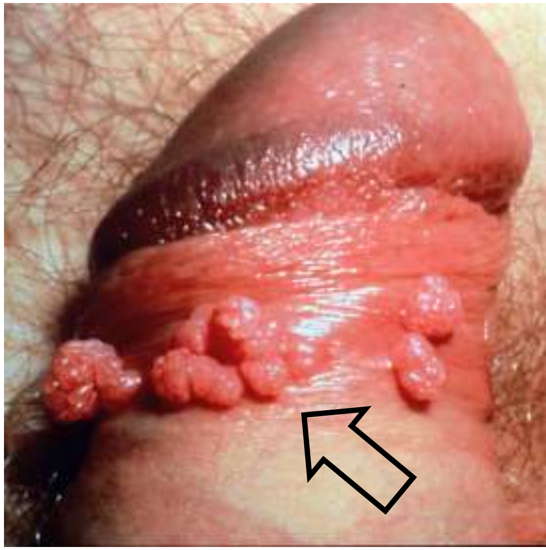
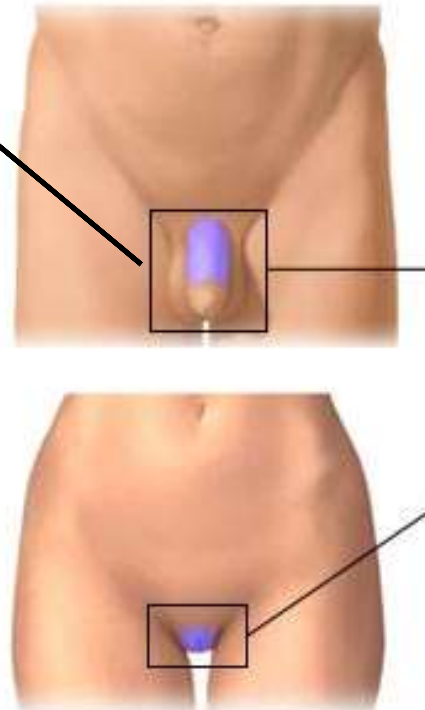
# Chapter 26

# Introduction to Viruses

**Modified by YJ Chuang at NTHU-MS**

# Human papillomavirus (HPV) 人類乳突病毒





Genital warts:
Found on shaft of penis (male), vagina, vulva, cervix (female), and around anus

性行為影響發病位置


HPV infection on the lips and in the mouth / 唇，口腔

HPV infection around/in anus / 肛門

# 2008 Nobel-Prize laureate for Physiology/Medicine

More information on NTHU web site:
諾貝爾大師在清華 http://www.nthu.edu.tw/nobel/index.php

- 2008年諾貝爾生理醫學獎得主--楚爾郝森 (Harald zur Hausen）教授應「溫世仁卓越學術講座」邀請，並於2009年11月30日(星期一)，假清大生科二館B1演講廳，以「人類癌症中的乳突病毒」為題，發表演講。

- 郝森教授的發現對於日後偵測與預防子宮頸癌提供了非常重要的根據，也促使HPV疫苗的研發，對抗子宮頸癌的發生。

清大生科二館B1演講廳

More on the **Nobelprize.org** website, next page

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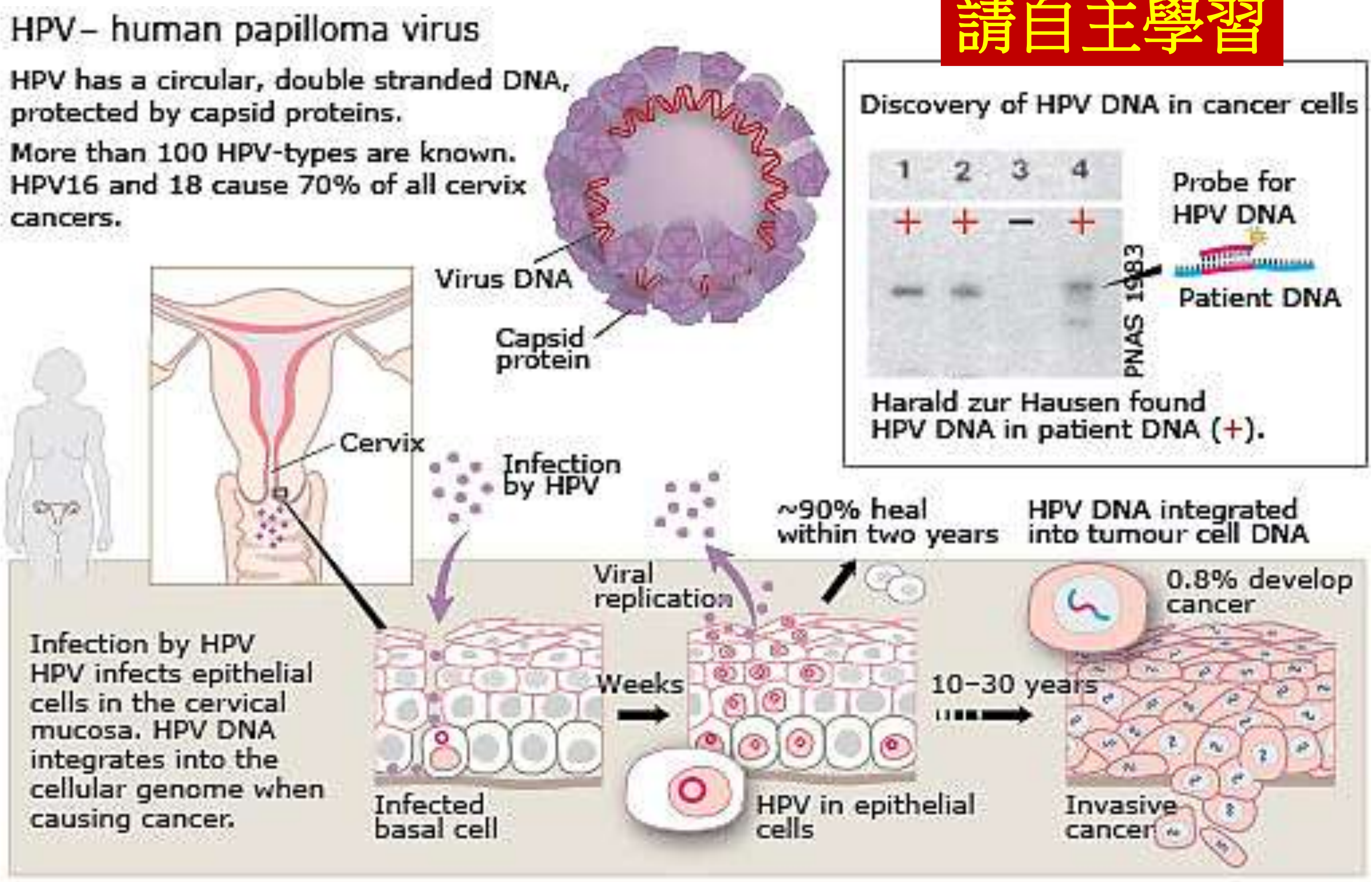
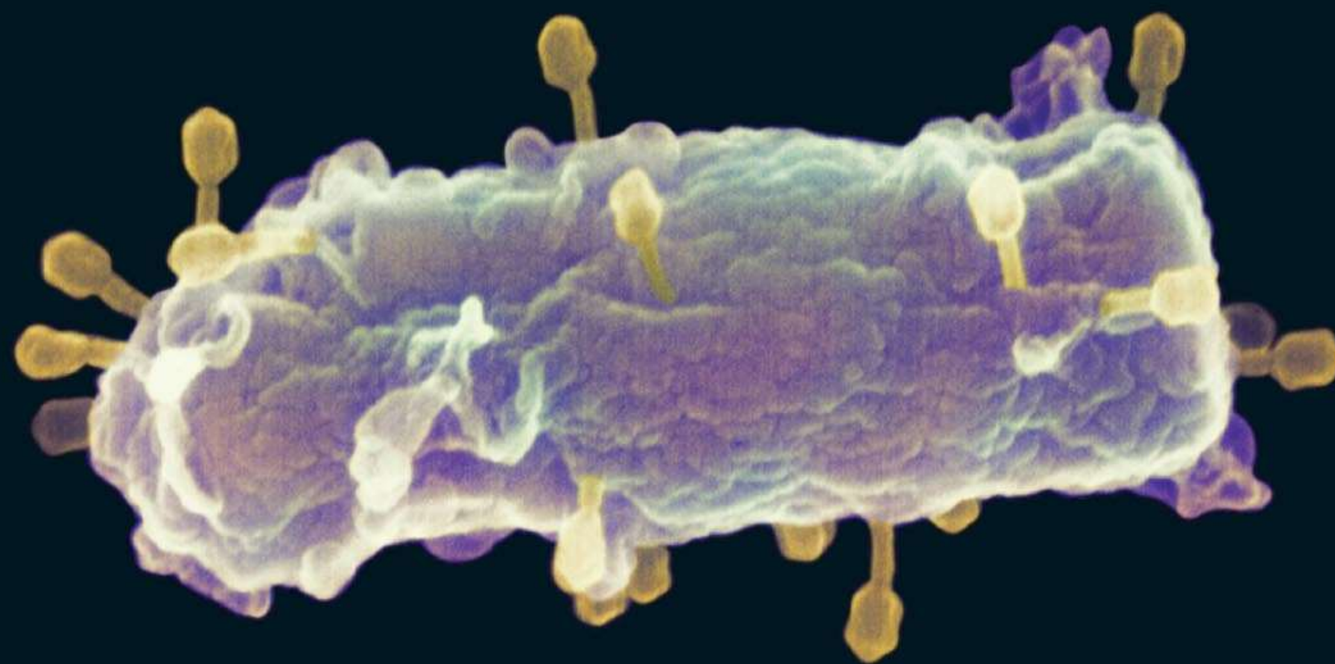



http://www.nobelprize.org/nobel_prizes/medicine/laureates/2008/press.html

# Overview: A Borrowed Life

- **Virus**es called **bacteriophage**s can infect and set in motion a genetic takeover of bacteria, such as *Escherichia coli*
- Viruses lead "a kind of borrowed life" between life-forms and chemicals
- Virus as a research system: the origins of molecular biology lie in early studies of viruses that infect bacteria

Are the tiny viruses infecting this *E. coli* cell alive?



Latin root for the work *virus* means “poison”

0.5 µm

## Concept 26.1: A virus consists of a nucleic acid surrounded by a protein coat

- Viruses were detected indirectly long before they were actually seen

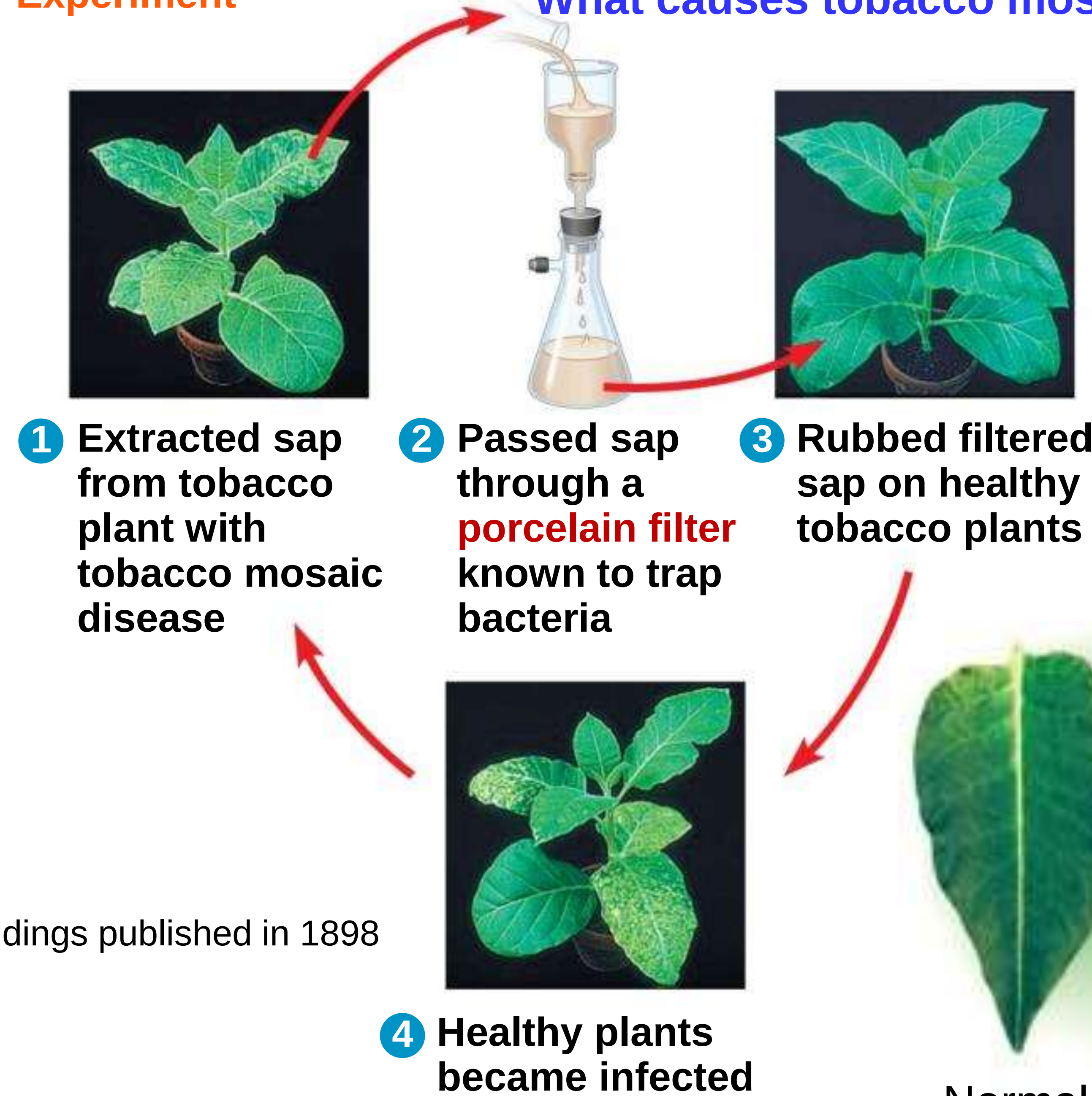
# The Discovery of Viruses: *Scientific Inquiry*

- Tobacco mosaic disease stunts growth of tobacco plants and gives their leaves a mosaic (馬賽克的;鑲嵌的) coloration
  - In the late 1800s, researchers hypothesized that a particle smaller than bacteria caused the disease
- In 1935, Wendell Stanley confirmed this hypothesis by crystallizing the infectious particle, now known as **tobacco mosaic virus (TMV)**

Figure 26.2

**Experiment**

# What causes tobacco mosaic disease?



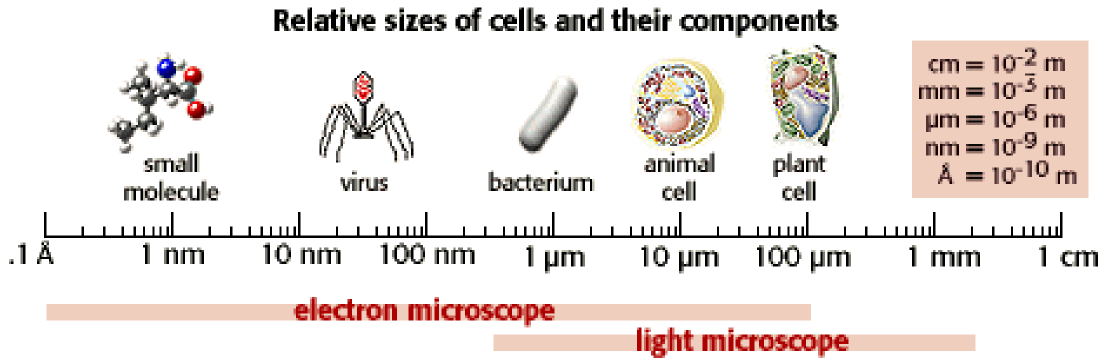


Original findings published in 1898

# Structure of Viruses

- **Viruses are not cells**
- Viruses are very small infectious particles consisting of

