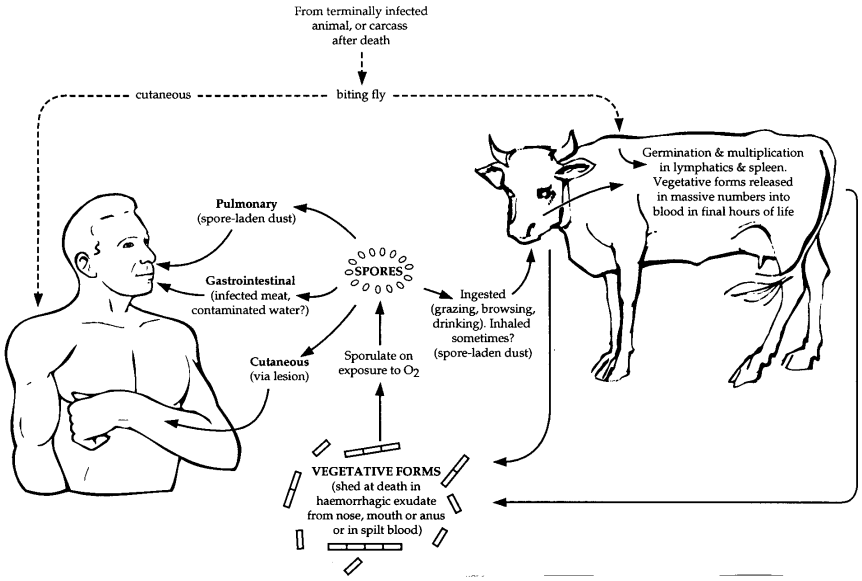
Anthrax

The anthrax attacks in the United States during the fall of 2001 killed five people and sickened another 17.

Bacillus anthracis is the causal agent of anthrax.



Predicted distribution of *Bacillus anthracis* in the 48 contiguous United States.

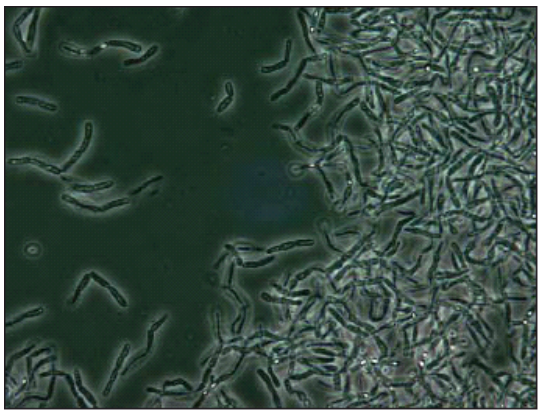


The anthrax cycle.

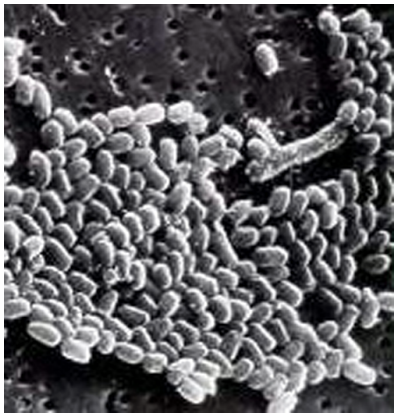
How do you get the bacteria to the intended victims ?

Disseminate spores

Once in an environment that is suitable for growth, the spores will germinate, become vegetative cells, and potentially infect.



