BIOL 4640 Study Guide for Exam 2 (Wed 10/28/26): Lecture 22 Viruses and Atypical Bacteria

Source: Dr. Rowen's lecture slides, in the order of the 2025 Exam 2 study guide outline.
Slide blanks still empty in the notes are filled from the textbook and marked "textbook".
Tags like [L16 p08] give the source page of each line.
Textbook to read (Slonczewski 6e, Textbook page on the site): Chapter 6 Viruses: 6.1 Viruses in Ecosystems, 6.2 Virus Structure, 6.3 Viral Genomes and Classification, 6.4 Bacteriophages and 6.5 Coronavirus SARS-CoV-2 and Other Viral Pathogens. **Also useful:** the atypical bacteria and giant viruses part is from the notes only.
(teal italics) = plain meaning of the word before it. ⚠ **Do not mix up = a look-alike pair to keep apart.**

Contents

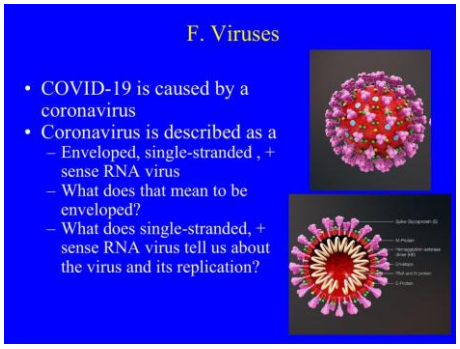
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Click a line to jump to it. The PDF side panel (bookmarks) has the same parts as tabs and topics as subtabs.

F. Viruses (Chapter 6)

COVID-19 is caused by a coronavirus. [L22 p03]
Coronavirus: an enveloped, single-stranded, + sense RNA virus. [L22 p03]
Coronavirus surface: spike glycoprotein (S), M protein, E protein, hemagglutinin-esterase dimer. [L22 p03]
Inside the envelope *(layers wrapped around the cell)*: the RNA genome with N protein. [L22 p03]
Coronavirus (SARS) is a Group IV, (+) sense ssRNA, enveloped animal virus. [L22 p19]



Coronavirus: spikes on the envelope; S, M, E and hemagglutinin-esterase proteins; RNA with N protein [L22 p03]

1. Size and shape observed

Book: 6.2 Virus Structure (chapter 6 PDF, p. 30); 6.2 Virus Structure, Symmetrical Virions (chapter 6 PDF, p. 31).

⚠ **Do not mix up: Most viruses are 10-100x SMALLER than bacteria; giant viruses are similar in size to some bacteria.** [L22 p05]

Size

Size: most viruses are between **0.02** and **0.2** microns *(one millionth of a meter)*. [L22 p05]

Most are 10-100x smaller than bacteria. [L22 p05]

Need an electron microscope to see them. [L22 p05]

Giant viruses: Pandoravirus and Mimivirus are similar in size to some bacteria. [L22 p05]

Compare: Pandoravirus **1 um**, Mimivirus **450 nm**, E. coli **2 um** long, Rickettsia **0.3 um**. [L22 p05]

Smaller viruses: HIV **110 nm**, influenza **100 nm**, polio **30 nm**, yellow fever **22 nm**. [L22 p05]

Shape

Shape: large diversity. [L22 p06]

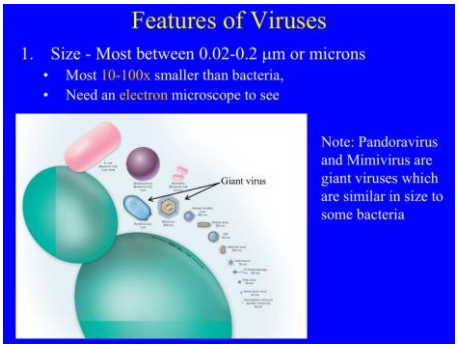
Icosahedron: a **20**-sided polyhedron *(3D shape with flat faces, straight edges, sharp corners)*. [L22 p06]

Other shapes: spherical, and complex *(more complicated)*. [L22 p06]

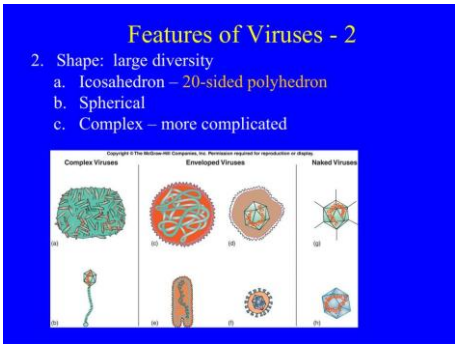
Complex viruses: poxvirus-like oval particles and tailed bacteriophages. [L22 p06]

Enveloped shapes: spherical, envelope *(layers wrapped around the cell)* around an icosahedral capsid, bullet-shaped helical. [L22 p06]

Naked viruses: icosahedrons, some with fibers. [L22 p06]



Size scale from yeast cell down to a hemoglobin molecule; giant viruses near bacteria [L22 p05]



Complex, enveloped and naked virus shapes [L22 p06]

2. Structural features: components of virus particles (core and covering)

Book: 6.2 Virus Structure, Symmetrical Virions (chapter 6 PDF, p. 31).

