2.2 Viruses, Viroids, and Prions

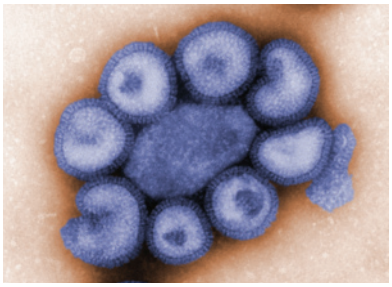

Figure 1 Human influenza viruses cause seasonal flu. It would take 10 million viruses placed side by side to cover a distance of 1 mm.

virus a small infectious particle containing genetic material in the form of DNA or RNA within a protein capsule

capsid a protein coat that surrounds the DNA or RNA of a virus

RNA (ribonucleic acid) a nucleic acid found in all cells and some viruses; usually carries genetic information that provides instructions for synthesizing protein

epidemic a large-scale outbreak of disease; usually confined to a limited geographic region

pandemic an epidemic that occurs over a widespread geographic area, often globally

Each fall millions of Canadians line up for an annual flu shot. The flu shot is a vaccine designed to help protect you from the influenza virus and prevent you from getting the seasonal flu (**Figure 1**).

In this section you will explore the biology of viruses and other infectious particles. You will examine their role in causing disease as well as how they can be used to treat or prevent disease.

Viruses

Viruses are small, non-living particles. A virus particle consists of genetic material surrounded by a capsule made of protein, called a **capsid**. Viruses have no cytoplasm, and many are less than 0.1 μm in diameter—hundreds of thousands of viruses could easily fit inside a typical human cell. Viruses cannot grow or reproduce on their own and do not produce or use energy. They do not create waste. You can think of them as packages of genetic instructions that can enter and take control of cells. Their genetic material is a piece of DNA or **RNA (ribonucleic acid)**. Like DNA, RNA can carry information that provides instructions for synthesizing protein molecules.

All viruses are infectious—they are passed from cell to cell and from organism to organism. After a virus enters a host cell, the viral DNA (or RNA) may begin to take control of the cell. The cell eventually makes copies of the virus.

Why Viruses Are Important

Viruses are responsible for many human diseases. Some viral diseases, such as the common cold and chicken pox, produce relatively mild symptoms. Others, such as AIDS, cholera, and rabies, are much more serious and can be deadly. Viral diseases are significant not only because they affect individuals, but also because of their ability to spread. Some, such as the influenza virus, are transmitted easily from person to person and can infect millions of people in a relatively short time. A large, rapidly spreading outbreak of disease in a particular region is called an **epidemic**. When an epidemic spreads on a global scale, it is called a **pandemic**. **Table 1** lists some significant viruses and the diseases they cause in humans.

A small number of viruses play a role in certain cancers. All cancers involve uncontrolled cell division caused by mutations in the cells' DNA. When viruses infect host cells, they sometimes create changes in the host's DNA that can lead to cancer. The hepatitis C virus, for example, has been shown to be a major contributor to liver cancer.

Viruses cause diseases in wild and domestic animals as well as in humans. Plant viruses destroy millions of tonnes of crops every year, especially cereals, potatoes, sugar beets, and sugar cane.

Although some viruses can be harmful, they are important in ecosystems. By causing disease, they control the populations of other organisms. Viruses are also extremely abundant. A single millilitre of ocean water can contain millions of viruses.

Table 1 Disease-Causing Viruses

DNA viruses	Disease
hepadnavirus	hepatitis B
herpesvirus	cold sores, genital herpes, chicken pox
adenovirus	respiratory infections, tumours
RNA viruses	**Disease**
paramyxovirus	measles, mumps, pneumonia, polio, common cold
retrovirus	HIV/AIDS
rhabdovirus	rabies

Classification and Phylogeny

Viruses challenge the basic categories of living and non-living. They are classified as non-living because they do not have the key characteristics of living cells. However, viruses do share one important trait with living things: they reproduce. Unlike other living things, however, viruses cannot reproduce without a host cell. The way viruses reproduce makes them very interesting to biologists.

Viruses are classified into orders, families, genera, and species. They are classified based on a variety of features including size, shape, and type of genetic material. About 4000 virus species have been classified, but scientists believe that there may be millions.