(1) **nucleic acid** enclosed in a (2) **protein coat** and, in some cases, (3) a **membranous envelope**



# *Viral Genomes*

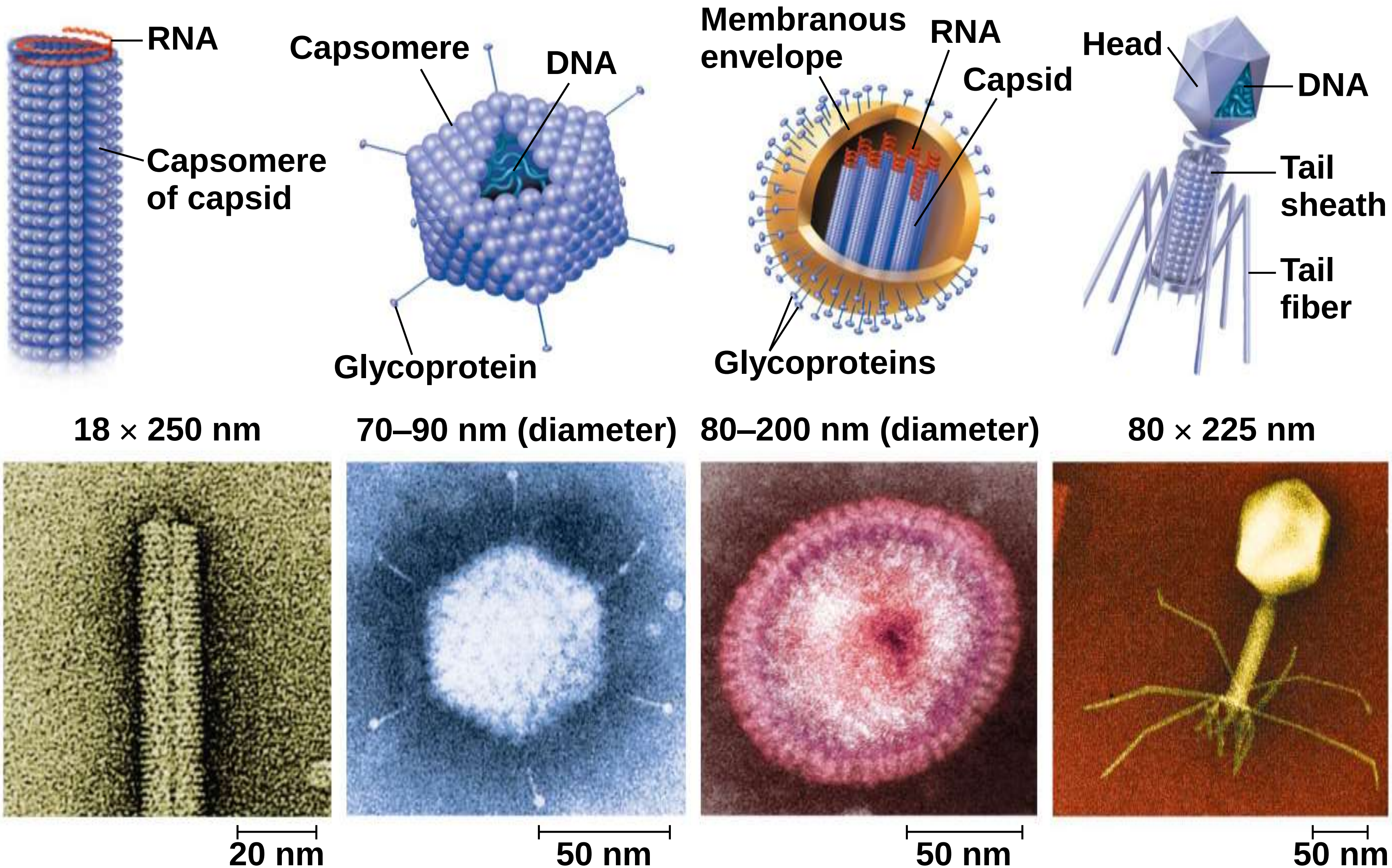
- Viral genomes may consist of either
  - **duble- or single-stranded DNA**, or
    - dsDNA or ssDNA
  - double- or single-stranded RNA
    - dsRNA or ssRNA
- Depending on its type of nucleic acid, a virus is called a DNA virus or an RNA virus
- The genome is either a single linear or circular molecule of the nucleic acid; with between three and several thousand genes in their genome

# *Capsids and Envelopes*

- A **capsid** is the protein shell that encloses the viral genome
- Capsids are built from protein subunits called *capsomeres*
- A capsid can have various structures

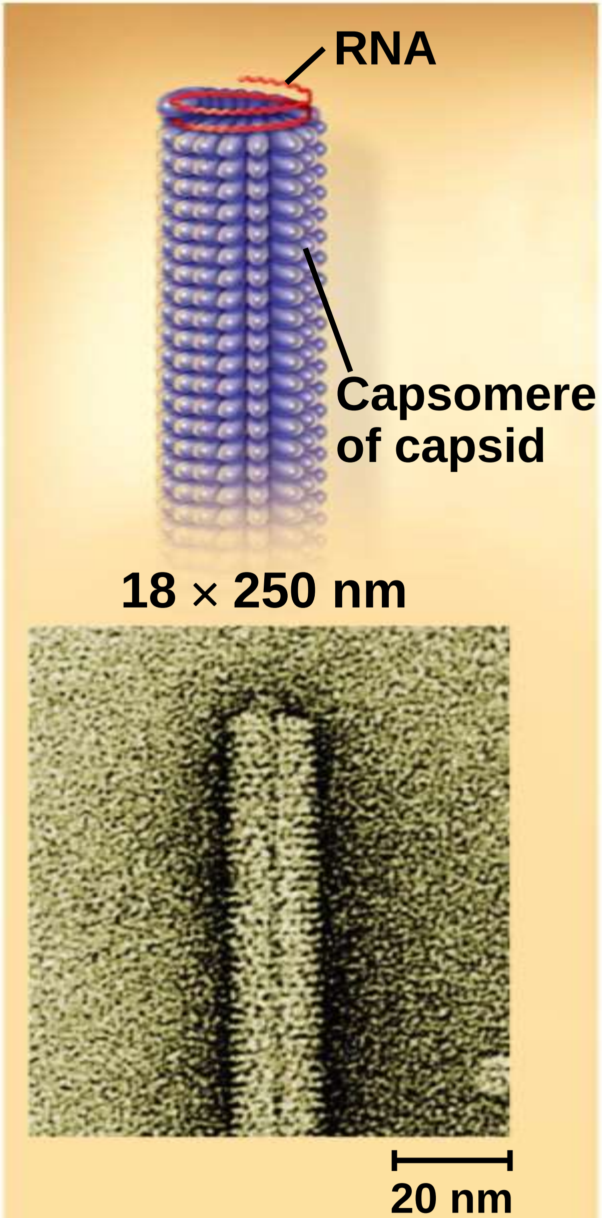
Figure 26.3

# Viral structures (overview, next page for individual view)




**(a)** Tobacco mosaic virus **(b)** Adenoviruses **(c)** Influenza viruses **(d)** Bacteriophage T4

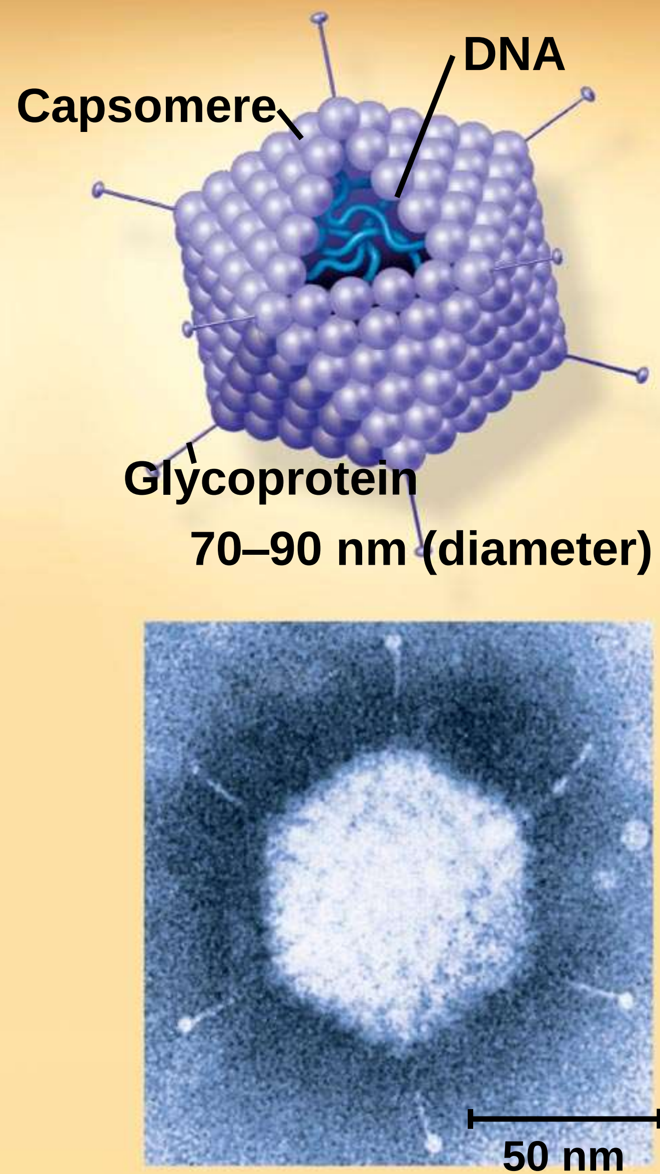
# Viral structure (1/4)



(a) Tobacco mosaic virus

Tobacco mosaic virus has a helical capsid (殼體) with the overall shape of a rigid rod

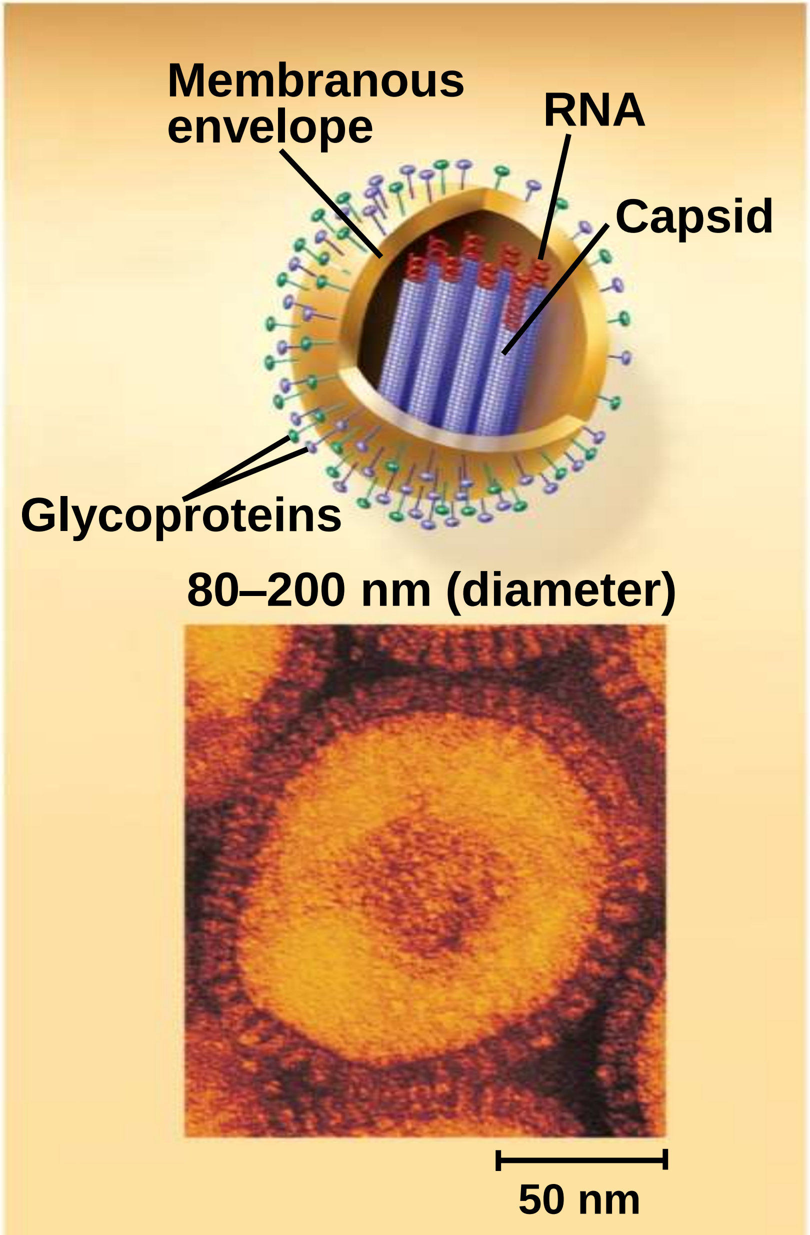
# Viral structure (2/4)



(b) Adenoviruses

Adenoviruses has an icosahedral (二十面體) capsid with a glycoprotein spike at each vertex

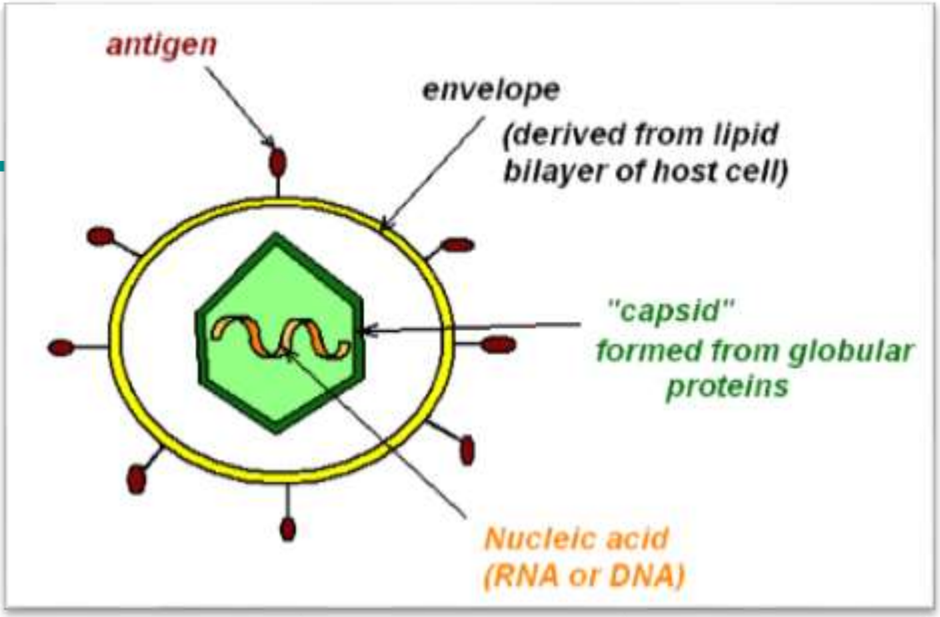
# Viral structure (3/4)



(c) Influenza viruses

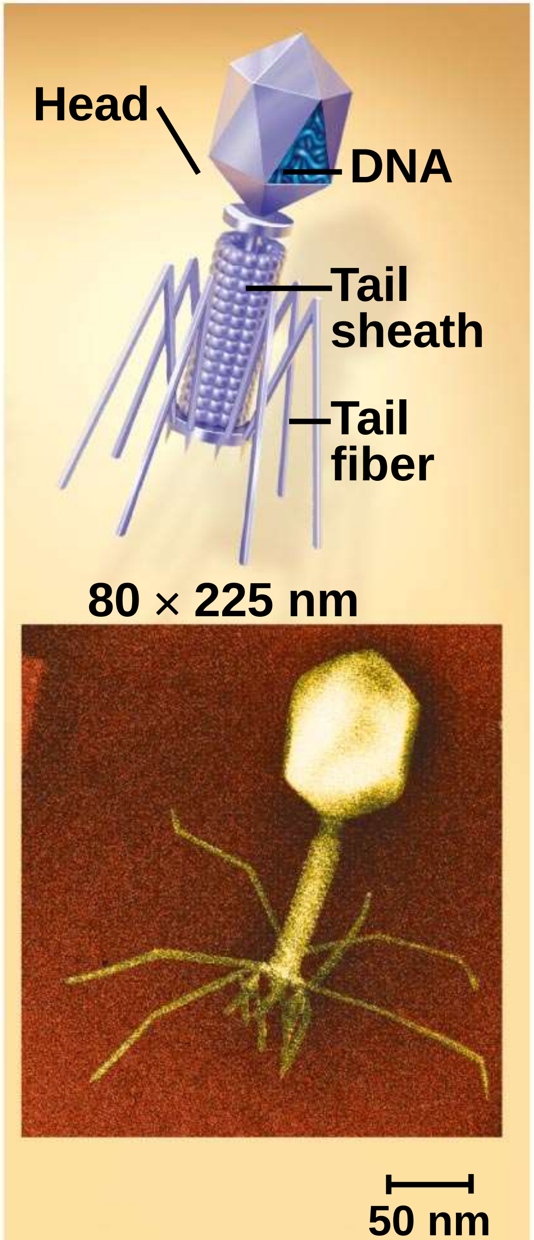
Influenza viruses have an outer envelope studded with glycoprotein spikes. The genome consists of eight different RNA molecules, each wrapped in a helical capsid.