⚠ **Do not mix up: The CORE is nucleic acid and enzymes; the COVERING is the capsid and envelope *(layers wrapped around the cell)*.** [L22 p08]

Simpler than cells

Viruses are simpler than cells: considered acellular *(not made of cells)*. [L22 p07]

Virus particles (virions) may contain just nucleic acid in a protein shell. [L22 p07]
Naked virus: capsid with spikes at the vertices, nucleic acid inside. [L22 p07]
Enveloped virus: nucleic acid, capsid, an outer envelope, spikes from the envelope. [L22 p07]

Core and covering

Components can be divided into core and covering. [L22 p08]
Core: nucleic acid and enzymes. [L22 p08]
Core also: matrix proteins; enzymes are not found in all viruses. [L22 p08]
Covering: capsid and envelope. [L22 p08]
Envelope: not found in all viruses. [L22 p08]

a. Nucleic acid

Nucleic acid: found in all viruses. [L22 p09]
Can be DNA *(cell genetic instruction molecule)* **or RNA**, but not both. [L22 p09]
May be single or double stranded. [L22 p09]
May be in multiple segments. [L22 p09]
May contain more than 1 copy. [L22 p09]
dsDNA examples: variola (smallpox), herpes simplex **2** (genital herpes). [L22 p09]
ssDNA example: parvovirus (erythema infectiosum). [L22 p09]
RNA examples: poliovirus ss (+), influenza ss (-), rotavirus dsRNA. [L22 p09]
HIV (AIDS): ssRNA with reverse transcriptase. [L22 p09]
Overlapping genes can be seen in viral nucleic acid. [L22 p10]
Multiple proteins can come from a single RNA and polypeptide. [L22 p10]
SARS-CoV-2 genome: about **29,903** nucleotides; ORF1a and ORF1b, then S, E, M, N genes. [L22 p10]
The ORF1a and ORF1b polyprotein is cut into nonstructural proteins NSP1 to NSP16. [L22 p10]
SARS-CoV-2 structural proteins: S, E, M, N; accessory proteins orf3a to orf10. [L22 p10]
Cauliflower mosaic virus: circular DNA genome of **8,000** bp with overlapping genes. [L22 p10]
Avian leukosis virus: RNA genome of **7,200** bp with gag (core), pol (enzymes), env (envelope). [L22 p10]

b. Enzymes

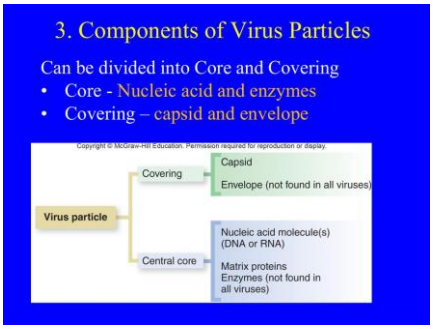
Enzymes: such as polymerase or reverse transcriptase. [L22 p11]
Enzymes sit inside the capsid. [L22 p11]
Enzymes are observed in some viruses. [L22 p11]
HIV (a retrovirus) carries reverse transcriptase, integrase and protease. [L22 p11]
HIV particle: GP-**120** knobs on GP-**41** stems; the capsid holds two RNA strands. [L22 p11]

c. Capsid

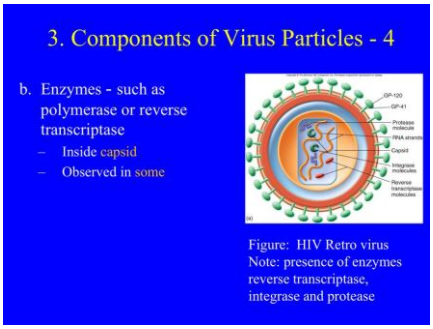
Capsid: protein coat or shell. [L22 p12]
The capsid is found in all viruses. [L22 p12]
Usually icosahedral (**20** sided) or helical in shape. [L22 p12]
Capsid proteins form identical capsomeres, which in turn form the capsid. [L22 p12]
Capsid and nucleic acid together form the nucleocapsid. [L22 p12]
Capsomeres form triangular facets and cluster at each vertex. [L22 p12]
Helical capsid: capsid proteins stacked around a helical nucleic acid. [L22 p12]

d. Envelope

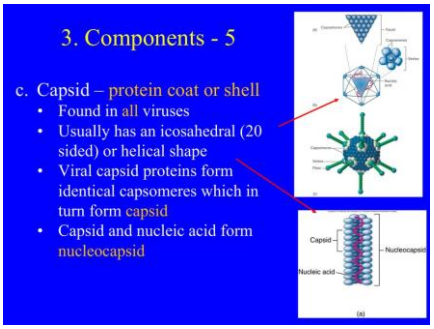
Envelope: phospholipid *(membrane fat with a charged head)* bilayer *(two layers)* membrane *(thin lipid layer)* with proteins and glycoproteins (spikes). [L22 p13]
The envelope is observed in some viruses. [L22 p13]



Virus particle: covering (capsid, envelope) and central core (nucleic acid, matrix proteins, enzymes) [L22 p08]



HIV particle: envelope with GP-120 and GP-41; capsid with RNA and enzymes [L22 p11]



Capsomeres, facets and vertices of an icosahedral capsid; helical nucleocapsid [L22 p12]

Components of virus particles

Component	Core or covering	In all viruses?	What it is
Nucleic acid	Core	Yes	DNA or RNA, but not both
Enzymes	Core, inside the capsid	Some	Such as polymerase or reverse transcriptase
Capsid	Covering	Yes	Protein coat or shell
Envelope	Covering	Some	Phospholipid bilayer membrane with proteins and glycoproteins (spikes)

Table source: [L22 p08, L22 p09, L22 p11, L22 p12, L22 p13]

Which components are found in all viruses?