Most viruses can infect only a single host species or a few closely related hosts. A species of virus might infect only one organ system, or a single tissue or cell type in its host. For example, human immunodeficiency virus (HIV) infects only certain immune system cells. However, some viruses can infect many species. For example, the rabies virus can likely infect all species of mammals and birds. Of the roughly 80 known virus families, 21 include viruses that cause disease in humans.

Viruses that infect bacterial cells are called **bacteriophages**, or phages. Most other types of viruses enter the host cell, but phages do not. Instead, they inject their DNA into the bacterium, and their protein capsule remains outside the cell (**Figure 2**). Phages have been the subject of intense research. Much of our early understanding about the structure and function of viruses came from this research.

bacteriophage a virus that infects bacteria

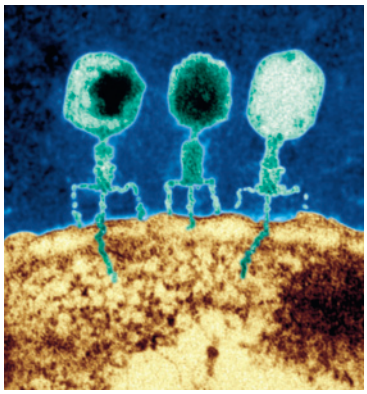

Figure 2 Three bacteriophages attach to the outer surface of a bacterium. You can see the strands of DNA that the phages are injecting into the cell.

The Origin of Viruses

Several different hypotheses have been proposed to explain the origin of viruses. One possibility is that viruses originated as small infectious cells that over time lost their cytoplasm and their ability to reproduce outside a living cell. Some biologists suspect that viruses originated as "escaped" fragments of DNA or RNA molecules that once formed part of living cells. A recent hypothesis suggests that viruses are ancient, and that virus-like particles existed even before the first cells.

Characteristics

Viruses vary in structure, but they all consist of an RNA or DNA molecule surrounded by a capsid. Some common virus shapes are shown in **Figure 3**. In addition to the capsid, some viruses are surrounded by an envelope. The envelope is created when a virus leaves a host cell and part of the host cell membrane wraps around the virus (**Figure 4**).

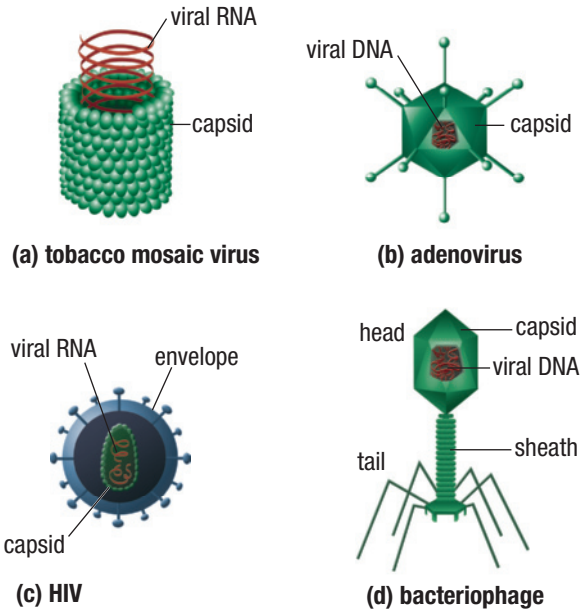

Figure 3 Viruses consist of a molecule of RNA or DNA surrounded by a capsid. (a) and (b) The capsid takes various geometric shapes. (c) Some viruses, such as HIV, also have an envelope made from the membrane of a host cell. (d) Phages have a complex head and tail structure.

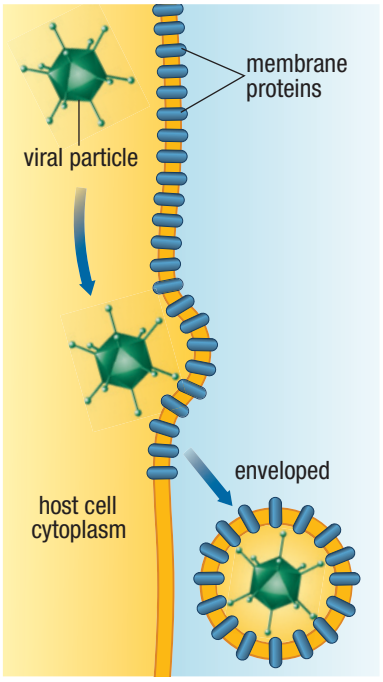

Figure 4 When some viruses leave their host cell, a membrane envelope forms around them.