***Bacillus anthracis* (vegetative)**



***B. anthracis* spores**

Spores enter the body through:

Ingestion - Progresses to sepsis (25 – 65% mortality if not treated)

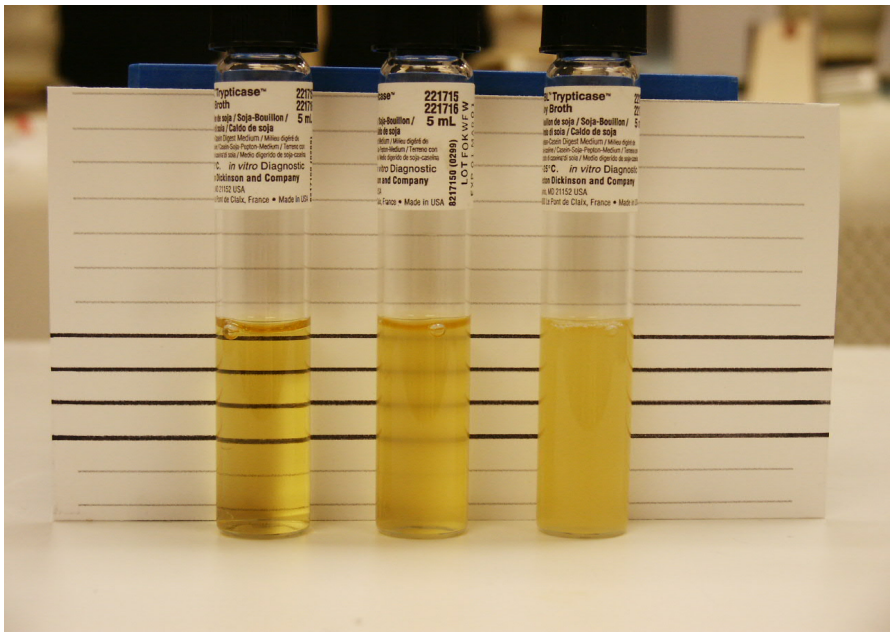
Inhalation - Macrophages engulf the inhaled endospores and transport them to lymph nodes. Progresses to meningitis (100%)

Cutaneous (skin) contact – Ulcer at site of infection. Rapidly progresses to necrosis. (20%).

What route of exposure might terrorist groups choose to use when weaponizing *B. anthracis*?

Growing *B. anthracis* is **easy**, but *weaponizing* it is **difficult**.

We can grow *Bacillus anthracis* to 10,000,000,000 bacteria ml^{-1} of broth.



0 cfu ml^{-1} 10^{9} 10^{10}

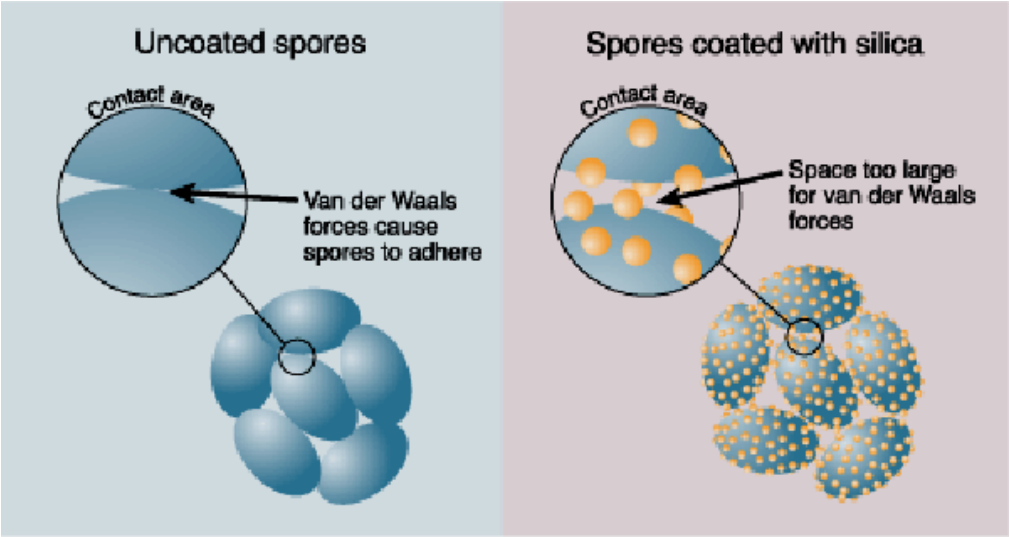
Lethal dose for man (inhalation) is estimated to be less than 50,000 *B. anthracis* spores.