Book: 6.2 Virus Structure, Symmetrical Virions (chapter 6 PDF, p. 31).

⚠ **Do not mix up: Nucleic acid and capsid are in ALL viruses; enzymes and envelope *(layers wrapped around the cell)* only in SOME.** [L22 p09, L22 p12, L22 p13]

Found in all viruses: nucleic acid and capsid. [L22 p09, L22 p12]

Found in some viruses only: enzymes and envelope. [L22 p08, L22 p11, L22 p13]

Naked vs enveloped viruses

Book: 6.2 Virus Structure, Symmetrical Virions (chapter 6 PDF, p. 31).

⚠ **Do not mix up: Naked viruses are TOUGHER; enveloped viruses are more sensitive and must remain wet.** [L22 p14]

Significance of the outer covering: naked vs enveloped. [L22 p14]

It affects viability *(able to still cause an infection)* outside a host cell. [L22 p14]

Naked (no membrane) viruses: generally tougher, survive longer. [L22 p14]

Naked viruses are more resistant to drying, detergents and acids. [L22 p14]

Enveloped viruses: more sensitive, must remain wet. [L22 p14]

The covering also determines the means of escape from the infected cell. [L22 p14]

Naked (nonenveloped) viruses must lyse the cell. [L22 p14]

Enveloped viruses can escape by budding. [L22 p14]

Naked vs enveloped viruses

Feature	Naked (nonenveloped)	Enveloped
Outer layer	Capsid, no membrane	Envelope over the capsid
Outside a host cell	Tougher, survive longer; resist drying, detergents, acids	More sensitive; must remain wet
Escape from the cell	Must lyse the cell	Can escape by budding

Table source: [L22 p07, L22 p14]

3. Features used to classify or group viruses (groups, subgroups, Baltimore Groups I to VII)

Book: 6.3 Viral Genomes and Classification, The Baltimore Virus Classification (chapter 6 PDF, p. 53).

⚠ **Do not mix up: GROUPS use genetic material and means of replication; covering, shape, host and segments define SUBGROUPS.** [L22 p17]

Groups and subgroups

Groups:

> Are based on the nature of genetic material: DNA *(cell genetic instruction molecule)* or RNA, ss vs ds.
> Are also based on the means of replication. [L22 p17, L22 p18]

Subgroups, a: outer covering, whether they have an envelope *(layers wrapped around the cell)* or not (nonenveloped). [L22 p17]

Subgroups, b: shape of the virus particle or capsid. [L22 p17]

Subgroups, c: organisms or cells the virus infects. [L22 p17]

Subgroups, d: whether the genome is segmented or not. [L22 p17]

Baltimore classification: seven groups of viruses, Group I to Group VII. [L22 p18, L22 p19]

Some refer to groups as families. [L22 p18, L22 p19]

Subgroup examples

Group I subgroups: nonenveloped head and tail bacteriophages; nonenveloped and enveloped animal viruses. [L22 p18]

Group I also includes archaeal *(of archaea)* viruses. [L22 p18]

Group III subgroups: nonsegmented enveloped bacteriophages; segmented nonenveloped animal and plant viruses. [L22 p18]

Group IV subgroups: nonenveloped phage (MS2); nonenveloped animal and plant (polio); enveloped (SARS). [L22 p19]

Group V subgroups: segmented enveloped (influenza); nonsegmented enveloped (Ebola, measles, rabies). [L22 p19]

Group VII subgroups: nonenveloped plant viruses (cauliflower mosaic); enveloped animal viruses (hepatitis B). [L22 p19]

Baltimore groups of viruses

Group	Genome	Replication	Examples
I	dsDNA	Host or viral DNA polymerase	T4, lambda, adenovirus, herpes, pox, Mimivirus
II	ssDNA, (+) sense	Host DNA polymerase; nonenveloped	M13, phiX174, parvovirus, geminivirus
III	dsRNA	Viral RNA-dependent RNA polymerase, usually packaged	Cystoviridae phages, reovirus (rotavirus)
IV	(+) sense ssRNA	Viral RNA-dependent RNA polymerase makes a (-) template	MS2, polio, rhinovirus, corona (SARS), Zika
V	(-) sense ssRNA	Viral RNA-dependent RNA transcriptase; genome often segmented	Influenza, Ebola, measles, mumps, rabies
VI	Retroviruses, ssRNA	Viral reverse transcriptase copies RNA to DNA for integration into the host chromosome	HIV, SIV
VII	Pararetroviruses, dsDNA	DNA transcribed to RNA, then reverse-transcribed to DNA	Cauliflower mosaic virus, hepatitis B

Table source: [L22 p18, L22 p19]

4. Reproduction

a. General features: obligate intracellular parasites, assembled from parts

Book: 6.1 Viruses in Ecosystems, Viruses Infect Specific Hosts (chapter 6 PDF, p. 12).