Infectious Cycles

Viruses do not carry out life functions like living cells do. They become active only when their genetic material has entered and taken control of a living cell. The process by which a virus infects a host cell, replicates, and destroys the host cell is called an infectious cycle. **Figure 5** shows two common infectious cycles using the *lambda* phage as an example.

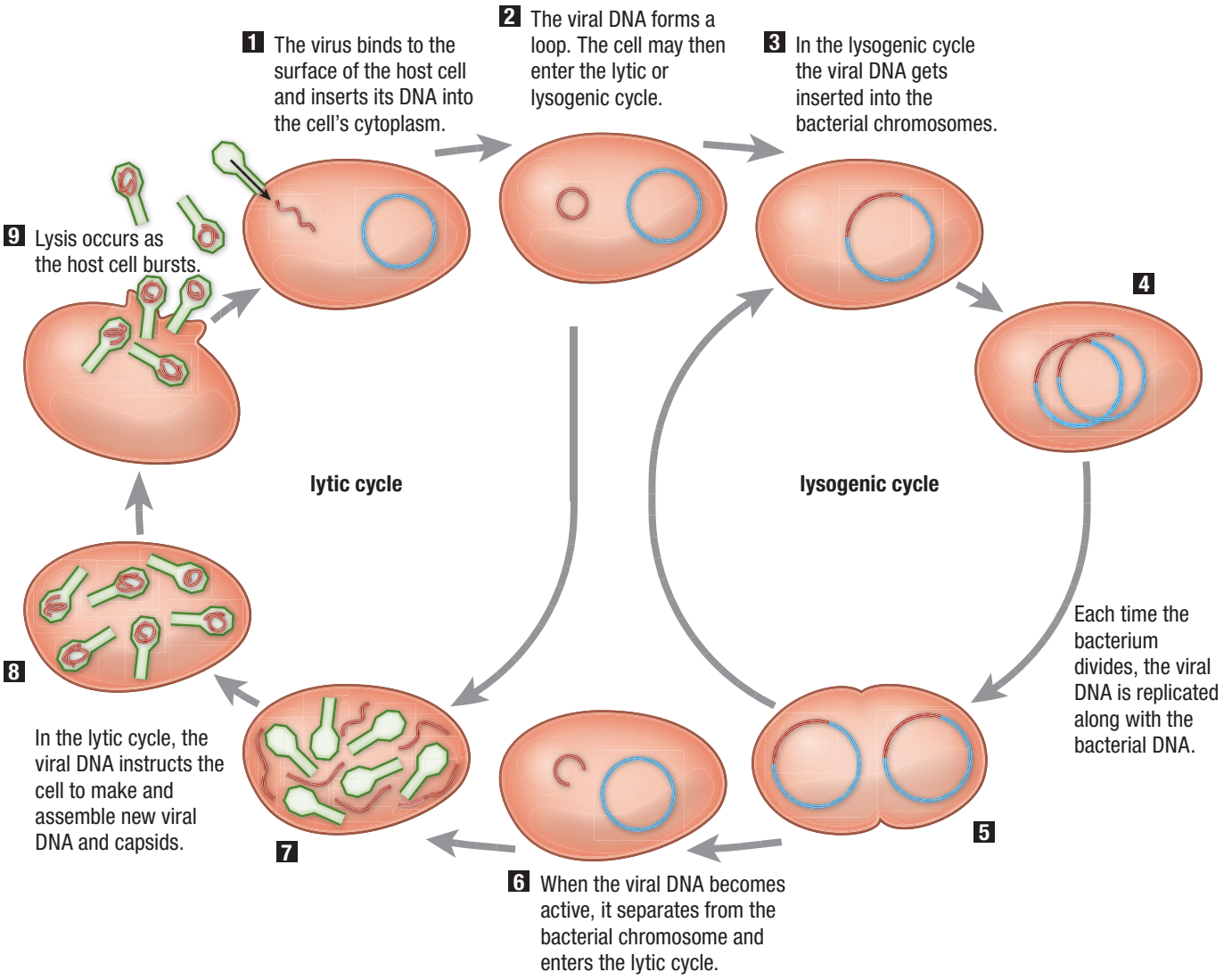

Figure 5 Phage infections can include both lytic and lysogenic cycles.