# Viral envelopes




- Some viruses have membranous envelopes that help them infect hosts
- These **viral envelopes** surround the capsids of influenza viruses and many other viruses found in animals
- Viral envelopes, which are derived from the host cell's membrane, contain a combination of viral and host cell molecules

# Viral structure (4/4)




(d) Bacteriophage T4

Bacteriophage T4, like other “T-even” phages, has a complex capsid consisting of an icosahedral head an a tail apparatus

# Bacteriophages

- **Bacteriophages**, also called **phages**, are viruses that infect bacteria
  - They have the most complex capsids found among viruses
  - Phages have an elongated capsid head that encloses their DNA
  - A protein tail piece attaches the phage to the host and injects the phage DNA inside

# Concept 26.2: Viruses replicate only in host cells

- Viruses are obligate intracellular parasites, which means they can reproduce only within a host cell
- Each virus has a **host range**, a limited number of host cells that it can infect

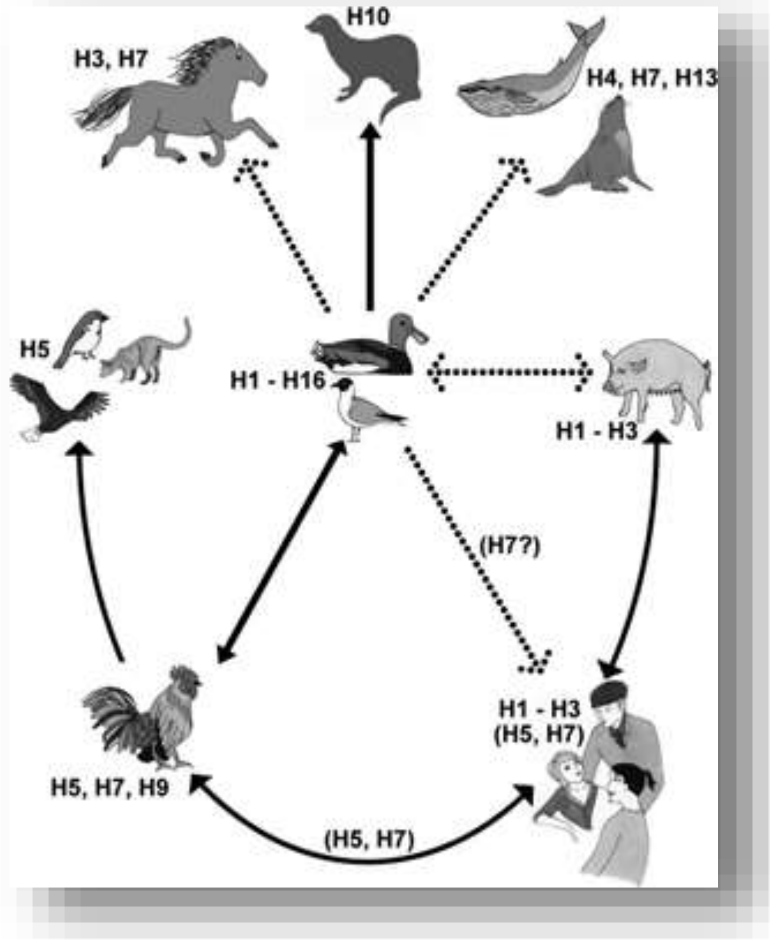



Illustration of the **host range of influenza A virus** with the natural reservoir of influenza A virus, accidental hosts, and the subtypes that have been identified in the different groups.

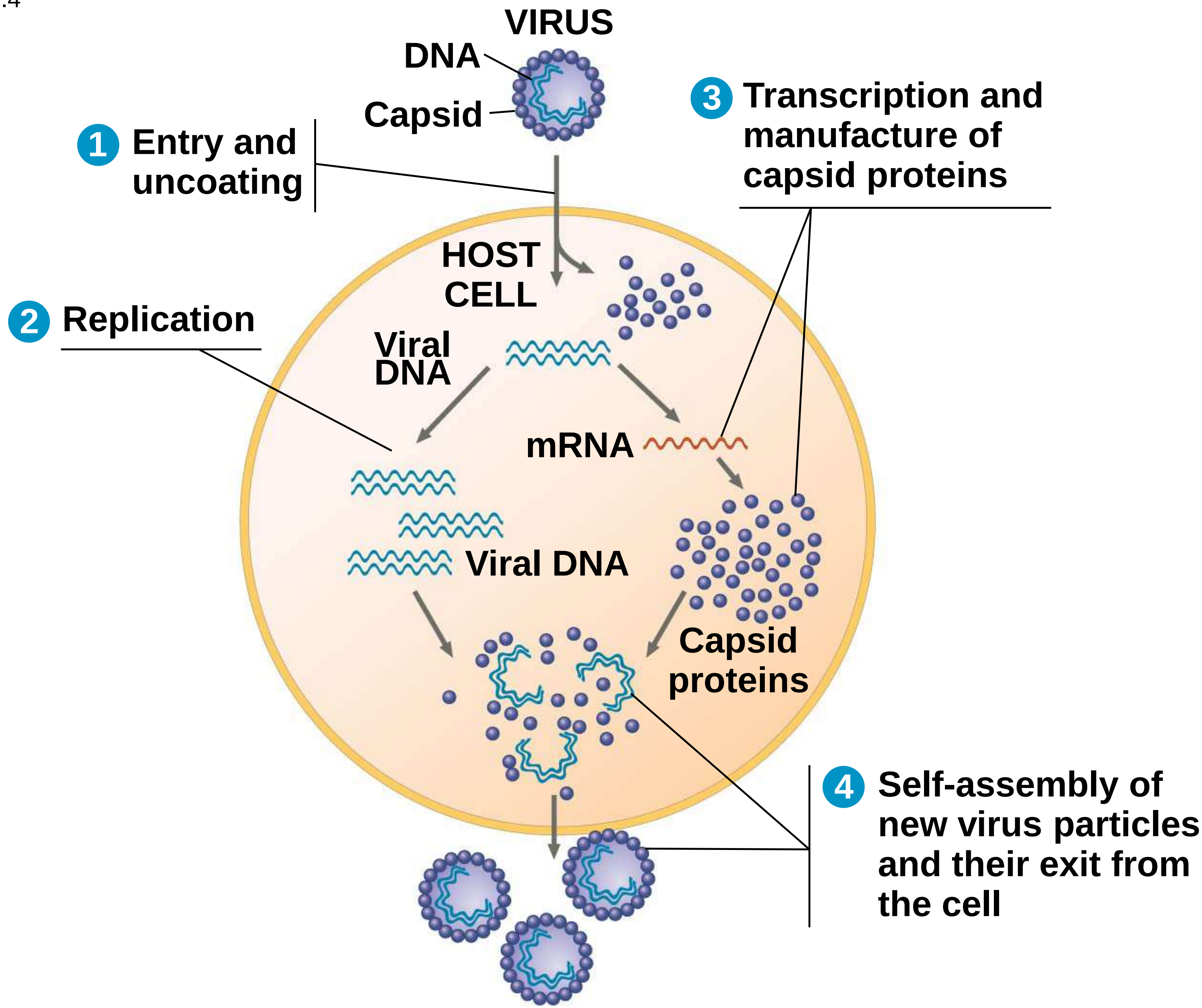
# General Features of Viral Reproductive Cycles

- Once a viral genome has entered a host cell, the cell begins to manufacture viral proteins
- The virus makes use of **host** enzymes, ribosomes, tRNAs, amino acids, ATP, and other molecules
- Viral nucleic acid molecules and capsomeres spontaneously self-assemble into new viruses

PLAY

**Animation: Simplified Viral Reproductive Cycle**

Figure 26.4


VIRUS
DNA
Capsid
1 Entry and uncoating
HOST CELL
2 Replication
Viral DNA
3 Transcription and manufacture of capsid proteins
mRNA
Viral DNA
Capsid proteins
4 Self-assembly of new virus particles and their exit from the cell

# Replicative Cycles of Phages

- Phages are the best understood of all viruses
- Phages have two replicative mechanisms: the **lytic cycle** and the **lysogenic cycle**

裂解期 潛溶期

# *The Lytic Cycle* 細胞裂解的週期

- The **lytic cycle** is a phage replicative cycle that culminates in the death of the host cell
- The lytic cycle produces new phages and digests the host's cell wall, releasing the progeny viruses
- A phage that reproduces only by the lytic cycle is called a **virulent phage** [**vir**-yuh-luh nt]
- Bacteria have defenses against phages, including **restriction enzymes** that recognize and cut up certain phage DNA