⚠ **Do not mix up: Viruses are ASSEMBLED from parts inside the host cell, not made by splitting.** [L22 p16, L22 p37]

Obligate intracellular parasites: **only** replicate or multiply inside a host cell. [L22 p15]

Obligate intracellular parasitism is also observed in some bacteria and protozoans. [L22 p15]

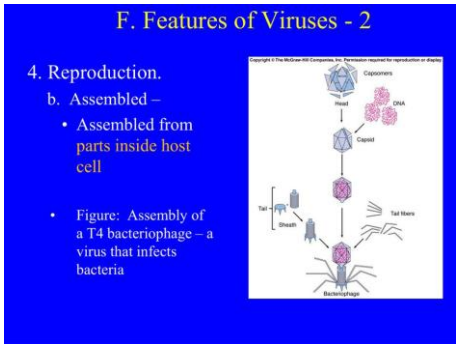
Phage *(virus that infects bacteria)* **cycle**: adsorption, penetration, duplication of phage parts, assembly, maturation, lysis *(bursting open)*, release. [L22 p15]

Lysogenic phase: viral DNA *(cell genetic instruction molecule)* becomes latent as a prophage. [L22 p15]

Assembled from parts inside the host cell. [L22 p16]

T4 bacteriophage *(a virus that infects bacteria)*: capsomers make the head; DNA is packed into the capsid. [L22 p16]

Tail and sheath are built separately; tail fibers are added last. [L22 p16]



Assembly of a T4 bacteriophage: head, DNA packing, tail and sheath, tail fibers [L22 p16]

b. Steps in multiplication cycle

Book: 6.5 Coronavirus SARS-CoV-2 and Other Viral Pathogens, Animal Viruses Bind Host Receptors and Enter the Cell (chapter 6 PDF, p. 86); 6.4 Bacteriophages: The Gut Virome, Bacteriophages Infect a Host Cell (chapter 6 PDF, p. 67).

⚠ **Do not mix up: Penetration is ENTRY into the cell; uncoating is RELEASE of the viral genome.** [L22 p22]

Animal virus cycle

Animal virus cycle: adsorption, penetration, uncoating, synthesis, assembly, release. [L22 p20]

Adsorption: spikes bind cell receptors *(proteins a signal or virus binds to)*. [L22 p20]

Penetration: the virus is engulfed into a vesicle. [L22 p20]

Uncoating frees the viral RNA into the cytoplasm *(jelly inside the cell membrane)*. [L22 p20]

Synthesis: (+) RNA to (-) RNA to new (+) RNA; new capsomers and spikes. [L22 p20]

Assembly: spike proteins go into the cell membrane *(thin skin around the cell)*; RNA and capsomers form the nucleocapsid. [L22 p20]

Release: the enveloped virus buds off the membrane, carrying an envelope *(layers wrapped around the cell)* with spikes. [L22 p20]

a. Adsorption

Adsorption: attachment to receptors on the host cell to be infected. [L22 p21]

Adsorption is the major factor determining host range *(the kinds of cells a virus can infect)*. [L22 p21]

SARS-CoV-2 binds the ACE2 receptor. [L22 p21]

Measles virus: an envelope protein binds a receptor protein, then the membranes fuse. [L22 p21]

b. Penetration and c. Uncoating

Penetration: entry into the cell. [L22 p22]

Uncoating: release of the viral genome. [L22 p22]

Two ways in: endocytosis to an endosome vesicle, or fusion of membranes. [L22 p22]

Endocytosis: attachment, engulfment, virus in a vesicle; vesicle, envelope and capsid break down. [L22 p22]

Fusion:

> Membranes fuse at the receptor-spike complex; the nucleocapsid enters, then uncoats.
> Releases the contents of the viral particle inside the cell. [L22 p22]

Uncoating mechanisms: in the endosome; by fusion and release; or at the nucleus. [L22 p23]

SARS-CoV-2 enters by endocytosis; its genome is uncoated within the endosome. [L22 p23]

Measles: the coated RNA genome enters the cytoplasm. [L22 p23]

Hepatitis C: uncoated in an endosome acidified by lysosome fusion. [L22 p23]

Adenovirus: the genome is uncoated at the nuclear pore complex. [L22 p23]

e. Assembly

Assembly: assembled from parts, not by splitting. [L22 p37]

Proteins assemble to make capsomers and the sheath. [L22 p37]

Parts of the virus are then assembled. [L22 p37]

f. Release or escape

Release, way 1: lysis *(bursting open)* of the host cell. [L22 p38]

Way 2: budding by enveloped viruses. [L22 p38]

Budding can result in a persistent infection. [L22 p38]

Budding: viral spikes and matrix protein go into the host membrane; the nucleocapsid pushes out. [L22 p38]

Filamentous Ebola virus buds out of the cell. [L22 p39]

Ebola virion: lipid envelope, nucleocapsid and RNA genome. [L22 p39]

Ebola virions exit as filaments: empty, linked, single or continuous. [L22 p39]

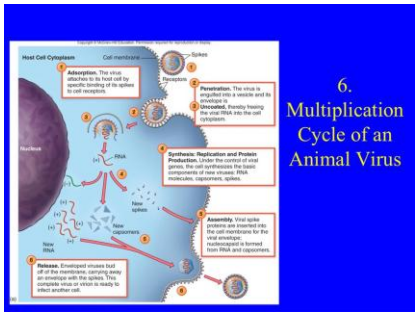
Tandem arrays of RNA genomes are held together in a flexible lipid envelope. [L22 p39]