So 10^{10} bacteria could kill nearly 200,000 people.

If released, it would only take kilogram quantities of spores to cover a 100 square km are and cause 50% mortality.

In 1979, an unintentional release of anthrax spores occurred in the former Soviet Union at a biological weapons facility. It was reported that 94 cases of anthrax occurred among citizens living near the facility resulting in 64 deaths. It was estimated that **less than one gram** of *Bacillus anthracis* spores were released during this accident. For a detailed report, see http://www.anthrax.osd.mil/documents/library/sverdlovsk.pdf

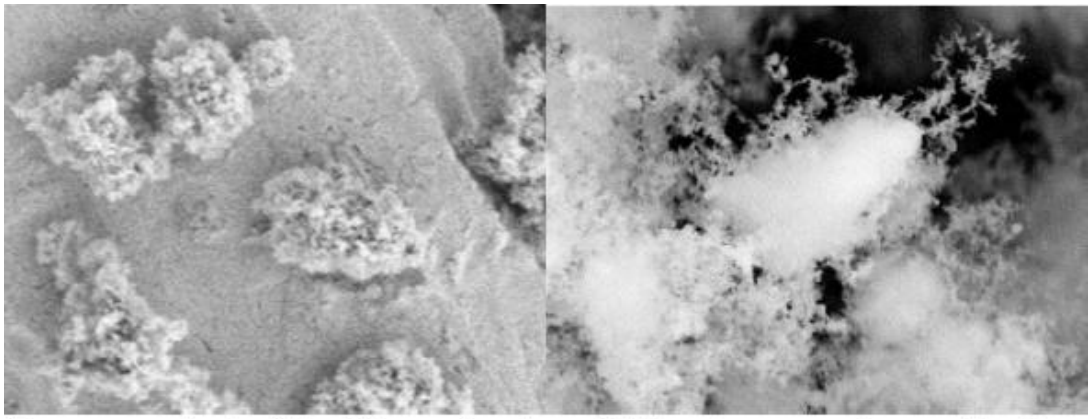
Aerosolization is a difficult process. What might make aerosolization difficult?



U.S. and Soviet bioweapons specialists discovered that adding silica particles to germ powders made them easier to disperse. Illustration by C. Cain, adapted from S. Jacobsen.

By alleviating the clumping, aerosol dissemination is much easier to achieve.

Eliminating clumping is likely the main obstacle preventing more widespread use of *B. anthracis* as a bioterrorism weapon.



Spores coated with silica using two different processing methods.

The flu virus - "success" of the flu virus has been evident throughout history.

An epidemic described by Hippocrates from the 5th century B.C. is thought to have been influenza.

In the last ~900 years, more than 300 flu-like epidemics have been recorded.

One epidemic occurs somewhere in the world approximately every **2.4** years.

In 1918 the "Spanish Flu" killed an estimated 20 million people worldwide.

Other outbreaks in the US occurred in the late 50s and then again in the late 60s.

Rows of cots filled with patients stricken in the 1918 influenza epidemic at a naval training station in California. It is believed that the massive movements of troops and refugees during World War I helped to spread the virus. From: U.S. Naval Center.