PLAY **Animation: Phage T4 Lytic Cycle**

Figure 26.5-1

## The lytic cycle of phage T4, a virulent phage

**1 Attachment**

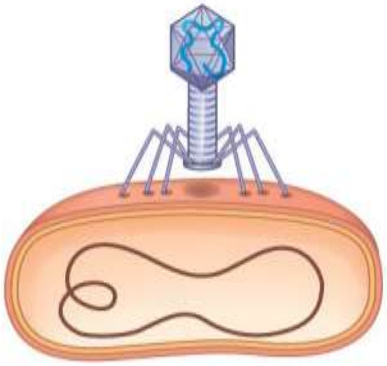


Figure 26.5-2

## The lytic cycle of phage T4, a virulent phage

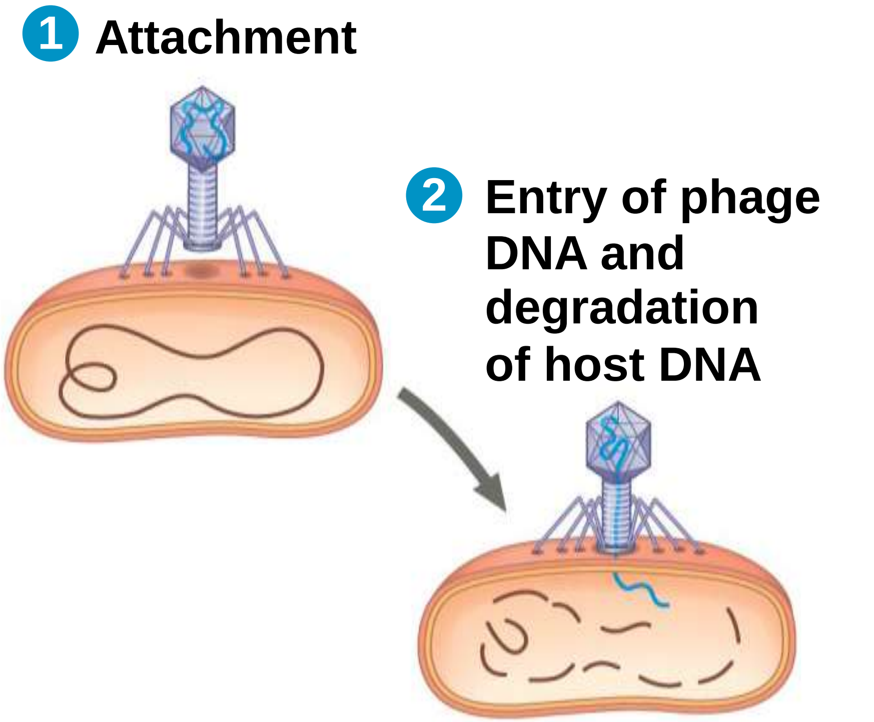


Figure 26.5-3

## The lytic cycle of phage T4, a virulent phage

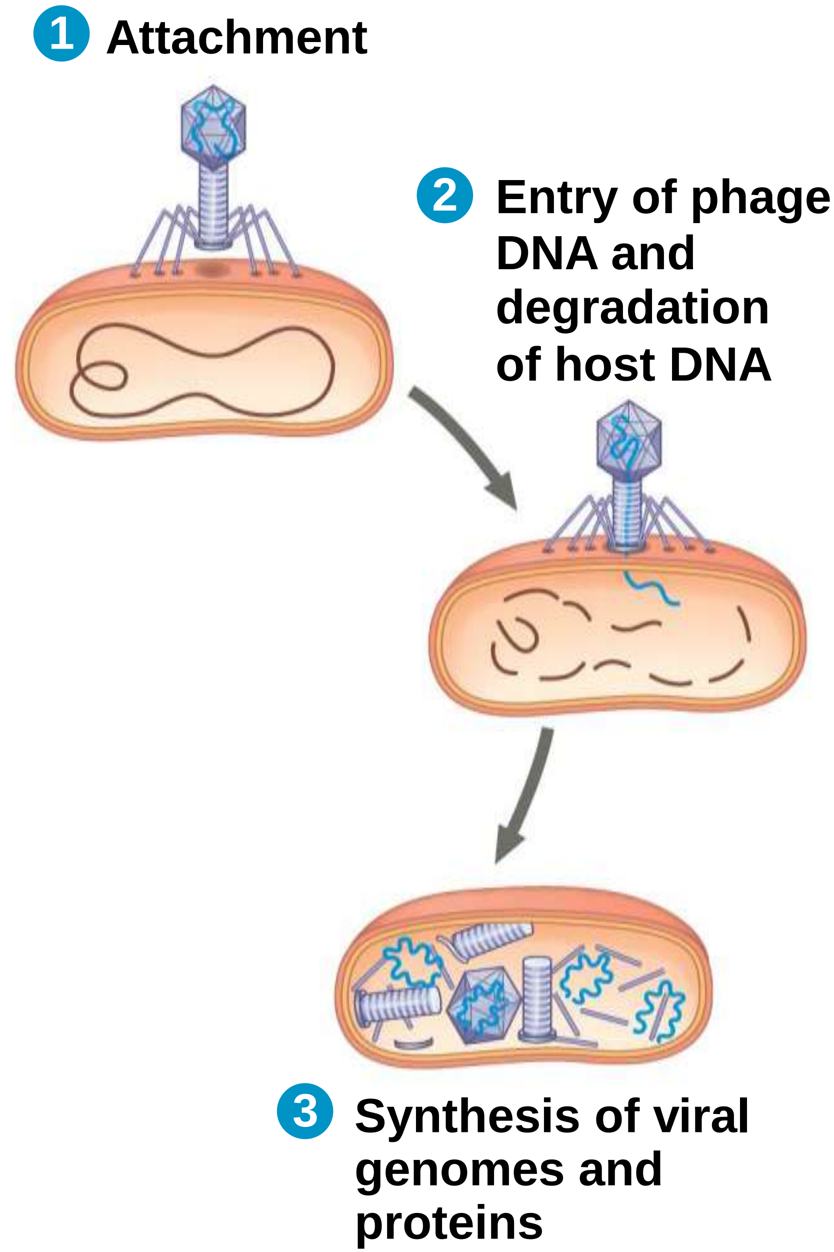


Figure 26.5-4

## The lytic cycle of phage T4, a virulent phage

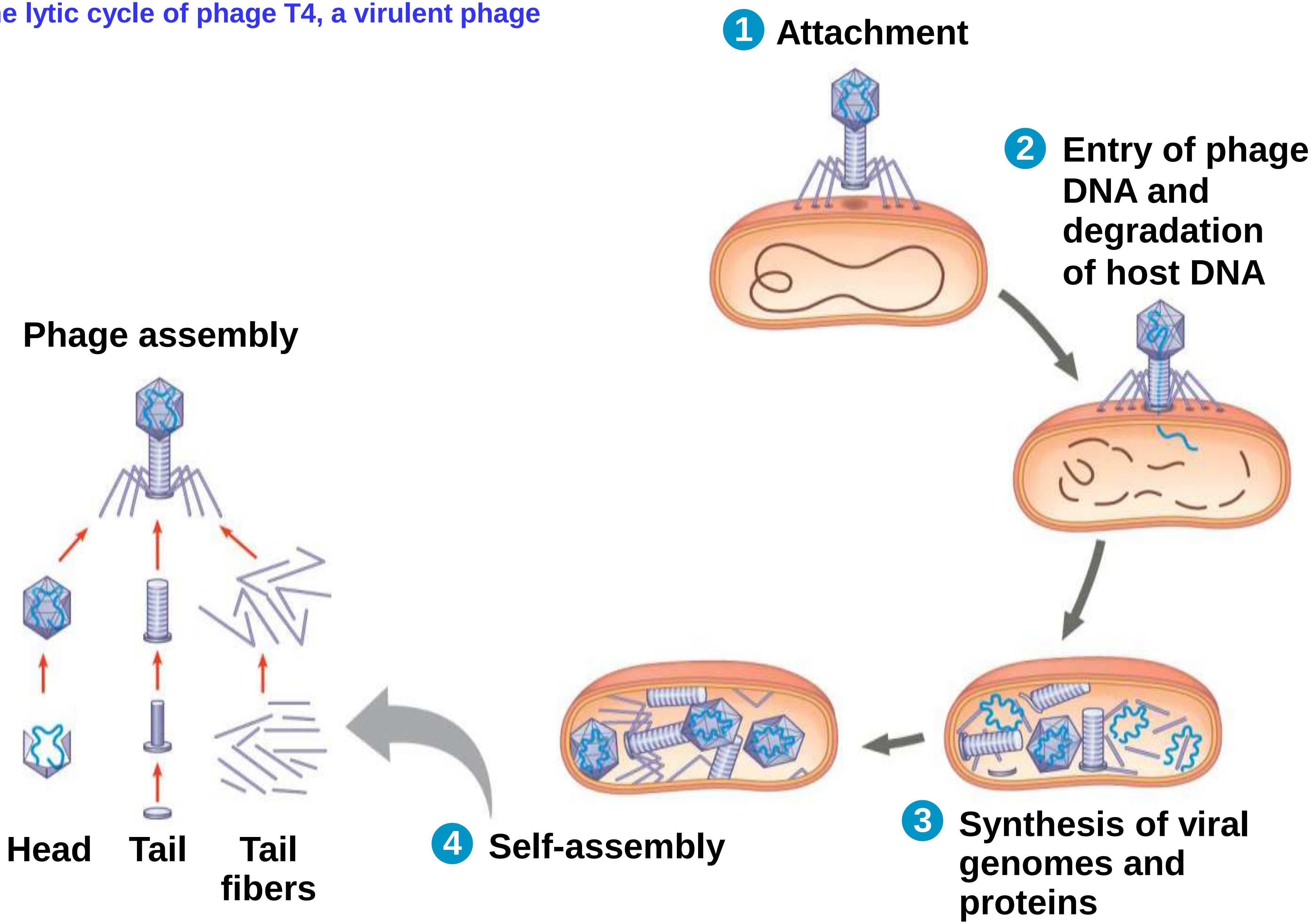
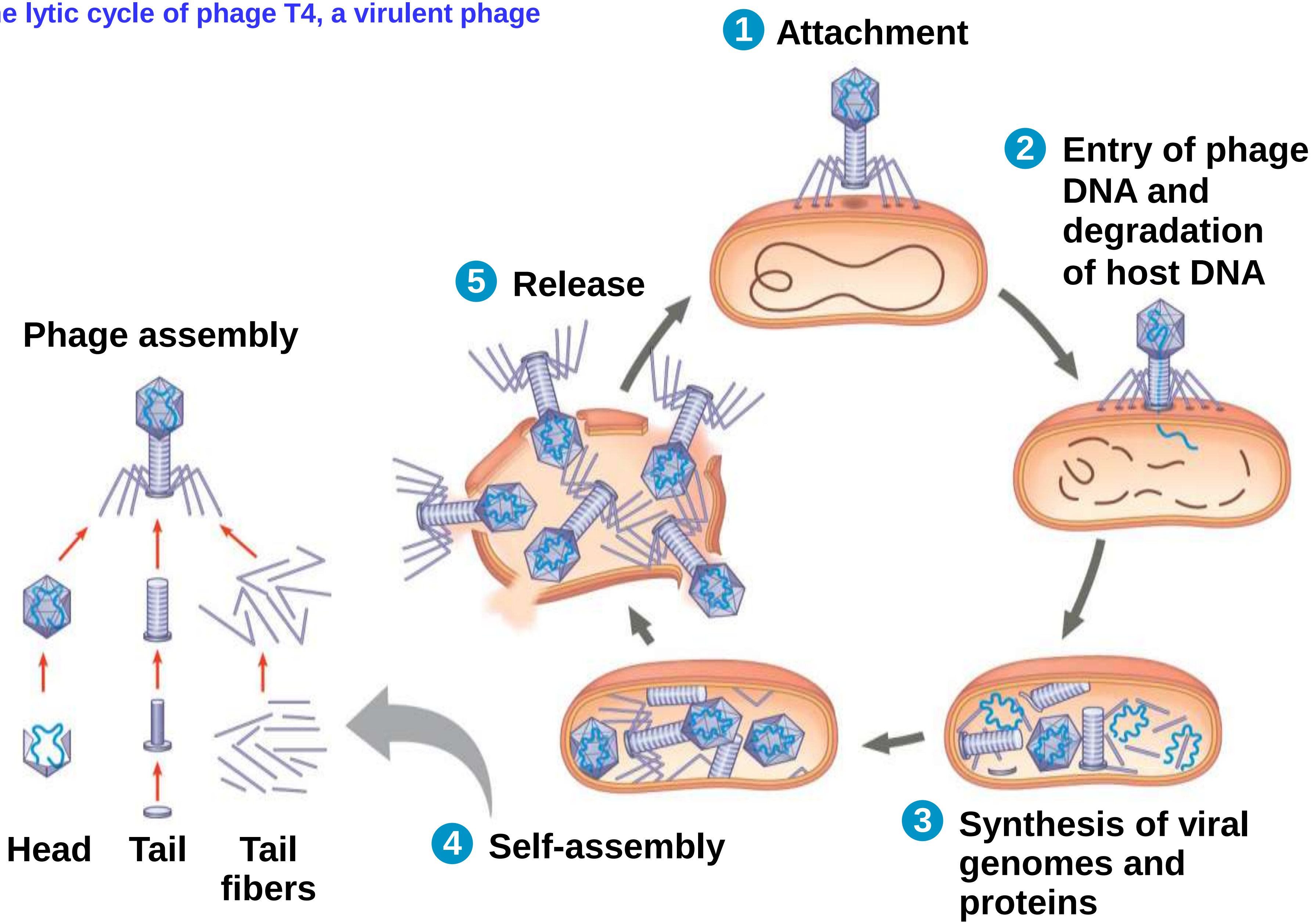


Figure 26.5-5

## The lytic cycle of phage T4, a virulent phage



# *The Lysogenic Cycle* 潛溶期

- The **lysogenic cycle** replicates the phage genome without destroying the host
- The viral DNA molecule is incorporated into the host cell's chromosome
- This integrated viral DNA is known as a **prophage**
- Every time the host divides, it copies the phage DNA and passes the copies to daughter cells

PLAY Animation: Phage Lambda Lysogenic and Lytic Cycles

- An environmental signal can trigger the virus genome to exit the bacterial chromosome and switch to the lytic mode
- Phages that use both the lytic and lysogenic cycles are called **temperate phages**（溫和、有節制的嗜菌體）

Figure 26.6b

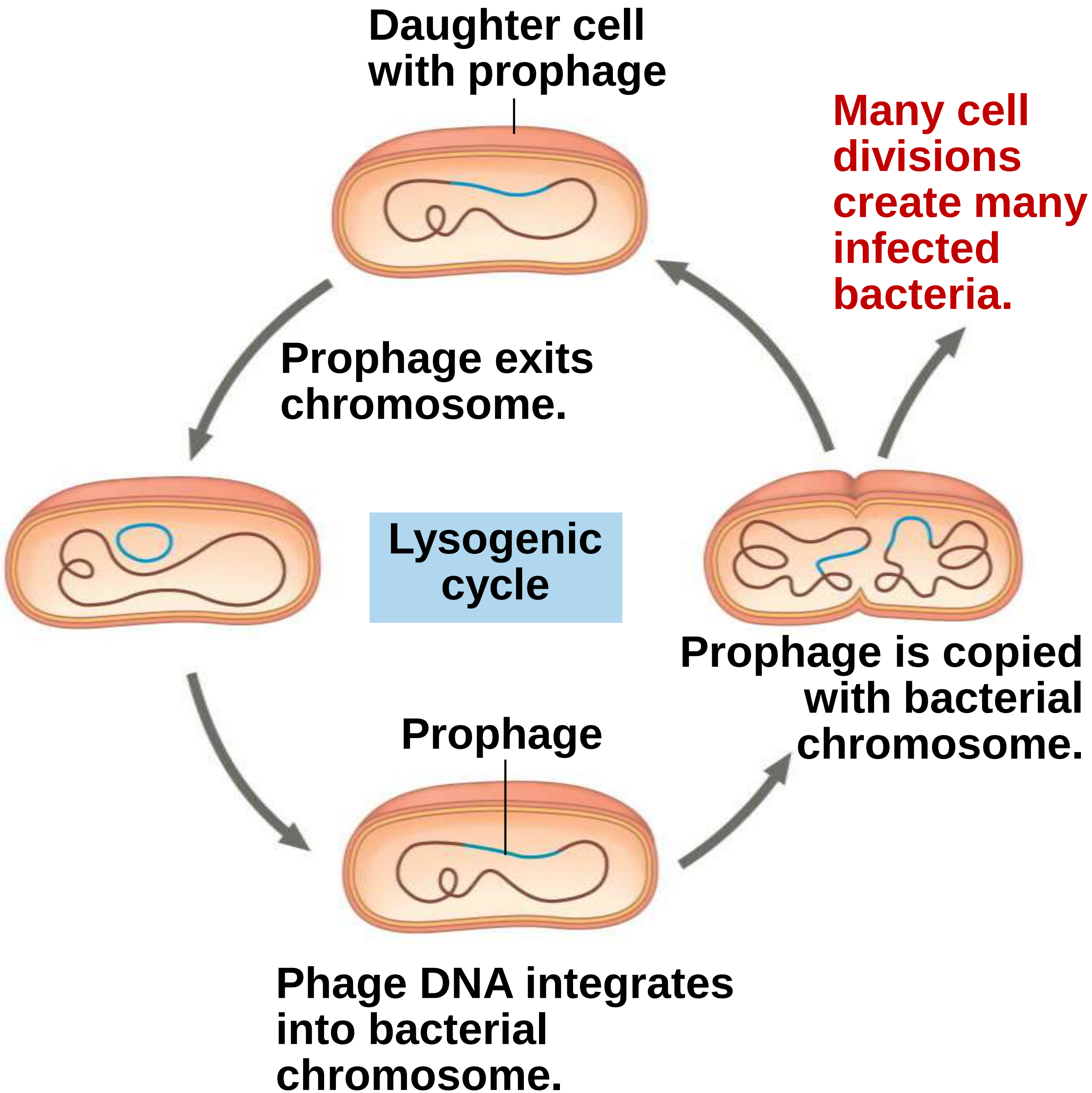
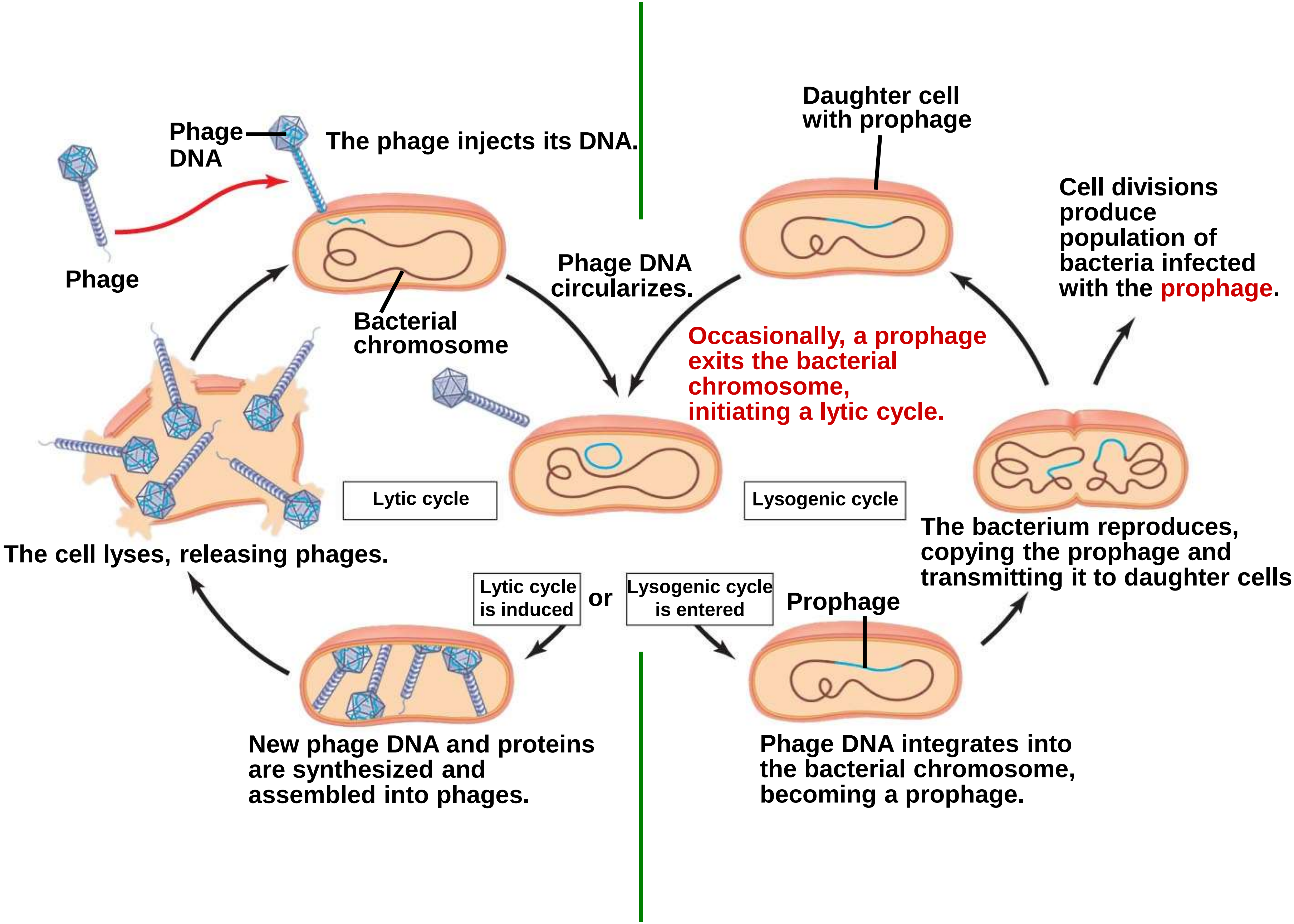

Daughter cell
with prophage
Many cell
divisions
create many
infected
bacteria.
Prophage exits
chromosome.
Lysogenic
cycle
Prophage is copied
with bacterial
chromosome.
Prophage
Phage DNA integrates
into bacterial
chromosome.