Way 3: cell-to-cell spread. [L22 p40]

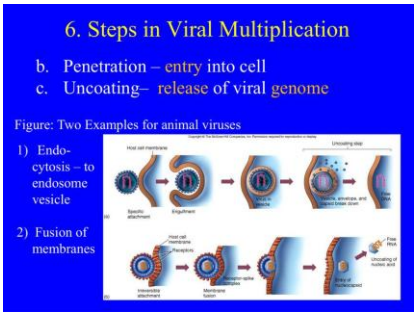
Cell-to-cell spread may lead to cell fusion: syncytia formation. [L22 p40]

Viral components pass along an F-actin bridge to a target cell. [L22 p40]

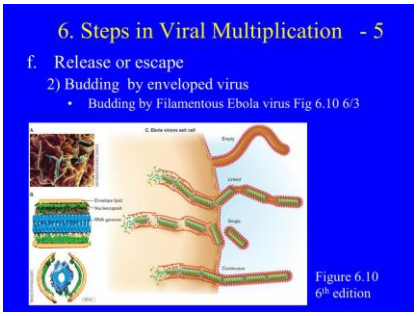
In epithelial cells, viral particles pass through the apical junction complex. [L22 p40]



Animal virus cycle: adsorption, penetration, uncoating, synthesis, assembly, release by budding [L22 p20]



Entry by endocytosis vs fusion of membranes, then uncoating [L22 p22]



Ebola virions budding out of a cell as filaments [L22 p39]

Steps in viral multiplication

Step	What happens
a. Adsorption	Attachment to receptors on the host cell
b. Penetration	Entry into the cell, by endocytosis or fusion
c. Uncoating	Release of the viral genome
d. Synthesis	Copies of the genetic material and of the proteins
e. Assembly	From parts, not by splitting
f. Release or escape	Lysis, budding by enveloped viruses, or cell-to-cell spread

Table source: [L22 p20, L22 p21, L22 p22, L22 p24, L22 p37, L22 p38, L22 p40]

c. Synthesis stage for the 7 types of viruses and the source of each enzyme

Book: 6.3 Viral Genomes and Classification, The Baltimore Virus Classification (chapter 6 PDF, p. 53).

⚠ **Do not mix up: Most host cells lack RNA-dependent RNA polymerase *(enzyme copying DNA into RNA)*, so RNA viruses usually encode their own.** [L22 p28, L22 p29]

Two jobs

Synthesis needs two things: replicate the genetic material and make many copies of proteins. [L22 p24]

Replicate: DNA *(cell genetic instruction molecule)* to more DNA, usually ds; ss RNA to more ss RNA. [L22 p24]

Proteins: viral mRNA *(message copy of a gene)* to proteins. [L22 p24]

Done in different ways by different viruses; it depends on the genetic material. [L22 p24]

Needed enzymes can be encoded by the virus or found in the host cell. [L22 p24]

Every group leads to (+) mRNA. [L22 p25]

RNA genomes

RNA genomes: usually single stranded (ss). [L22 p28]

Problem: RNA must be the template to make more RNA (RNA-dependent RNA polymerase, RdRP). [L22 p28]

Main host DNA pol and RNA pol use DNA as the template. [L22 p28]

Most host cells have no RdRP or very low levels. [L22 p28]

Solution: viruses usually encode enzymes that can replicate RNA. [L22 p29]

Mechanism 1: RNA-dependent RNA polymerases: ssRNA to complementary ssRNA to ssRNA. [L22 p29]
Mechanism 2: reverse transcriptase of retroviruses: ssRNA to ssDNA to dsDNA to ssRNA. [L22 p29]
(+) strand: the strand that serves as template for translation. [L22 p30]
(-) strand: the strand complementary to the (+) strand. [L22 p30]

Group I: dsDNA

Group I genome: dsDNA to more dsDNA; DNA polymerase from the host cell or virus. [L22 p26]
Group I proteins: dsDNA to ssRNA to proteins; DNA-dependent RNA pol from host or virus. [L22 p26]
Group I ribosomes *(protein building machine)*: host cell. [L22 p26]
Papillomavirus:

> Genome uncoated at the nuclear pore; host RNA and DNA polymerases do the work.
> Assembles in the nucleus; **only** shedding epithelial cells release virions. [L22 p26]

Group I is the most similar to cellular processes. [L22 p26]

Group II: ssDNA

Group II genome: ssDNA to dsDNA to ssDNA; DNA polymerase from the host. [L22 p27]
Group II proteins: dsDNA to RNA to protein; RNA polymerase from host or virus. [L22 p27]
Group II ribosomes: host. [L22 p27]
Parvovirus infects dividing erythroid precursor cells; its +DNA becomes +/-DNA in the nucleus. [L22 p27]

Group III: dsRNA

Group III genome: dsRNA to (+) ssRNA to dsRNA, using RdRP from the virus. [L22 p31]
Group III proteins: (+) ssRNA to proteins on host ribosomes. [L22 p31]
Reovirus: enters by receptor-mediated endocytosis; uncoating in the endosome releases the core. [L22 p31]
In the core, viral RdRP makes (+) ssRNA; new dsRNA forms inside the capsid. [L22 p31]
Reovirus is released by lysis *(bursting open)* of the host cell. [L22 p31]