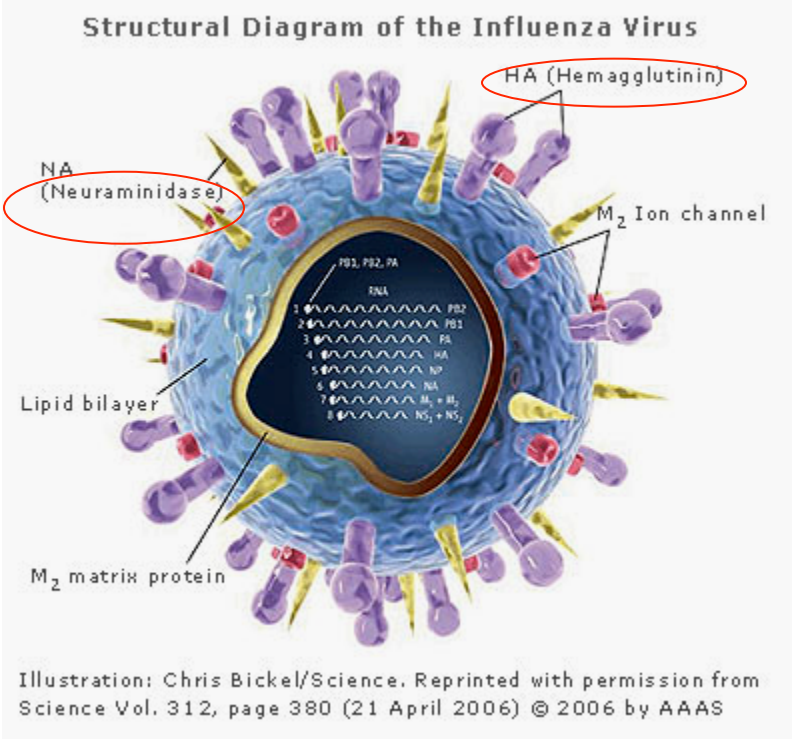
This May 29, 1919 photograph shows rows of tents that were set up on a lawn at Emery Hill in Lawrence, Massachusetts where victims of the 1918 influenza pandemic were treated.

Why is the flu such a "successful" disease?

1. The virus appears in many different forms, called **strains.**

   Influenza virus is an RNA virus - it encodes its genome in RNA rather than DNA.

   The viral RNA genome is composed of 8 segments, each of which carries different genes



Structure of the Influenza A virus. The eight RNA segments carry the genes used by the virus for synthesizing various proteins. Among those proteins are the envelope glycoproteins hemagglutinin (HA) and neuraminidase (NA), which are the primary antigens recognized by the immune system.

Two viral genes, hemagglutinin (H) and neuraminidase (N) are of particular importance to both the virulence and epidemiology of influenza.

Each is located on a different segment of the genome and essential to the completion of viral replication cycle.

Hemagglutinin is the viral envelope glycoprotein - responsible for *attachment* to and *penetration* of host respiratory cells.

Neuraminidase is an envelope enzyme - allows newly formed viral particles to *leave the host cell*.

Ironically, these proteins are also the principle antigens recognized by your host immune system, i.e., when you are infected with influenza, i.e., you produce antibodies against the H and N antigens.

Memory to these antigens is protective against a second infection by the same strain. **So, why do humans often suffer from multiple bouts of the flu in their lifetimes?**

This is because different stains of influenza differ in their H and N antigens.

13 known variations of hemagglutinin and 9 neuraminidase immunological types are known to exist, all of which cause different immune responses.

Immunologic memory against one type of H or N does not guarantee protection against other types.

Flu epidemic	Causal flu antigenic strain
1918 Spanish Flu	H1N1
1957 Asian Flu	H2N2
1968 Hong Kong Flu	H3N2
2003 Bird Flu	H5N1
2009 Swine Flu	H1N1

2. Epidemic outbreaks of influenza occur as the virus **changes genetically.**

The segmented RNA genome of the flu virus has two important consequences for influenza epidemiology.