Fig. 26-6

# The lytic and lysogenic cycles of phage λ, a temperate phage



# Replicative Cycles of Animal Viruses

- There are two key variables used to classify viruses that infect animals:
  - DNA or RNA
  - Single-stranded or double-stranded
  - Whereas few bacteriophages have an envelope or an RNA genome, many animal viruses have both
  - (and, Reverse transcription or not?)

Table 26.1

# Classes of Animal Viruses

| Class/Family | Envelope? | Examples That Cause Human Diseases |
|---|---|---|
| **I. Double-Stranded DNA (dsDNA)** | | |
| Adenovirus (see Figure 19.3b) | No | Respiratory viruses; tumor-causing viruses |
| Papillomavirus | No | Warts, cervical cancer |
| Polyomavirus | No | Tumors |
| Herpesvirus | Yes | Herpes simplex I and II (cold sores, genital sores); varicella zoster (shingles, chicken pox); Epstein-Barr virus (mononucleosis, Burkitt's lymphoma) |
| Poxvirus | Yes | Smallpox virus; cowpox virus |
| **II. Single-Stranded DNA (ssDNA)** | | |
| Parvovirus | No | B19 parvovirus (mild rash) |
| **III. Double-Stranded RNA (dsRNA)** | | |
| Reovirus | No | Rotavirus (diarrhea); Colorado tick fever virus |
| **IV. Single-Stranded RNA (ssRNA); Serves as mRNA** | | |
| Picornavirus | No | Rhinovirus (common cold); poliovirus; hepatitis A virus; other intestinal viruses |
| Coronavirus | Yes | Severe acute respiratory syndrome (SARS) |
| Flavivirus | Yes | Yellow fever virus; West Nile virus; hepatitis C virus |
| Togavirus | Yes | Rubella virus; equine encephalitis viruses |
| **V. ssRNA; Serves as Template for mRNA Synthesis** | | |
| Filovirus | Yes | Ebola virus (hemorrhagic fever) |
| Orthomyxovirus | Yes | Influenza virus (see Figures 19.3c and 19.9a) |
| Paramyxovirus | Yes | Measles virus; mumps virus |
| Rhabdovirus | Yes | Rabies virus |
| **VI. ssRNA; Serves as Template for DNA Synthesis** | | |
| Retrovirus | Yes | Human immunodeficiency virus (HIV/AIDS; see Figure 19.8); RNA tumor viruses (leukemia) |

Table 26.1a

# Classes of animal viruses

| | Class/Family | Envelope? | Examples That Cause Human Diseases |
|---|---|---|---|
| | **I. Double-Stranded DNA (dsDNA)** | | |
| 腺 | Adenovirus (see Figure 19.3b) | No | Respiratory viruses; tumor-causing viruses |
| 乳突 | Papillomavirus | No | Warts, cervical cancer |
| | Polyomavirus | No | Tumors |
| 疹 | Herpesvirus | Yes | 皰疹 Herpes simplex I and II (cold sores, genital sores); varicella zoster (shingles, chicken pox); Epstein-Barr virus (mononucleosis, Burkitt's lymphoma) |
| 痘 | Poxvirus | Yes | Smallpox virus; cowpox virus |
| | **II. Single-Stranded DNA (ssDNA)** | | |
| 細小 | Parvovirus | No | B19 parvovirus (mild rash) |
| | **III. Double-Stranded RNA (dsRNA)** | | 輪狀病毒 |
| 呼腸弧 | Reovirus | No | Rotavirus (diarrhea); Colorado tick fever virus |

Table 26.1b

# Classes of animal viruses

| | Class/Family | Envelope? | Examples That Cause Human Diseases | |
|---|---|---|---|---|
| | **IV. Single-Stranded RNA (ssRNA); Serves as mRNA** | | | |
| 微小 核糖核酸 | Picornavirus | No | Rhinovirus (common cold); poliovirus; hepatitis A virus; other intestinal viruses | |
| 冠狀 | Coronavirus | Yes | Severe acute respiratory syndrome (SARS) | |
| 黃 | Flavivirus | Yes | Yellow fever virus; West Nile virus; hepatitis C virus | Dengue 登革熱 |
| 披蓋 | Togavirus | Yes | Rubella virus; equine encephalitis viruses | Rubella 德國麻疹 |
| | **V. ssRNA; Serves as Template for mRNA Synthesis** | | | |
| 絲狀 | Filovirus | Yes | Ebola virus (hemorrhagic fever) | |
| 正黏液 | Orthomyxovirus | Yes | Influenza virus (see Figures 19.3c and 19.9a) | |
| 副黏液 | Paramyxovirus | Yes | 麻疹; 腮腺炎<br>Measles virus; mumps virus | |
| 彈狀 | Rhabdovirus | Yes | Rabies virus | |
| | **VI. ssRNA; Serves as Template for DNA Synthesis** | | | |
| 反轉錄 | Retrovirus | Yes | Human immunodeficiency virus (HIV/AIDS; see Figure 19.8); RNA tumor viruses (leukemia) | HIV |

# 幼兒預防接種 (病毒+細菌)

## 我國現行預防接種時程

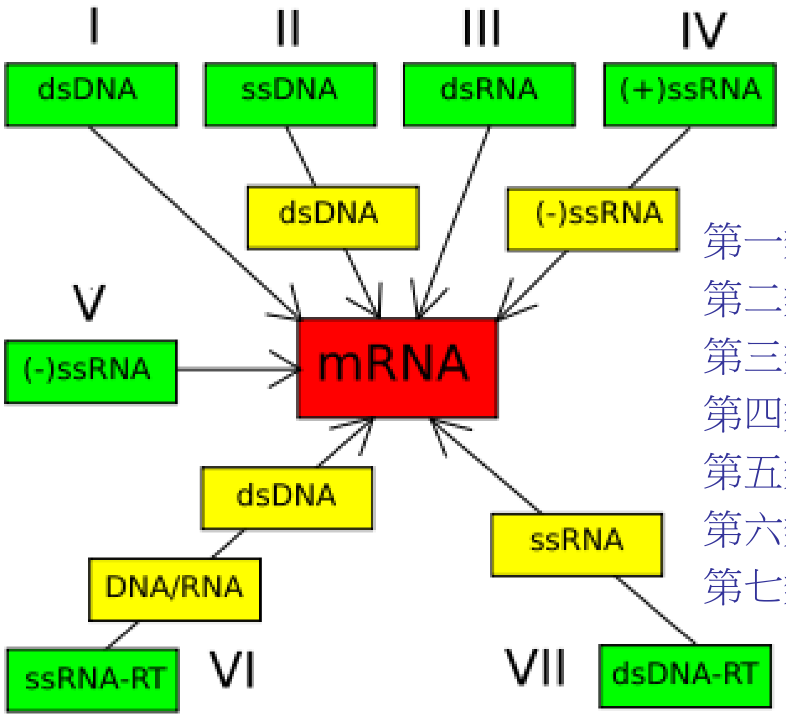
105 年 1 月 1 日版

| 疫苗 \ 接種年齡 | 24hr 內儘速 | 1 month | 2 months | 4 months | 5 months | 6 months | 12 months | 15 months | 18 months | 24 months | 27 months | 30 months | 滿 5 歲至入國小前 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B 型肝炎疫苗(HepB) | 第一劑 | 第二劑 | | | | 第三劑 | | | | | | | |
| 卡介苗(BCG)[1] 預防結核病 | | | | | 一劑 | | | | | | | | |
| 白喉破傷風非細胞性百日咳、b 型嗜血桿菌及不活化小兒麻痺五合一疫苗(DTaP-Hib-IPV) | | | 第一劑 | 第二劑 | | 第三劑 | | | 第四劑[6] | | | | |
| 結合型肺炎鏈球菌疫苗(PCV13)[2] | | | 第一劑 | 第二劑 | | | 第三劑 | | | | | | |
| 水痘疫苗(Varicella) | | | | | | | 一劑 | | | | | | |
| 麻疹腮腺炎德國麻疹混合疫苗(MMR) | | | | | | | 第一劑 | | | | | | 第二劑 |
| 日本腦炎疫苗(JE)[3] | | | | | | | | 第一劑<br>第二劑 | | | 第三劑 | | 第四劑 |
| 流感疫苗(Influenza)[4] | | | | | | ← 初次接種二劑，之後每年一劑 → | | | | | | | |
| A 型肝炎疫苗(HepA)5[4] | | | | | | | 第一劑 | | 第二劑 | | | | |
| 減量破傷風白喉非細胞性百日咳及不活化小兒麻痺混合疫苗(Tdap-IPV) | | | | | | | | | | | | | 一劑 |

1. 105年起，卡介苗接種時程由出生滿24小時後，調整為出生滿5個月(建議接種時間為出生滿5-8個月)。
2. 104年起，結合型肺炎鏈球菌疫苗(PCV13)納入幼兒常規接種項目 。第一劑與第二劑接種至少間隔8週。
3. 日本腦炎疫苗出生滿15個月接種第一劑;間隔2週接種第二劑。
4. 8歲(含)以下兒童，初次接種流感疫苗應接種二劑，二劑間隔1個月以上 。
5. A型肝炎疫苗免費接種之實施對象為設籍於30個山地鄉、9個鄰近山地鄉之平地鄉鎮及金門、連江兩縣之兒童，接種時程為出生滿1歲接種第一劑，間隔6-12個月接種第二劑。
6. 因應全球五合一疫苗缺貨，自103年1月起暫時將五合一疫苗第四劑接種年齡調整為出生滿27個月接種。

# Baltimore Classification (巴爾的摩分類法)

- Different route to synthesize viral mRNA




第一類是雙鏈DNA病毒（如腺病毒、皰疹病毒、痘病毒）
第二類是單鏈DNA病毒（+）DNA（如小DNA病毒）
第三類是雙鏈RNA病毒（如呼腸孤病毒）
第四類是（+）單鏈RNA病毒（如微小核糖核酸病毒、披蓋病毒）
第五類是（-）單鏈RNA病毒（如正黏液病毒、炮彈病毒）
第六類是單鏈RNA反轉錄病毒（如反轉錄病毒）
第七類是雙鏈DNA反轉錄病毒（如肝病毒）

http://zh.wikipedia.org/w/index.php?title=%E7%97%85%E6%AF%92&variant=zh-tw

# 課本分類法未提及的第七類病毒

## VII. dsDNA-RT

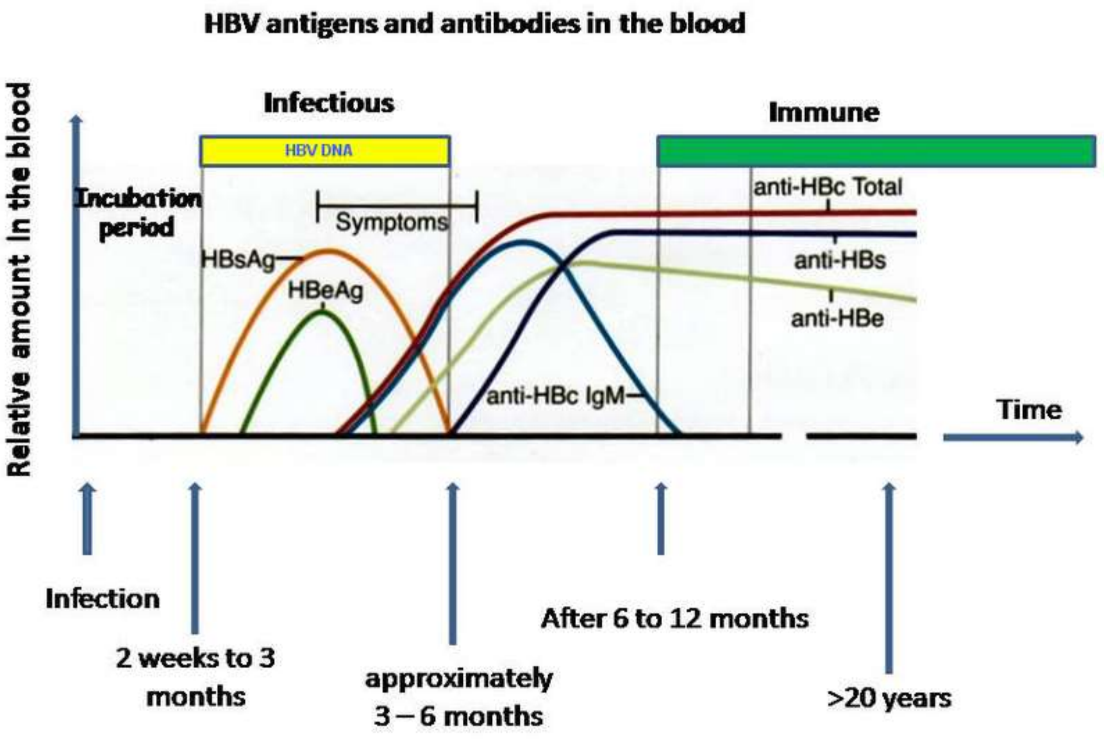
正肝 Orthohepadnavirus

禽肝 Avihepadnavirus

Yes on envelope

Example

- Hepatitis B virus



# *Viral Envelopes*

- Many viruses that infect animals have a membranous envelope
- Viral glycoproteins on the envelope bind to specific receptor molecules on the surface of a host cell
- Some viral envelopes are formed from the host cell's plasma membrane as the viral capsids exit

# Viral membranes are provided by the host

- Other viral membranes form from the host's nuclear envelope and are then replaced by an envelope made from Golgi apparatus membrane