Group IV: (+) ssRNA

Group IV genome: (+) ssRNA to (-) ssRNA to (+) ssRNA, using RdRP from the virus. [L22 p32]
Group IV proteins: the (+) ssRNA carried in the particle can be translated immediately. [L22 p32]
Group IV ribosomes: host. [L22 p32]
Picornavirus: the (+) RNA is translated first to make the RdRP. [L22 p32]
Picornavirus (-) RNA is made in a virus-induced vesicle from the ER. [L22 p32]

Group V: (-) ssRNA

Group V genome: (-) ssRNA to (+) ssRNA to (-) ssRNA, using RdRP from the virus. [L22 p33]
Group V proteins: (+) ssRNA to proteins on host ribosomes. [L22 p33]
The virus brings its RdRP in with the (-) RNA genome. [L22 p33]

Group VI: retroviruses

Group VI genome: (+) ssRNA to ssDNA to dsDNA to (+) ssRNA. [L22 p34]
Reverse transcriptase comes from the virus; the last step uses host DNA-dependent RNA pol. [L22 p34]
Group VI proteins: dsDNA to (+) ssRNA to protein; RNA polymerase and ribosomes from host. [L22 p34]
Retrovirus: the dsDNA copy integrates into the host genome; host RNA Pol II transcribes it. [L22 p34]
Retroviruses leave the cell by budding. [L22 p34]

Group VII: DNA reverse-transcribing

Group VII genome: dsDNA to (+) ssRNA to dsDNA. [L22 p35]
Group VII reverse transcriptase comes from the virus or the host cell. [L22 p35]
Group VII proteins: dsDNA to (+) ssRNA to protein on host ribosomes. [L22 p35]
Cauliflower mosaic virus: dsDNA genome passed on through an aphid bite. [L22 p35]
It spreads to uninfected cells through the plasmodesma. [L22 p35]

Enzyme sources compared

Parvovirus and papillomavirus: host DNA pol for the first step. [L22 p36]

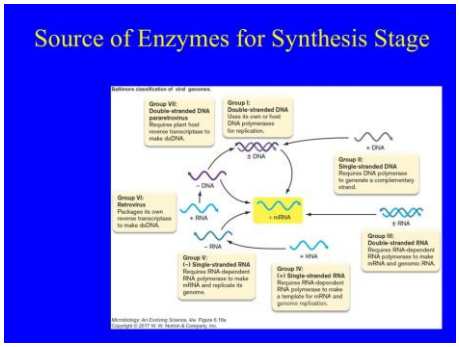
Adenovirus, herpesvirus, poxvirus: virus-encoded DNA-dependent DNA pol for the first step. [L22 p36]

Poxvirus is the exception for transcription: its RNA polymerase is virus encoded. [L22 p36]

RNA retroviruses: virus-encoded RNA-dependent DNA polymerase for the first step. [L22 p36]

(+) and (-) ssRNA viruses: virus-encoded RNA-dependent RNA pol; ribosomes from the host. [L22 p36]

First step: host ribosomes for (+) ssRNA; viral RdRP for (-) ssRNA. [L22 p36]



Every group leads to (+) mRNA; the enzyme each group needs [L22 p25]

Synthesis stage: route and source of each enzyme, Groups I to VII

Group	Route	Replication enzyme	RNA polymerase for transcription	Ribosomes
I dsDNA	dsDNA to dsDNA; dsDNA to ssRNA to protein	DNA polymerase: host or virus	Host or virus (virus in poxvirus)	Host
II ssDNA	ssDNA to dsDNA to ssDNA; dsDNA to RNA to protein	DNA polymerase: host	Host or virus	Host
III dsRNA	dsRNA to (+) ssRNA to dsRNA	RdRP from the virus	RdRP from the virus makes the (+) ssRNA	Host
IV (+) ssRNA	(+) ssRNA to (-) ssRNA to (+) ssRNA	RdRP from the virus	Not needed: the (+) ssRNA is translated immediately	Host
V (-) ssRNA	(-) ssRNA to (+) ssRNA to (-) ssRNA	RdRP from the virus	Not host: viral RdRP makes the (+) ssRNA	Host
VI retrovirus	(+) ssRNA to ssDNA to dsDNA to (+) ssRNA	Reverse transcriptase: virus	Host	Host
VII DNA reverse-transcribing	dsDNA to (+) ssRNA to dsDNA	Reverse transcriptase: virus or host cell	Host	Host

Table source: [L22 p25, L22 p26, L22 p27, L22 p31, L22 p32, L22 p33, L22 p34, L22 p35, L22 p36]

▸ Multiplication cycles of SARS-CoV-2, plant viruses and bacteriophage

Book: 6.5 Coronavirus SARS-CoV-2 and Other Viral Pathogens, Coronavirus (chapter 6 PDF, p. 84); 6.5 Coronavirus SARS-CoV-2 and Other Viral Pathogens, Plant Viruses (chapter 6 PDF, p. 107); 6.4 Bacteriophages: The Gut Virome, Bacteriophages Infect a Host Cell (chapter 6 PDF, p. 67).