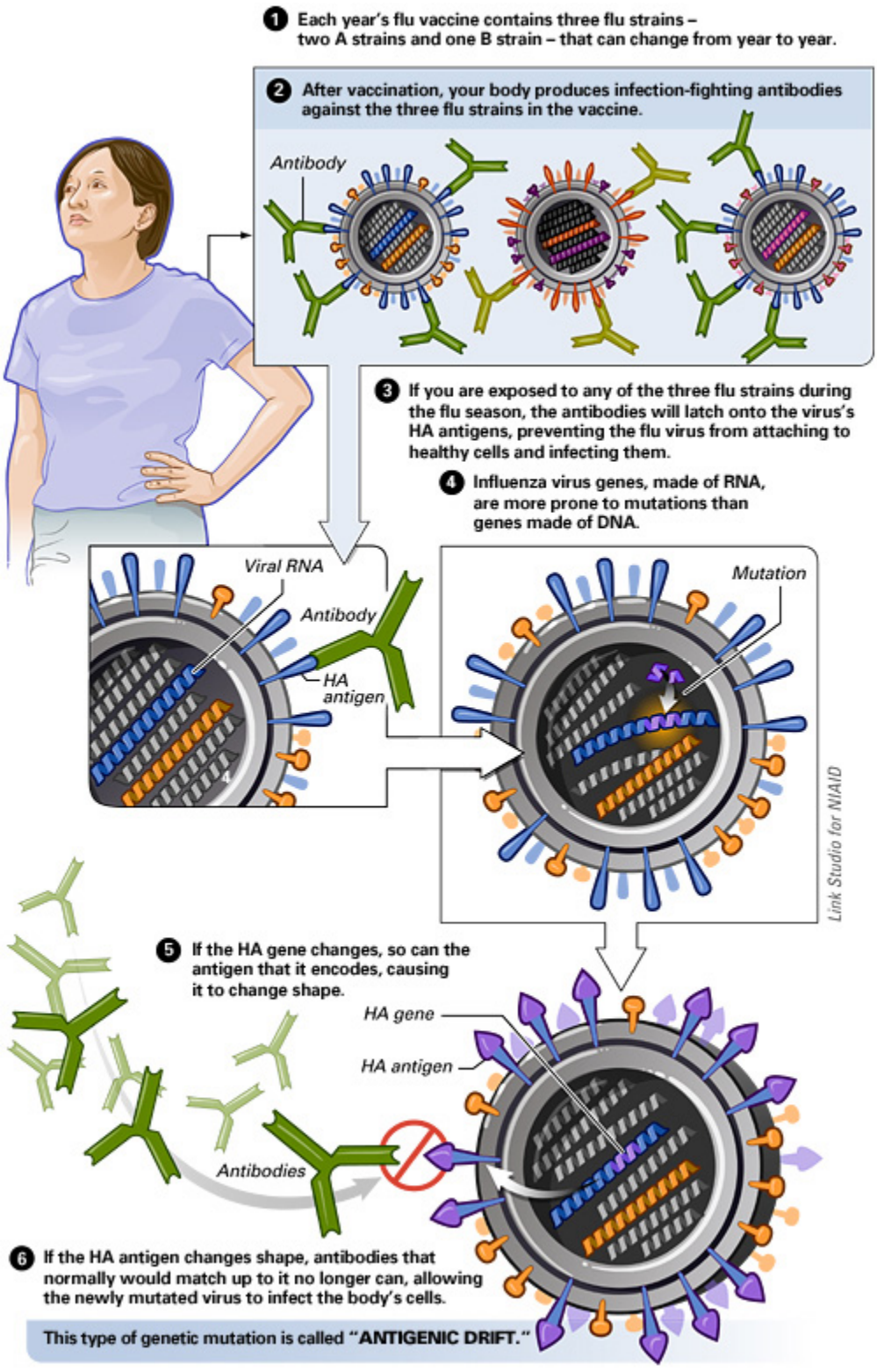
First, like all RNA viruses, influenza virus mutates rapidly, much faster than DNA viruses, bacteria, or eukaryotes.

No repair mechanisms in RNA viruses.

Allows a large number of mutations to be constantly being introduced, therefore changing the viruses genetically.

Some of the mutations might affect proteins (e.g. H and N) that are recognized by a host immune system as antigens – called **antigenic drift**.

Your immune system might not recognize the virus anymore.