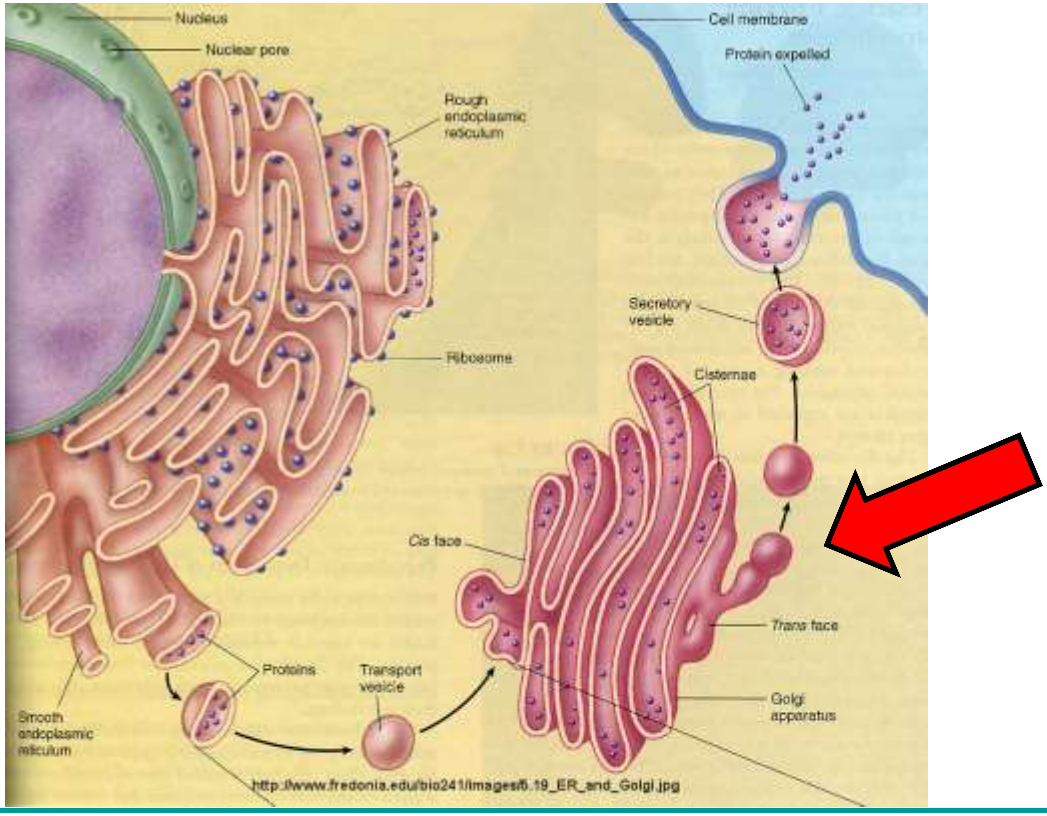
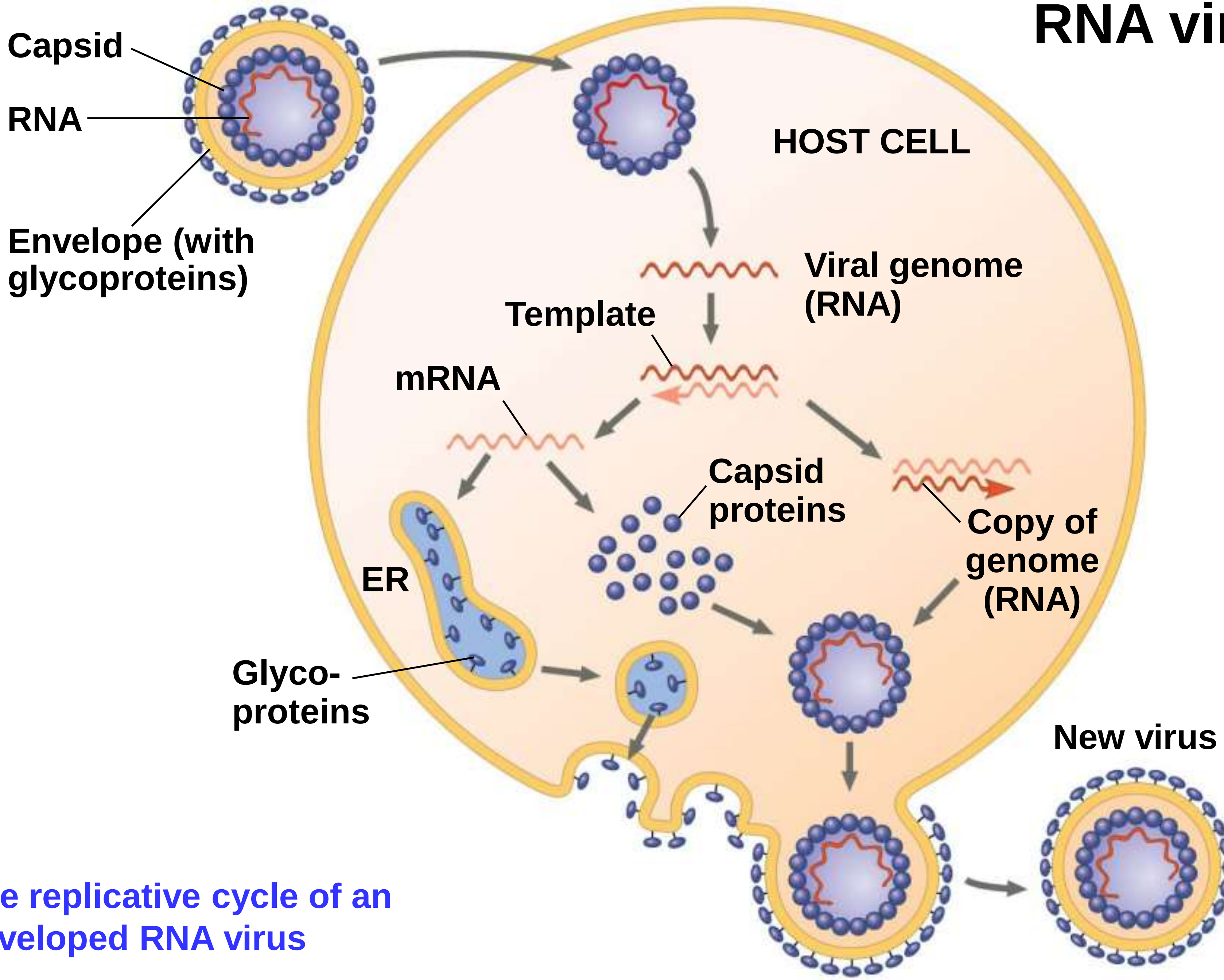


Figure 26.7

# RNA virus




The replicative cycle of an enveloped RNA virus

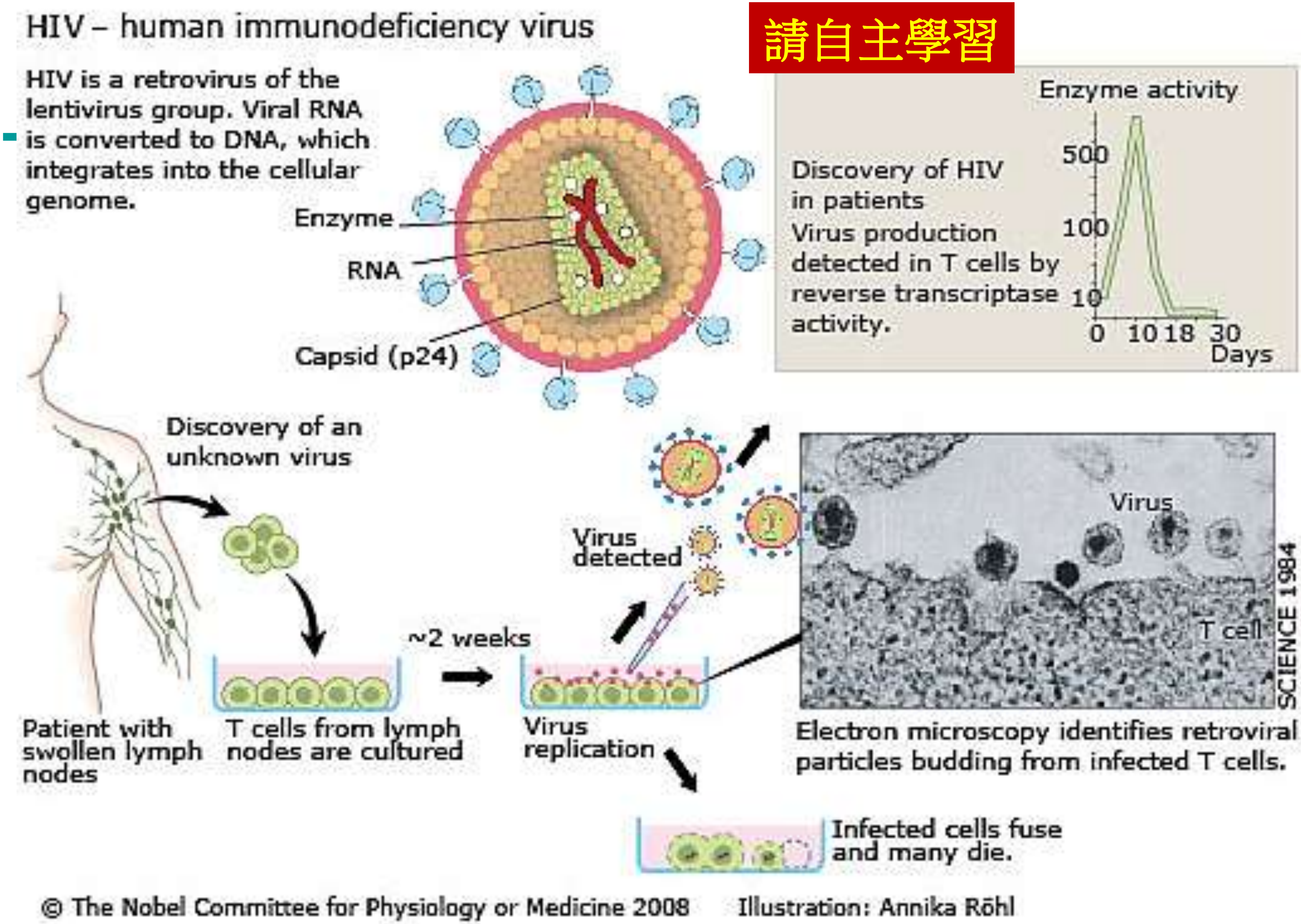
# *RNA as Viral Genetic Material*

- The broadest variety of RNA genomes is found in viruses that infect animals
- **Retroviruses** use **reverse transcriptase** to copy their RNA genome into DNA
- **HIV (human immunodeficiency virus**人類免疫缺陷病毒**)** is the retrovirus that causes **AIDS (Acquired ImmunoDeficiency Syndrome)**

More information on NTHU web site:
諾貝爾大師在清華 http://www.nthu.edu.tw/nobel/index.php

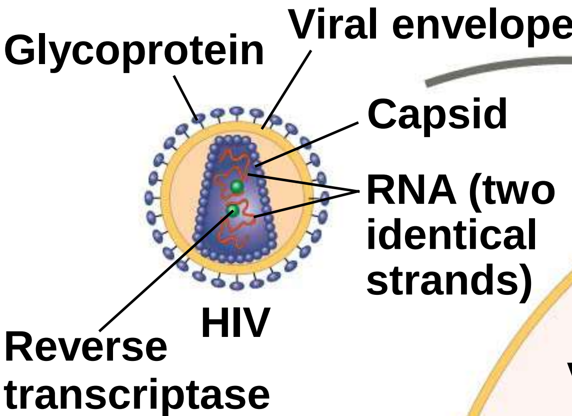

The Nobel Prize in Physiology/Medicine 2008 was awarded to Françoise Barré-Sinoussi & Luc Montagnier *"for their* **discovery of human immunodeficiency virus***"*.