⚠ Do not mix up: Plant viruses need help past the cell wall *(stiff layer around the cell membrane)*; most phages *(virus that infects bacteria)* inject DNA *(cell genetic instruction molecule)*, leaving the particle outside. [L22 p42, L22 p43]

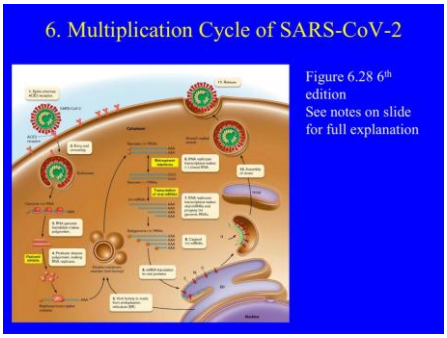
SARS-CoV-2

Step 1: the spike attaches to the ACE2 receptor. [L22 p41]

Step 2: entry by endocytosis and uncoating in the host cytoplasm *(jelly inside the cell membrane)*. [L22 p41]

Step 3: host ribosomes *(protein building machine)* translate the RNA genome into a polyprotein. [L22 p41]

Step 4: a protease cleaves the polyprotein, making RNA replicase (RdRP); Paxlovid inhibits this. [L22 p41]



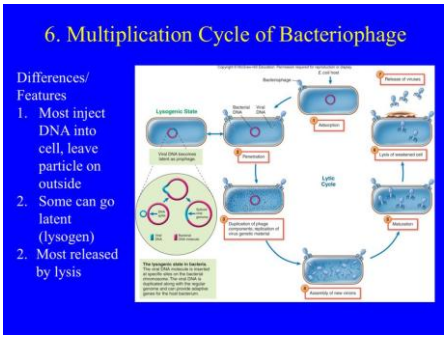
SARS-CoV-2 cycle: ACE2 binding, entry, polyprotein, replicase, ER factories, assembly, release [L22 p41]

Step 5: ER membrane *(thin lipid layer)* becomes viral factories (double-membrane vesicles). [L22 p41]
Step 6: replicase makes (-) strand RNA; molnupiravir interferes. [L22 p41]
Steps 7 and 8: the (-) strand templates viral mRNAs and new (+) genomes. [L22 p41]
Step 9: mRNAs are translated into viral proteins (E, M, S on the ER; N). [L22 p41]
Steps 10 and 11: virions assemble via the Golgi and bud out of the cell. [L22 p41]

Plant viruses

Plant viruses: entry and penetration are different. [L22 p42]
The cell wall blocks entry without help. [L22 p42]
Ways in: an animal vector (insect) damages cells; contact with damaged tissue; infected seeds. [L22 p42]
Then the virus moves cell to cell through plasmodesma connections. [L22 p42]
Cauliflower mosaic virus uses host RNA polymerase *(enzyme copying DNA into RNA)* and host reverse transcriptase. [L22 p42]

Bacteriophage

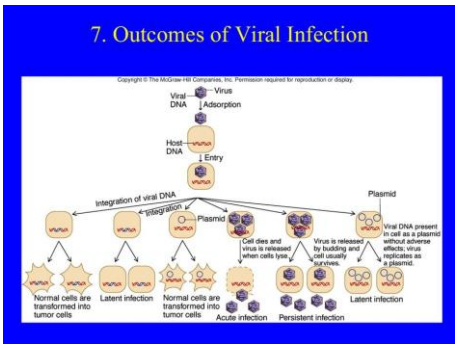


Bacteriophage cycle with the lysogenic prophage state [L22 p43]

Most phages inject DNA into the cell and leave the particle on the outside. [L22 p43]
Some can go latent (lysogen) *(phage DNA kept quietly in the host)*. [L22 p43]
Most are released by lysis *(bursting open)*. [L22 p43]
Prophage: viral DNA inserted at specific sites on the bacterial chromosome *(one long DNA molecule)*, copied with it. [L22 p43]
Prophages can give the host adaptive genes. [L22 p43]

5. Outcomes of viral infections

Possible outcomes: acute infection, persistent infection, latent infection, transformation *(cell taking up free DNA)* into tumor cells. [L22 p44]



Outcomes of viral infection after adsorption and entry [L22 p44]

Different possible outcomes for the host cell

Book: 6.5 Coronavirus SARS-CoV-2 and Other Viral Pathogens, Oncogenic Viruses (chapter 6 PDF, p. 106); 6.1 Viruses in Ecosystems, Integrated Viral Genomes (chapter 6 PDF, p. 15).

⚠ **Do not mix up: Persistent infection is ONLY by enveloped viruses that leave by budding; the cell survives.** [L22 p45]

Acute and persistent

a. Acute infection: death of host cells due to cell lysis *(bursting open)*. [L22 p45]
b. Persistent infection: host cells keep producing virus particles over a long period of time. [L22 p45]
Slow release of virus. [L22 p45]
Persistent infection is only done by enveloped viruses, which leave by budding. [L22 p45]

Latent

c. Chronic, latent infection: the virus goes dormant *(inactive, not growing)* in the host cell. [L22 p46]

It can later reactivate and release virus particles. [L22 p46]

Example: herpes virus goes latent in a nerve cell. [L22 p46]

Herpes will occasionally release virus particles, which cause skin lesions. [L22 p46]

HSV-1: first infection at **3** to **5** years old (cold sores). [L22 p46]