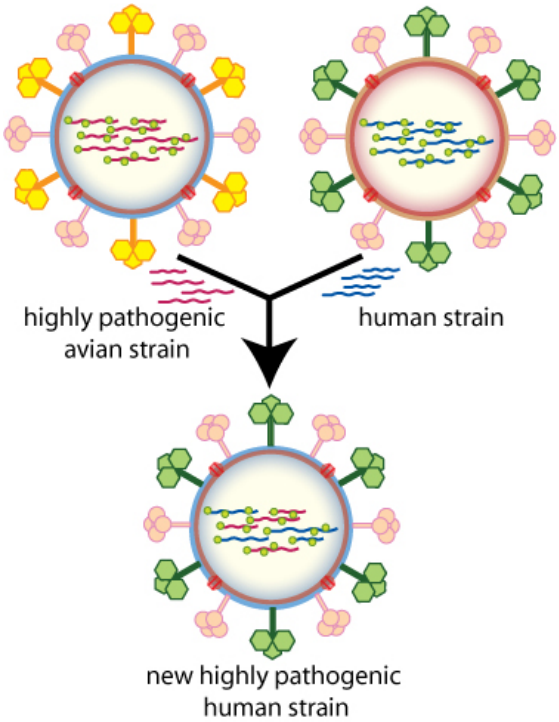

1 Each year's flu vaccine contains three flu strains – two A strains and one B strain – that can change from year to year.
2 After vaccination, your body produces infection-fighting antibodies against the three flu strains in the vaccine.
Antibody
3 If you are exposed to any of the three flu strains during the flu season, the antibodies will latch onto the virus's HA antigens, preventing the flu virus from attaching to healthy cells and infecting them.
4 Influenza virus genes, made of RNA, are more prone to mutations than genes made of DNA.
Viral RNA
Antibody
HA antigen
Mutation
Link Studio for NIAID
5 If the HA gene changes, so can the antigen that it encodes, causing it to change shape.
HA gene
HA antigen
Antibodies
6 If the HA antigen changes shape, antibodies that normally would match up to it no longer can, allowing the newly mutated virus to infect the body's cells.
This type of genetic mutation is called "ANTIGENIC DRIFT."

Second, sometimes a cell can be infected by **two** influenza viruses at the same time.