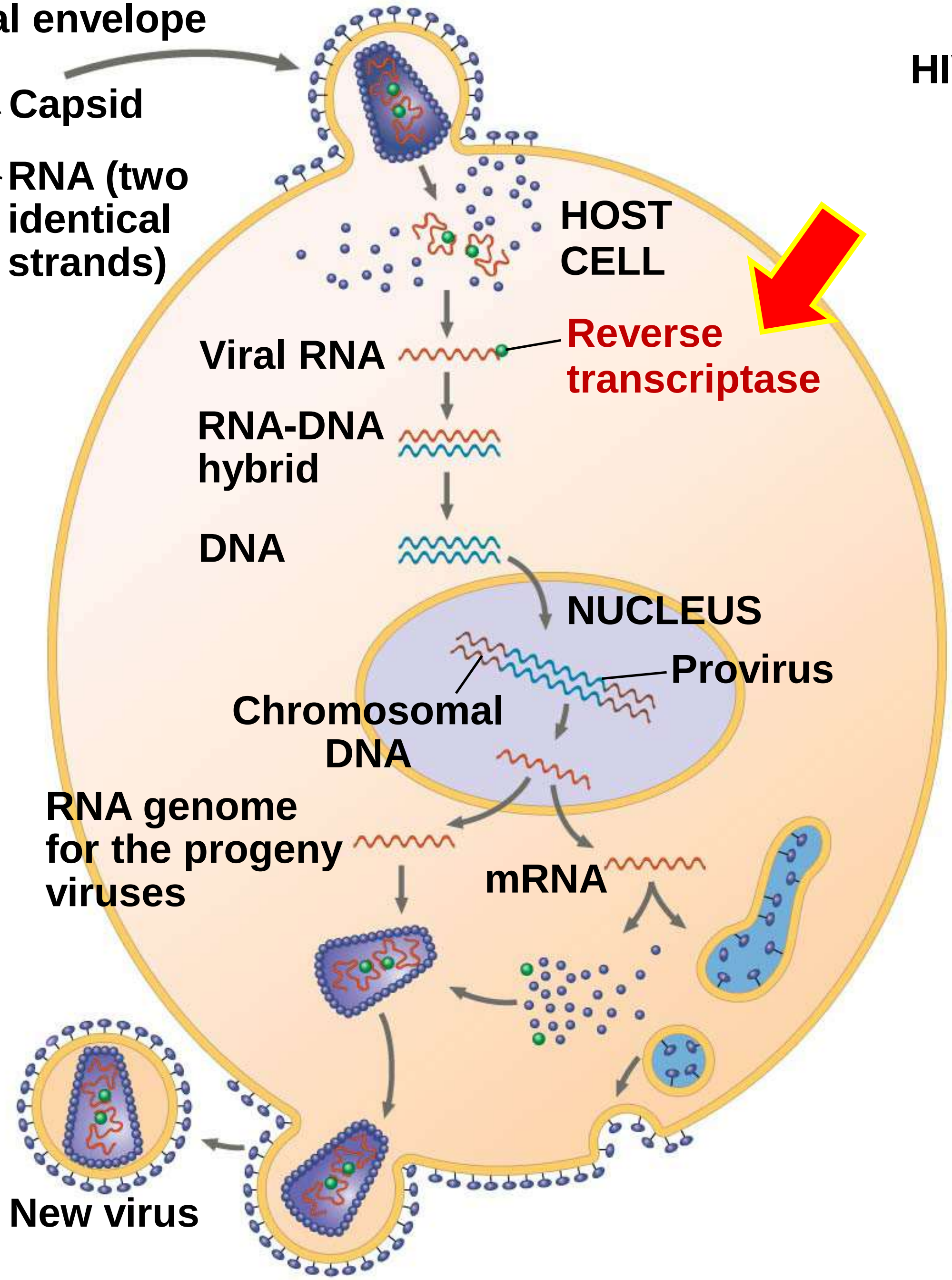
**請自主學習**

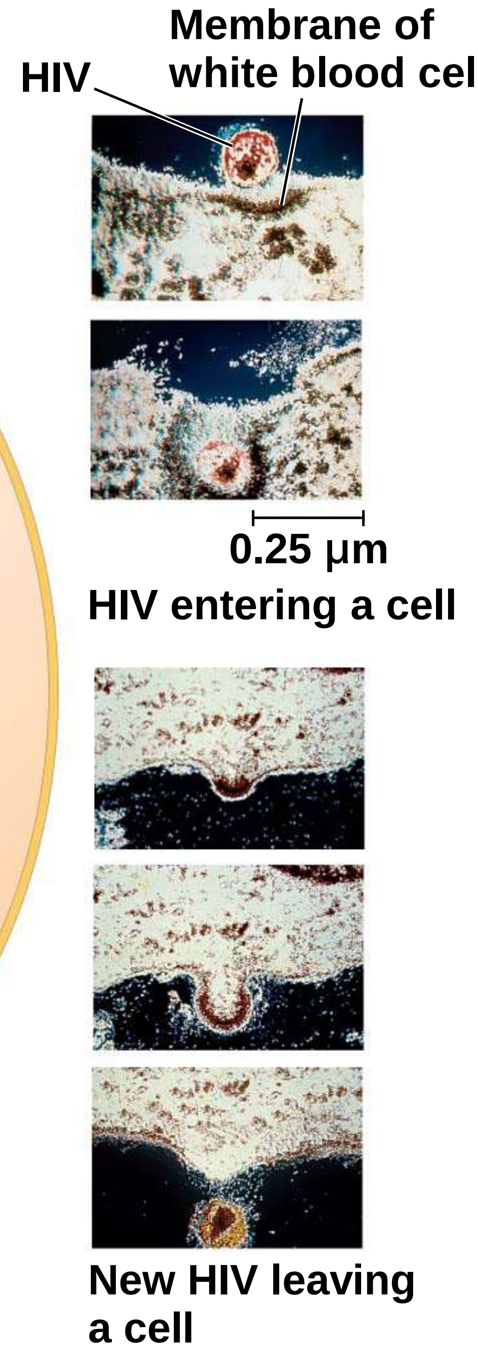



http://www.nobelprize.org/nobel_prizes/medicine/laureates/2008/press.html

Figure 26.8



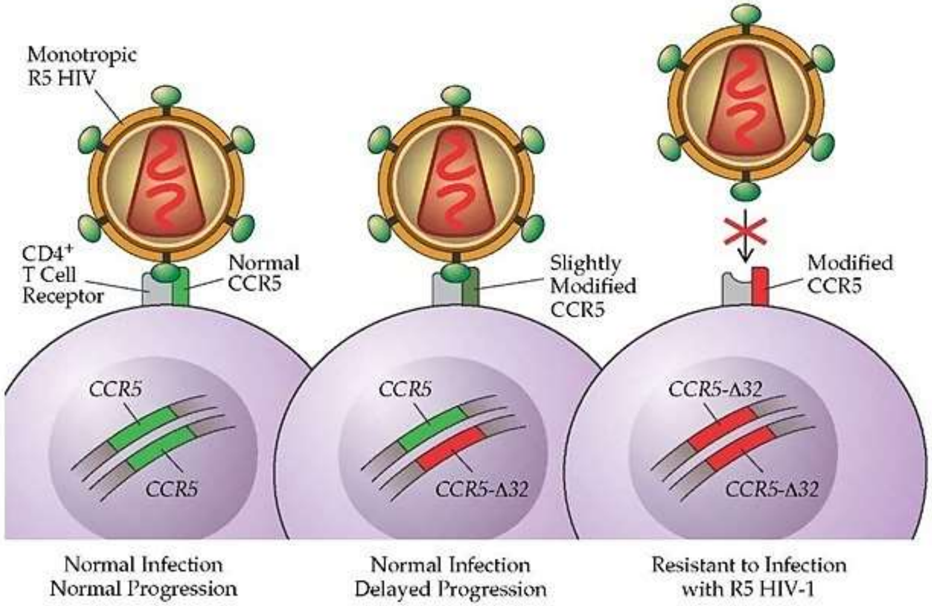

The replicative cycle of HIV, the retrovirus that causes AIDS

**Thinking Question:**

# Stem cell therapy cure AIDS? How?

CNN February 11, 2009

A 42-year-old HIV patient with leukemia appears to have no detectable HIV in his blood and no symptoms **after a stem cell transplant** from a donor carrying a gene mutation (CCR5) that confers natural resistance to the virus that causes AIDS, according to a report published Wednesday in the New England Journal of Medicine.




How about Gene editing technology?

# Provirus

- The viral DNA that is *integrated into the host genome* is called a **provirus**
- Unlike a prophage, a provirus remains a permanent resident of the host cell
- The host's RNA polymerase transcribes the proviral DNA into RNA molecules
- The RNA molecules function both as mRNA for synthesis of viral proteins and as genomes for new virus particles released from the cell

# Evolution of Viruses

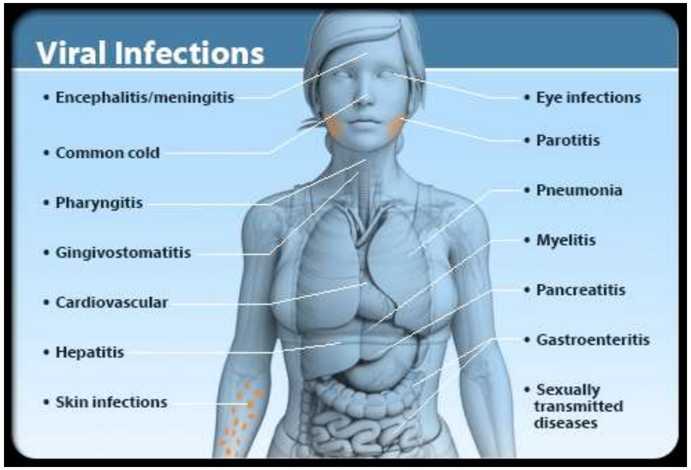
- Viruses do not fit our definition of living organisms
- Since viruses can reproduce only within cells, they probably evolved as bits of cellular nucleic acid
- Candidates for the source of viral genomes are plasmids, circular DNA in bacteria and yeasts, and transposons, small mobile DNA segments
- Plasmids, transposons, and viruses are all mobile genetic elements

## **Mimivirus :** origin of viruses

- Mimivirus, a double-stranded DNA virus, is the largest virus yet discovered – size of a small bacterium
  - some of the genes code for proteins of a cellular genome
  - Hypotheses: (1) virus evolved before the first cells ; (2) virus evolved more recently
    - There is controversy about whether this virus evolved before or after cells

# Concept 26.3: Viruses, viroids, and prions are formidable pathogens in animals and plants

- Diseases caused by viral infections affect humans, agricultural crops, and livestock worldwide




## 補充: 腸道中的有益病毒?!

研究指出: 小鼠腸道微生物群中的病毒成員能夠形成**共生關係**，產生與我們小腸內的細菌所產生的相似的一個有益效應。An enteric virus (Murine norovirus; MNV) can replace the beneficial function of commensal bacteria by supporting intestinal homeostasis and shaping mucosal immunity.

*Nature 516, 94–98 (04 December 2014)*

# Viral Diseases in Animals

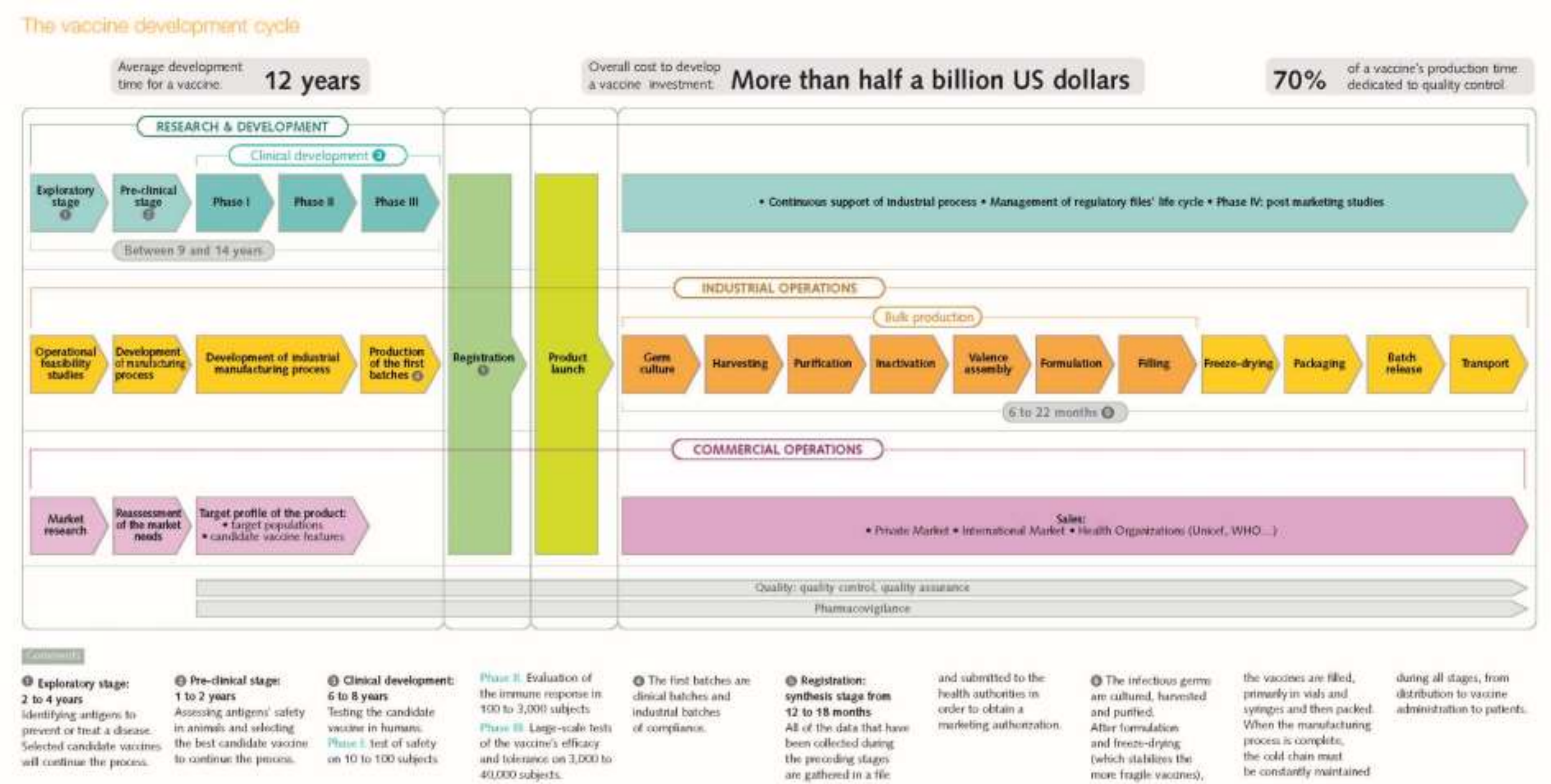
- Viruses may damage or kill cells by causing the release of hydrolytic enzymes from lysosomes (溶酶體/溶菌體)
- Some viruses cause infected cells to produce toxins that lead to disease symptoms
- Others have molecular components such as envelope proteins that are toxic

# Vaccines

- **Vaccines** are harmless derivatives of pathogenic microbes that stimulate the immune system to mount defenses against the actual pathogen
- Vaccines can prevent certain viral illnesses
- Viral infections cannot be treated by antibiotics (as compared to **protease inhibitors**)
- Antiviral drugs can help to treat, though not cure, viral infections

# 補充: The vaccine development cycle

請自主學習

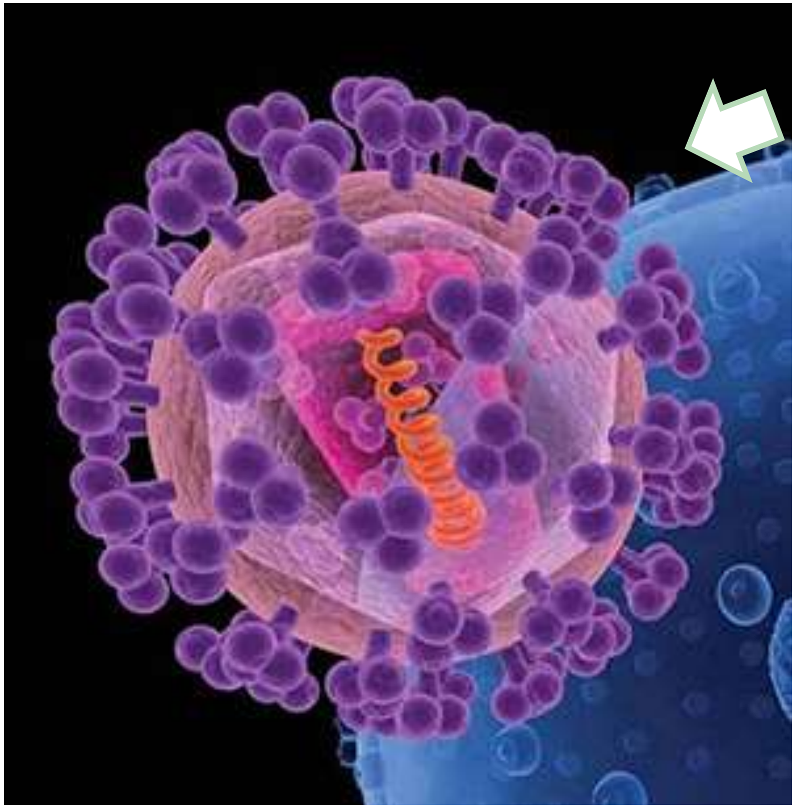



http://www.sanofipasteur.com/en/Documents/PDF/Vaccine_development_cycle.pdf

# 補充: Update on **HIV vaccine**

請自主學習

## New molecule shows promise in HIV vaccine design



The knobs (purple) covering the HIV virus are sugar-protein molecules, including **gp120**, that shield the rest of the virus (pink).

A small fragment of gp120 protein that is common among HIV strains was made by synthetic chemistry method to combine the gp120 fragment with a sugar molecule, also shared among HIV strains, to mimic the sugar shield on the HIV envelope. This protein-sugar vaccine candidate was injected into rabbits and found that the rabbits' immune systems produced antibodies that physically bound to gp120 in four dominant strains of HIV in circulation.

Hui Cai et al, **Synthetic Three-Component HIV-1 V3 Glycopeptide Immunogens Induce Glycan-Dependent Antibody Responses**, Cell Chemical Biology(2017). DOI: 10.1016/j.chembiol.2017.09.005

# Emerging Viruses （新生，新興的病毒）

- Emerging viruses are those that appear suddenly or suddenly come to the attention of scientists
  - In 2009, a general outbreak (**epidemic**) of a flu-like illness appeared in Mexico and the United States, caused by an influenza virus named H1N1
  - Flu epidemics are caused by new strains of influenza virus to which people have little immunity

- New viral diseases can emerge when viruses spread from animals to humans (i.e. SARS, Avian flu)
- Viral strains that jump species can exchange genetic information with other viruses to which humans have no immunity

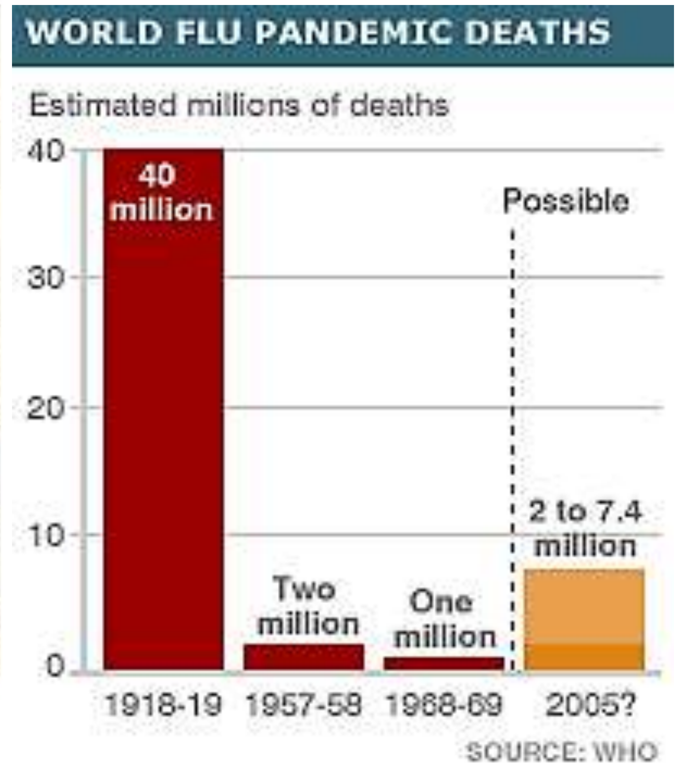


# Epidemics 疫情 vs. Pandemics 大流行

- Flu **epidemics** are caused by new strains of influenza virus to which people have little immunity
- Viral diseases in a small isolated population can emerge and become global (i.e. HIV)
- These strains can cause **pandemics**, global epidemics

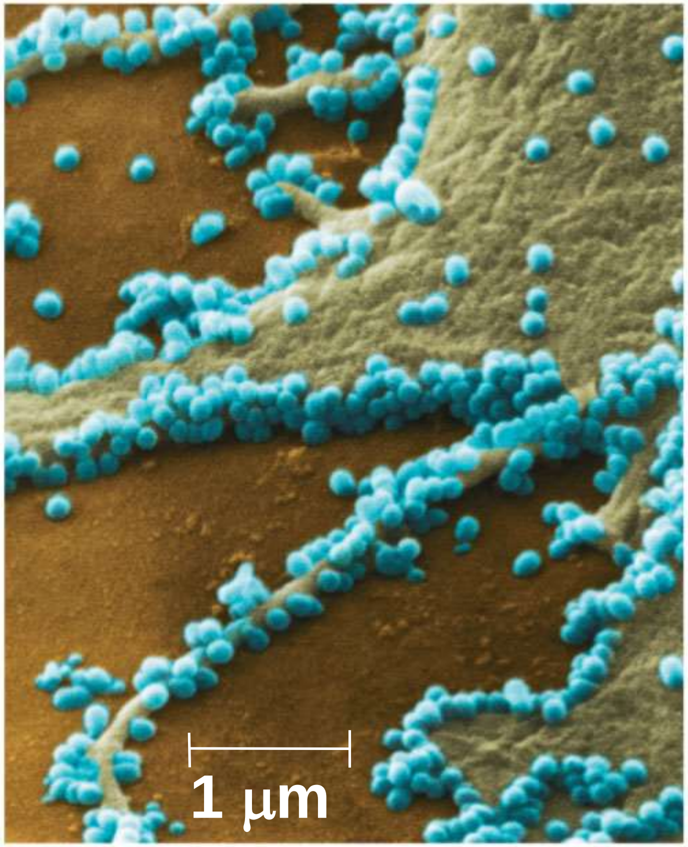
# The 1918 flu pandemic

- predominantly killed healthy young adults through immune overreaction.