lysis the rupturing of a cell; can occur when newly made viruses are released from a host cell

lysogeny a state of dormancy in which viral DNA may remain within a host cell's chromosome for many cell cycle generations

transduction a type of gene transfer in which a virus transfers DNA from one bacterium to another

In the lytic cycle, when assembly is complete, **lysis** occurs as the host cell ruptures, or bursts, releasing about 100 to 200 new viruses into the host cell's surroundings. The host cell is then destroyed. This entire lytic cycle can take less than one hour.

In the lysogenic cycle, the viral DNA can stay in a dormant state, called **lysogeny**, for many years. The bacterium continues to grow and divide normally, but each time it divides it makes a copy of the virus DNA that was inserted within its own chromosome. When triggered by a change within the cell's environment, the viral DNA becomes active, separates from the bacterial chromosome, and enters the lytic cycle.

On rare occasions, when the viral DNA separates from the bacterial chromosome (Step 6 in Figure 5), a small piece of the bacterial DNA may separate from the chromosome and become incorporated into the viral DNA (this process is not illustrated in Figure 5). When this happens, the newly released viruses carry this piece of bacterial DNA and may insert it into different bacteria when they infect other cells. This is a form of gene transfer called **transduction**.

The infectious cycles of animal viruses follow a pattern similar to that of bacteriophages, except that the virus's capsid enters the cell along with the viral DNA. Some viruses do not cause lysis. Some animal viruses enter a dormant phase, similar to the lysogenic cycle for bacteriophages, in which the viral DNA is incorporated into the cell's chromosomes.

Sometimes the whole virus stays in the cell's cytoplasm in a dormant state. For example, the herpes viruses that infect humans remain dormant in the cytoplasm of some body cells for the person's entire life. At times, particularly during periods of stress, the virus becomes active in some cells. The viruses are replicated and destroy the cells as they are released. When this occurs in large numbers of cells, noticeable ulcers, or cold sores, form. The viruses then infect other cells and may once again go dormant. In this way, the person stays permanently infected with the virus.

Viruses are spread, or transmitted, in many ways. Some spread through the air or by direct physical contact with an infected individual. Others are spread by biting insects or enter the body through injuries. **Table 2** lists some viruses and the ways they are transmitted.

Table 2 Viral Transmission

Disease	Method of transmission
rabies	bite by infected mammal
HIV/AIDS	exchange of body fluids
influenza, common cold, chicken pox	airborne and by contact
measles, mumps	direct contact

Vaccinations and Human Health

Vaccines are mixtures that contain weakened forms or parts of a dangerous virus. When these altered viruses are injected into an individual's body, they trigger a response by the immune system without causing an infection. This exposure creates a form of chemical "memory" that allows the immune system to react quickly if the individual ever comes in contact with the real virus. Vaccination programs have dramatically reduced human suffering and saved countless lives. In countries with modern healthcare systems, many serious diseases have been nearly eliminated. Smallpox was once a dreaded disease, but it has been completely eradicated (**Figure 6**).

Figure 6 The last recorded case of smallpox was in 1977.

In 2006, a vaccine was created for several strains of the human papillomavirus (HPV). HPV is spread through sexual contact and is responsible for more than 70 % of all cancers of the cervix, a part of the female reproductive system. The vaccine is considered more than 99 % effective at preventing the spread of the virus.

Unfortunately, it is not always possible to develop effective vaccines. For some diseases, such as AIDS, the structure of the virus and characteristics of the infection are obstacles to vaccine development. For other diseases, such as influenza, the virus is constantly changing, so a vaccine that works against a form of the disease in one year is unlikely to be as effective the next year.