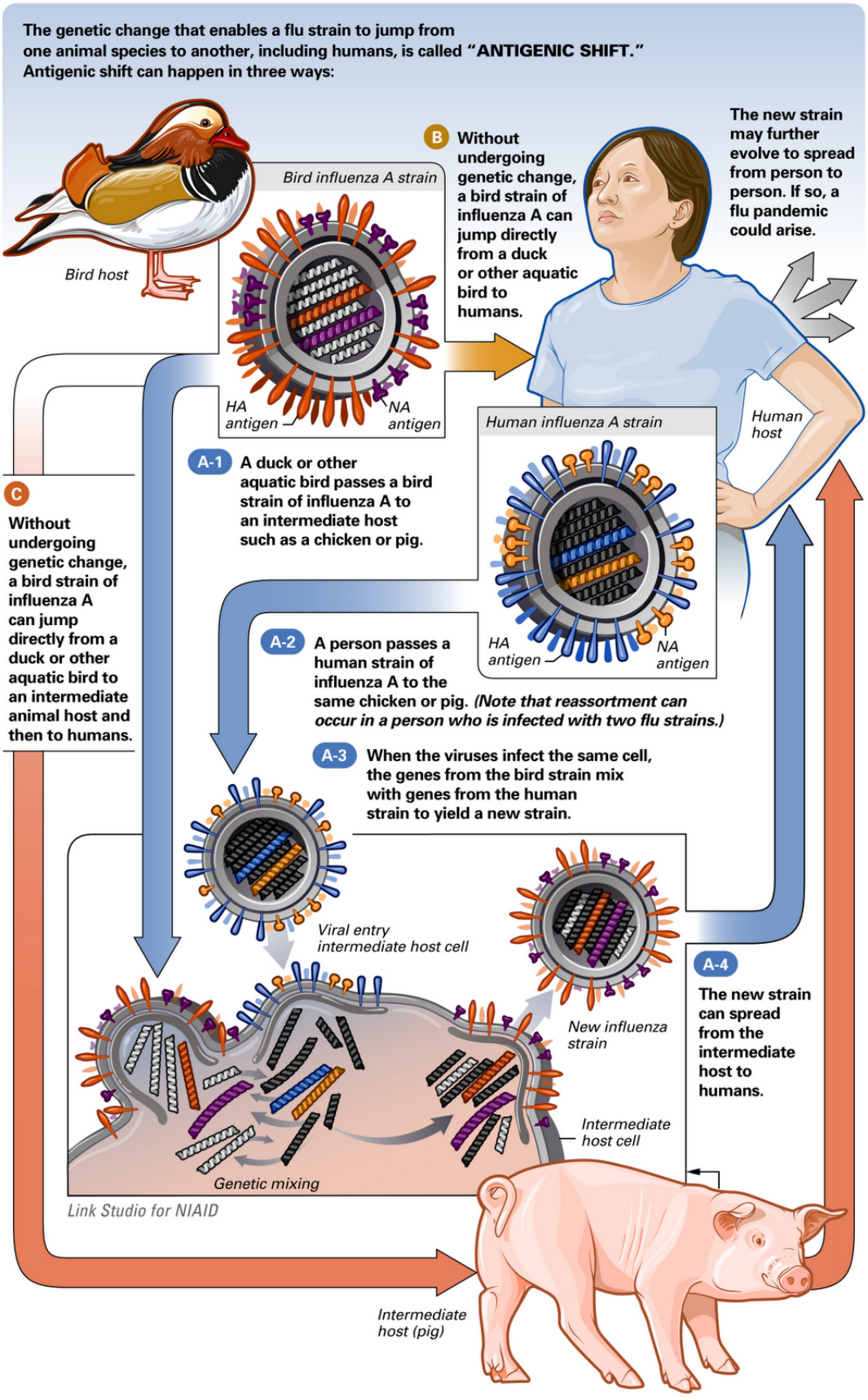
Each of these viruses will replicate all 8 of its RNA segments, but when the new viruses are assembled, they might get some of the eight segments from one parent virus and some from the other.

This reshuffling of the genetic material can cause dramatic new viral strains to emerge for which herd immunity in humans is essentially absent.

This process is called **antigenic shift**, and is the principle reason for the emergence of new viral strains.



How antigenic shift, or reassortment, can result in novel and highly pathogenic strains of human influenza. From: Wikipedia.


The genetic change that enables a flu strain to jump from one animal species to another, including humans, is called "ANTIGENIC SHIFT." Antigenic shift can happen in three ways:
Bird host
Bird influenza A strain
HA antigen
NA antigen
B Without undergoing genetic change, a bird strain of influenza A can jump directly from a duck or other aquatic bird to humans.
The new strain may further evolve to spread from person to person. If so, a flu pandemic could arise.
Human host
Human influenza A strain
HA antigen
NA antigen
A-1 A duck or other aquatic bird passes a bird strain of influenza A to an intermediate host such as a chicken or pig.
C Without undergoing genetic change, a bird strain of influenza A can jump directly from a duck or other aquatic bird to an intermediate animal host and then to humans.
A-2 A person passes a human strain of influenza A to the same chicken or pig. (Note that reassortment can occur in a person who is infected with two flu strains.)
A-3 When the viruses infect the same cell, the genes from the bird strain mix with genes from the human strain to yield a new strain.
Viral entry intermediate host cell
New influenza strain
A-4 The new strain can spread from the intermediate host to humans.
Intermediate host cell
Genetic mixing
Link Studio for NIAID
Intermediate host (pig)

Because of antigenic drift and shift, influenza is a moving target for epidemiologists.