Spanish Flu pandemic of 1918-1919 killed 25~40 million people, including many WWI soldiers. Evidence points to **birds** as the source. (1918年大流感 台灣死逾4萬人)

# Influenza in humans : H1N1 Flu / **A型H1N1流感**




**(a) 2009 pandemic H1N1 influenza A virus**


**(b) 2009 pandemic screening**

**H: Hemagglutinin** 血球凝集素 for attachment; 16 types

**N: Neuraminidase** 神經氨酸酶 for release; 9 types

# Viral Diseases in Plants 植物病毒病害

- More than 2,000 types of viral diseases of plants are known and cause spots on leaves and fruits, stunted growth, and damaged flowers or roots
- Most plant viruses have an RNA genome

# Viral infection of plants

Viruses cause irregular brown patches on tomatoes, black blotching on squash, and streaking in tulips (redistribution of pigment granules)

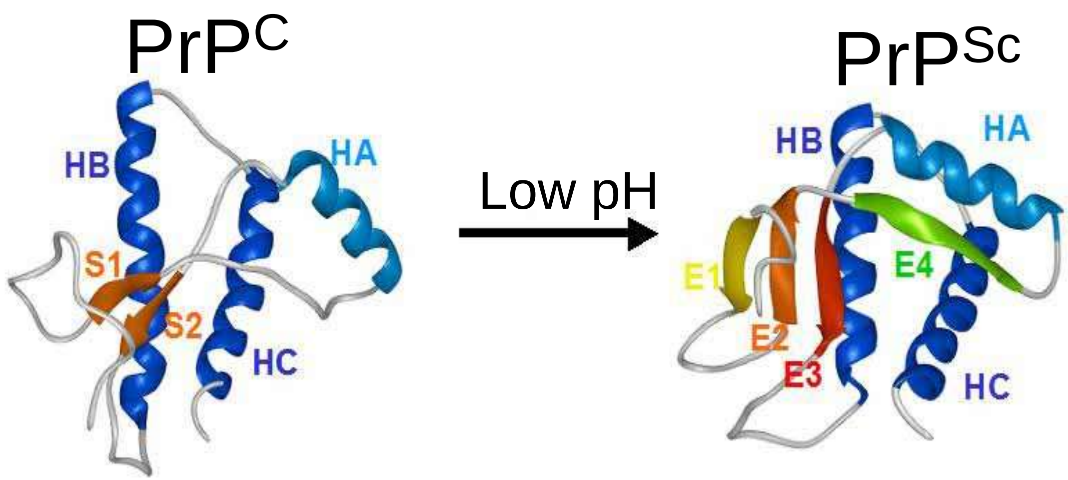
# Horizontal vs. Vertical Transmission

- Plant viruses spread disease in two major modes:
  - *Horizontal transmission*, entering through damaged cell walls
  - *Vertical transmission*, inheriting the virus from a parent

# Viroids and Prions: The Simplest Infectious Agents

- Smaller, less complex entities called viroids and prions also cause disease in plants and animals, respectively

**Same protein, different structure**

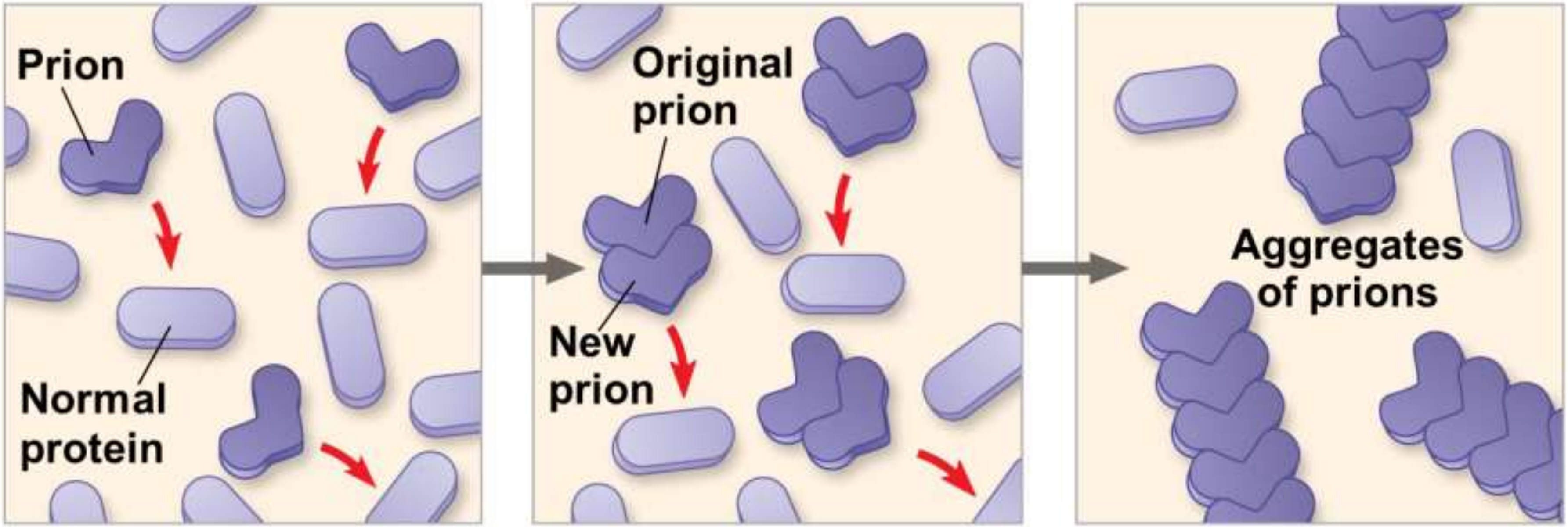


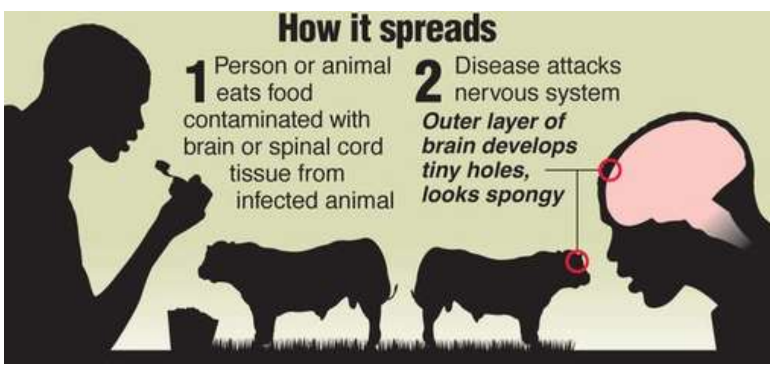

M. L. DeMarco and V. Daggett *Proc. Natl. Acad. Sci. USA* **101**, 2293-2298, 2004.

Scrapie : an affected animal scraping off its wool or hair due to the neurological irritation.

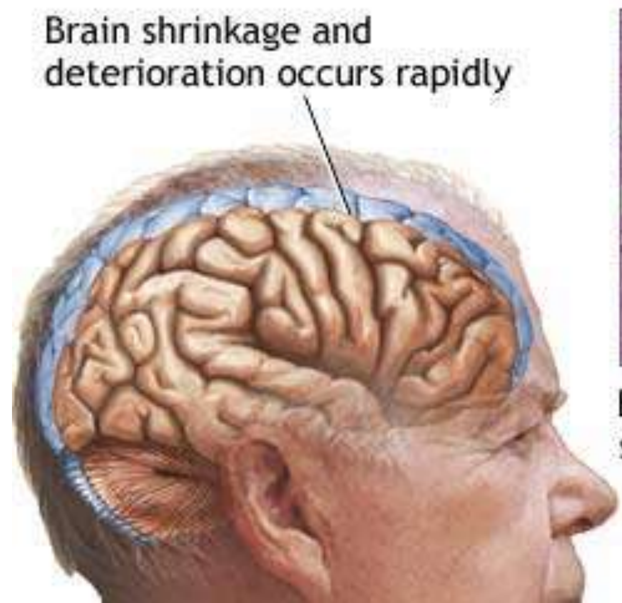
Fig. 26-10

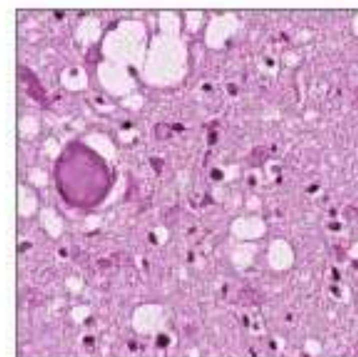
# Model for how prions propagate




**The discovery of misfolded prions as an infectious agent.** Acta Paediatr. 2010 Dec;99(12):1910-3.



Brain section showing spongiform pathology characteristic of Creutzfeldt-Jakob

# Summary

- **Viroids**（類病毒）are circular RNA molecules that infect plants and disrupt their growth
- **Prions**（傳染性蛋白質）are slow-acting, virtually indestructible infectious proteins that cause brain diseases in mammals
  - Prions propagate by converting normal proteins into the prion version
  - Scrapie in sheep, mad cow disease, and Creutzfeldt-Jakob disease in humans are all caused by prions

# You should now be able to:

Explain how capsids and envelopes are formed

Distinguish between the lytic and lysogenic reproductive cycles

Explain why viruses are obligate intracellular parasites

Describe the reproductive cycle of an HIV retrovirus

Describe three processes that lead to the emergence of new diseases

Describe viroids and prions

# 補充: 腸道中的有益病毒

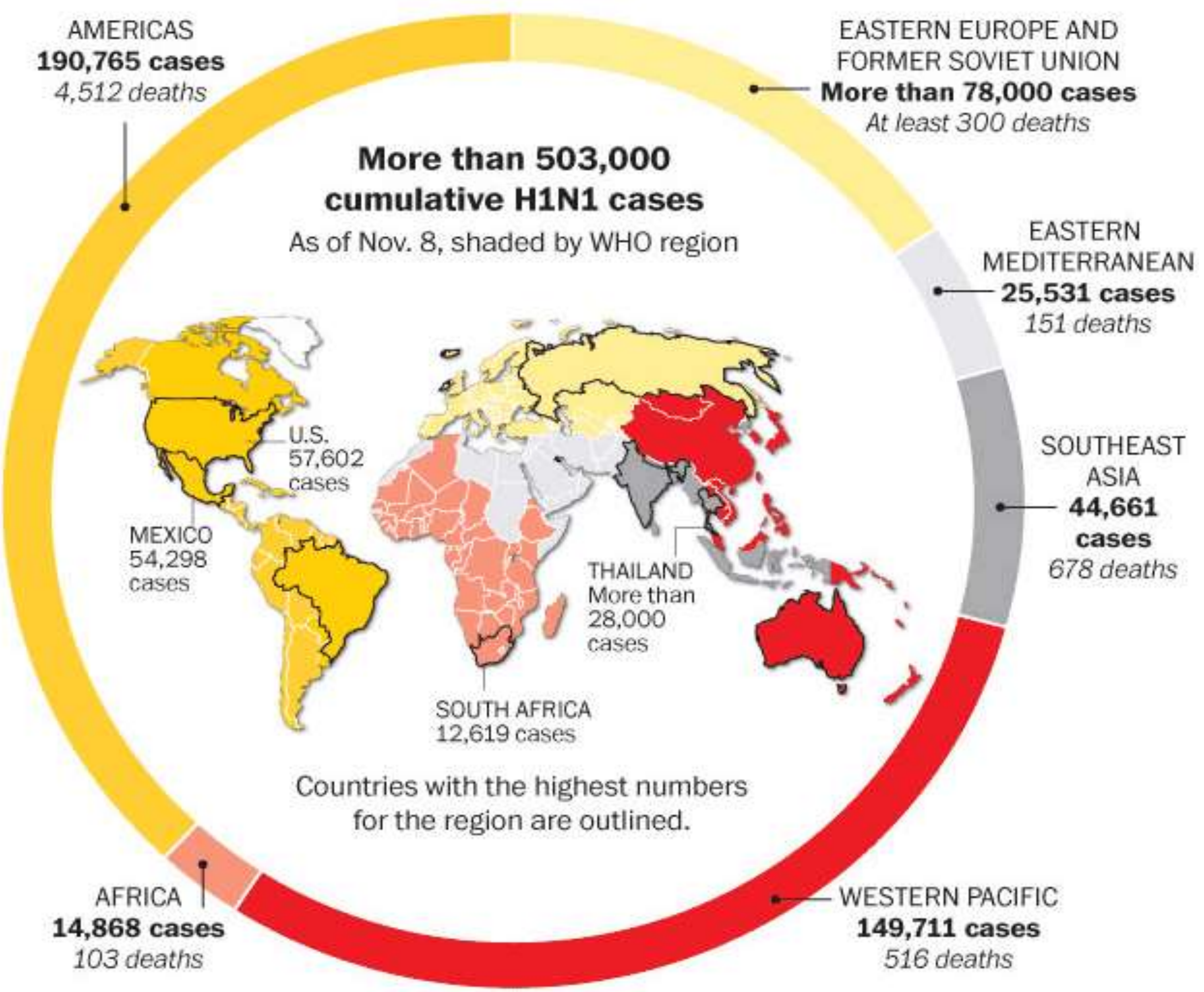
**Abnormalities in germfree mice are reversed by murine norovirus infection.**

| Abnormalities in germfree mice | Effect of MNV |
|---|---|
| Small intestinal morphology: thin villi, lack of T cells in villi, and small crypts | |
| Paneth cell defects: decrease in granule numbers and lysozyme expression | |
| Decreased cellularity of small intestinal lamina propria and mesenteric lymph nodes | |
| Reduced CD4 and CD8 T cell numbers and IFN-γ production | |
| Reduced IgA in intestine and IgG in serum | |
| Expansion of type 2 innate lymphoid cells | |
| Decreased expression of genes associated with immune system development and function | ISGs, TFs, cytokines, . . . |
| Susceptibility to intestinal damage caused by chemical injury and bacterial infection | |

Ken Cadwell J. Virol. 2015;89:1951-1953

**Thinking Question:**

# What is the best way to detect emerging new virus?




22 Nov 2009

One answer: DNA microarray based approaches