Research This

Viral Diseases and the WHO

Skills: Researching, Analyzing, Evaluating, Communicating

SKILLS HANDBOOK A2.1, A5.1

The World Health Organization (WHO) monitors and controls outbreaks of infectious diseases, such as SARS, malaria, tuberculosis, swine flu, and AIDS. Each year, they predict which viral diseases are most likely to become a serious concern. They then recommend the mass production of a vaccine for those strains. In this investigation, you will examine the role of the WHO and research a viral disease of your choice.

1. Visit the website of the World Health Organization.
2. Choose a viral disease from the WHO website and research its cause, symptoms, prevention, and treatment (if any).
3. List and describe any disease outbreaks currently being reported.

A. Summarize your findings, including the WHO recommendations about your selected disease. T/I C

B. List and summarize the current status of any other viral disease outbreaks reported by the WHO. T/I C

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Putting Viruses to Work

gene therapy a method of treating disease in which genes are introduced into cells to replace, supplement, or repair a defective gene

Although all viruses cause disease, they can be beneficial. As mentioned before, viruses play an important role in ecosystems. Of particular interest to humans is the role viruses play in lowering the numbers of harmful bacteria.

Recently scientists have been exploring the use of viruses in genetic engineering and in **gene therapy**—the treatment of diseases using genes. As you have learned, viruses can enter specific cells, and some can insert their own DNA into the chromosomes of the cells they infect. Scientists can therefore use viruses to deliver drugs or genes to targeted cells (**Figure 7**). They place drugs inside virus capsules or replace the viral DNA with DNA they want to insert into a host cell. This technology is still relatively new, but it is being used effectively in some applications and holds great promise in others. **Table 3** lists some possible uses of viruses in biotechnology.

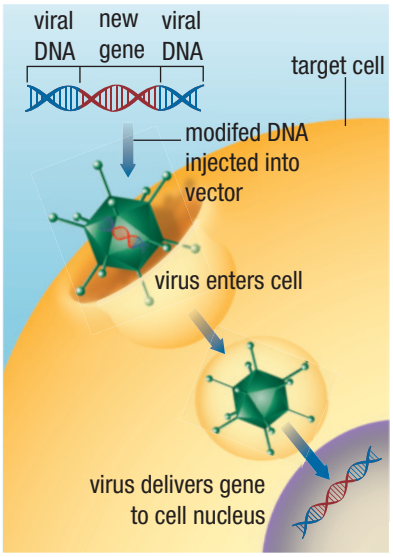

Figure 7 Viruses can be used to deliver genes and drugs to targeted cells.

Table 3 Applications of Technologies That Use Viruses

Technology	Application or possible application
using a virus capsule to deliver a drug	• This method may be used to deliver drugs to targeted cells in the body, for example, to deliver toxic chemotherapy drugs to cancerous tumour cells.
using a virus to insert a new copy of a gene	• This method may be used to insert corrective genes into individuals who suffer from a genetic disorder.
using a virus to insert a gene taken from one species into another species	• This method can be used to create genetically modified organisms. • It is widely used in the genetic engineering of plants.

The use of viruses in medicine has technological problems, serious risks, and ethical concerns. Early attempts to treat people with virus therapies have had only limited success and have directly caused at least one death. The most recent trials, however, have been more promising.

Viroids and Prions

viroid a very small infectious piece of RNA responsible for some serious diseases in plants

Viroids are small, infectious pieces of RNA that were first discovered in 1971. Viroids are smaller than any virus and do not have a capsid. They also differ from viruses in that their RNA does not code for any proteins. Viroids are plant pathogens that can quickly destroy entire fields of citrus, potatoes, tomatoes, coconut palms, and other crop plants. In one case, a viroid outbreak killed more than 10 million coconut palms in the Philippines, devastating this important agricultural crop. Scientists do not know how viroids cause disease. Recent research indicates that the viroid may interfere with the normal formation and functioning of RNA within the host cell.

prion an abnormally shaped infectious protein responsible for some brain diseases of mammals, including humans

Prions, or proteinaceous infectious particles, cause a number of rare diseases in mammals. Prions are abnormally shaped proteins found in the brain and nervous tissues of infected animals. When those tissues are eaten by another animal, the prions enter that animal's bloodstream and go to its brain. In the infected animal's brain, the prions interact with normally shaped proteins, causing those proteins to change shape and become abnormal and infectious. The brains of affected animals are full of spongy holes.