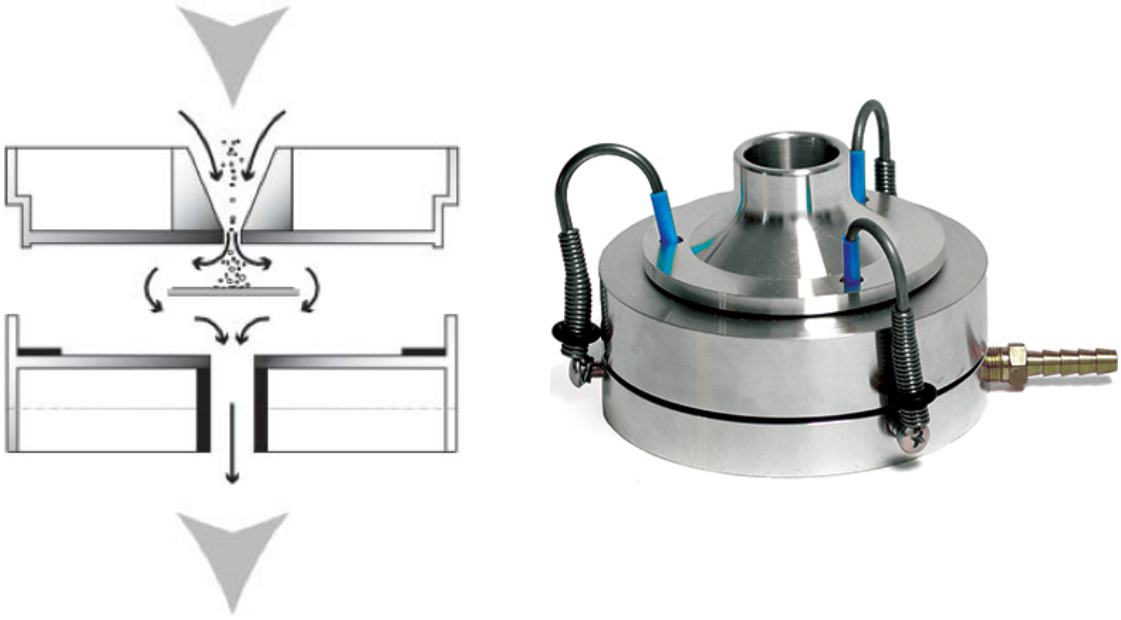
This is the reason why this year's flu shot will likely not work for next year's flu strain.

Bioaerosol sampling methods

Impaction

Impactors utilize the bioaerosol inertia to collect the bioaerosol onto a solid or semi-solid collection medium on a Petri dish.

The impactor forces the air stream to turn a tight corner. If the inertia of the bioaerosol is great enough, then the bioaerosol will fall out of the airstream and impact onto the collection medium.



Schematic of air-flow through an impactor and the impactor manifold.

Once the bioaerosols are collected onto the collection medium, they can be cultivated to determine the viable count.

Multi-stage impactors can be used to collect a wide range of bioaerosol

sizes. Because the impactor utilizes inertia to physically collect particles, its physical collection efficiency is highly dependent on particle size.

Multi-stage impactors.

Advantages and disadvantages…what do you think?

Impingement

Liquid impingers also use inertia to physically collect bioaerosols. However, they also use diffusion.

Rather than having a solid or semi-solid collection medium like the impactor, the collection medium of the impinger is liquid buffer.

The air stream is similarly forced to take a tight corner, and the bioaerosols are collected into the liquid by inertial impaction.

Bioaerosols can also diffuse out of the air stream into the buffer.

> Although liquid impingers rely partly on impaction, diffusion also contributes to the physical collection efficiency of very small bioaerosols.

Once the bioaerosols are collected onto the collection buffer, the buffer can be (i) enriched for the organisms of choice (liquid or solid media), or processed for DNA/RNA isolation and molecular techniques.

Advantages and disadvantages…what do you think?