Prion diseases made headlines around the world in the late 1980s when farmers in the United Kingdom reported a new disease spreading among their cattle. The disease, called bovine spongiform encephalopathy (BSE), or "mad cow disease," is estimated to have infected over 900 000 cattle in the United Kingdom. Many of those infected cattle entered the human food chain before developing symptoms. Tragically, some people who ate the contaminated meat developed a new human disease, known as variant Creutzfeldt-Jakob disease (CJD). Between 1996, when variant CJD was first described, and 2007, there were 208 cases in 11 countries. The vast majority of these cases were in the United Kingdom.

2.2 Summary

- Viruses are tiny, nonliving particles that infect cells and cause diseases.
- Viruses consist of genetic material in the form of either DNA or RNA surrounded by a capsid.
- After a virus or its genetic material enters a host cell, it takes control of the cell in order to reproduce itself.
- Phages are viruses that infect bacteria. They undergo lytic or lysogenic cycles.
- Some viruses stay dormant in their host cells for many years.
- Important human viral diseases include HIV/AIDS, influenza, measles, mumps, chicken pox, and hepatitis.
- Vaccinations have been extremely successful in reducing the incidence of many serious viral diseases.
- Viruses are being used as tools for inserting drugs or DNA into cells.
- Viroids are small, infectious pieces of RNA that cause diseases in plants.
- Prions are abnormal infectious proteins that cause disease in mammals.

2.2 Questions

1. Why are viruses considered to be non-living? K/U
2. What characteristic do viruses share with all living things? K/U
3. Which viral diseases are quite common and associated with the winter season? K/U
4. Create labelled sketches of
   (a) a virus surrounded by an envelope
   (b) a bacteriophage
   (c) the lytic cycle of a bacteriophage K/U C
5. How is the behaviour of a bacteriophage different from that of a virus that infects an animal cell? K/U
6. Explain the relationship between a virus's dormant period in a cell and the appearance of cold sores. K/U
7. Give examples of viral diseases that are spread by
   (a) the bite of an animal
   (b) the exchange of bodily fluids
   (c) direct contact or through the air K/U A
8. Smallpox viruses can replicate only inside a human cell. Human influenza viruses can replicate in human cells and in the cells of pigs and some other animals. How might this difference influence the success of vaccination programs? K/U A
9. The human influenza virus H1N1—also referred to as the 2009 swine flu—was declared a pandemic by the World Health Organization. Use the Internet and other sources to answer the following questions:
   (a) What criteria does the WHO use to designate a disease outbreak as a "pandemic"?
   (b) How many deaths are thought to have resulted from this pandemic?
   (c) How many countries have reported cases of H1N1?
   (d) How did Canada respond to this outbreak? T/I
10. Viruses control populations of organisms by causing disease. Humans have also used viral diseases to control pests and invasive species. Do online research to find an example of a virus used to control rabbit populations in Australia. K/U T/I
    (a) When and why did rabbits become a problem in Australia?
    (b) Why and how were viruses used to control the rabbits?
    (c) How successful was the viral pest control?
    (d) What are some possible drawbacks of using viruses as pest control? Have any examples of these drawbacks been observed?
11. Kuru is a human prion disease discovered among some indigenous peoples of New Guinea. Research how this disease is transmitted and how long it takes to develop. T/I
12. Use the Internet and other sources to find out what routine vaccinations are currently recommended by the Ontario Ministry of Health. T/I
13. Conduct research to find out what vaccinations are recommended for travel to a tropical country of your choice. T/I
14. Dogs and cats are susceptible to a number of serious viral diseases. Check with your local veterinary clinic or go online to see what vaccinations are recommended for these pets. Report your findings to the class in a format of your choice. T/I C
15. Mumps is a potentially serious viral disease. It can cause deafness, sterility, meningitis, and encephalitis. Do online research to answer the following questions:
    (a) Why is there renewed concern about this disease when there is already a vaccination program in place?
    (b) What does "herd immunity" mean? How does it help control the spread of disease?
    (c) Why is getting the disease after puberty of particular concern to males? T/I

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