Then it stays latent in a root ganglion neuron; when activated it travels the trigeminal nerve. [L22 p46]

Latent infection can also be viral DNA *(cell genetic instruction molecule)* kept as a plasmid *(small extra DNA circle)* without adverse effects. [L22 p44]

Cytopathic changes

d. Cytopathic changes: infection alters the appearance of the cell. [L22 p47]

Cytopathic changes are sometimes used in diagnosis. [L22 p47]

Transformation and syncytia

e. Transformation *(cell taking up free DNA)*: the cell becomes cancerous. [L22 p48]

Some viruses contain an oncogene, or their integration generates an oncogene. [L22 p48]

The oncogene promotes growth of the host cell. [L22 p48]

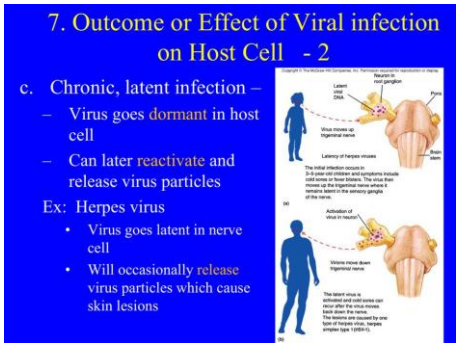
Infected cells round up, clump and detach; normal cells lie flat and spread out. [L22 p48]

f. Syncytia: large, multinucleated cells. [L22 p49]

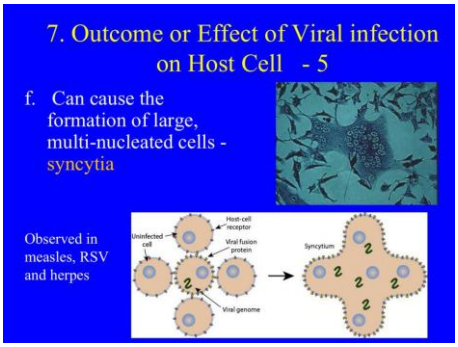
Syncytia are observed in measles, RSV *(respiratory syncytial virus)* and herpes. [L22 p49]

How: a viral fusion protein on an infected cell binds receptors *(proteins a signal or virus binds to)* on uninfected neighbors. [L22 p49]

The cells fuse into one syncytium with several nuclei. [L22 p49]



Herpes latency in a nerve root ganglion and later activation with cold sores [L22 p46]



Syncytium: infected cell fusion protein binds neighbors; one cell with many nuclei [L22 p49]

Outcomes for the host cell

Outcome	What happens to the host cell	Virus release
a. Acute	Host cells die due to cell lysis	Released when the cells lyse
b. Persistent	Cell usually survives	Slow release by budding over a long period
c. Chronic, latent	Virus goes dormant in the host cell	Can later reactivate and release virus particles
e. Transformation	Cell becomes cancerous (tumor cell)	Viral DNA integrated, or kept as a plasmid

Table source: [L22 p44, L22 p45, L22 p46, L22 p48]

Cytopathic changes

Virus	Cytopathic change	Inclusions
Smallpox	Cells round up	Cytoplasmic
Herpes simplex	Cells fuse to form multinucleated syncytia	Nuclear
Adenovirus	Clumping	Nuclear
Poliovirus	Cell lysis	None
Reovirus	Cell enlargement, vacuoles	Cytoplasmic
Influenza	Cells round up	None
Rabies	No change in shape	Cytoplasmic (Negri bodies)
Measles	Syncytia form (multinucleate)	

Table source: [L22 p47]

Effects on populations of microbes

Book: 6.1 Viruses in Ecosystems, Viruses Limit Host Populations and Increase Diversity (chapter 6 PDF, p. 19); 6.1 Viruses in Ecosystems, Viruses Cycle Nutrients and Share Host Genes (chapter 6 PDF, p. 22); 6.4 Bacteriophages: The Gut Virome, Bacteriophages Within the Gut Community (chapter 6 PDF, p. 79).

⚠ **Do not mix up: Phage *(virus that infects bacteria)* lysis *(bursting open)* at the ocean SURFACE releases organic matter that would otherwise sink.** [L22 p51]

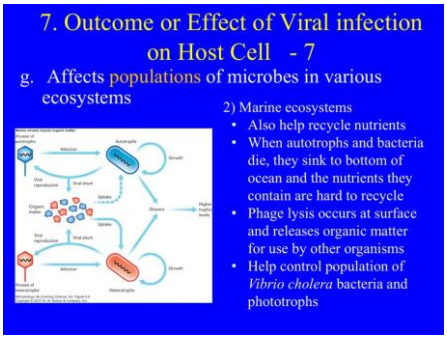
g. Viruses affect populations of microbes in various ecosystems. [L22 p50]

Mammalian gut: lots of bacteriophages that act against bacteria in the intestine. [L22 p50]

Gut phages can transfer host DNA (transduction) and may stimulate the immune system. [L22 p50]

Lysogenized bacteria can have enhanced traits and express virulence *(ability to cause disease)*, such as toxins. [L22 p50]

Marine ecosystems: viruses also help recycle nutrients. [L22 p51]



Marine viruses recycle organic matter through the viral shunt [L22 p51]

Dead autotrophs and bacteria sink to the ocean bottom, where their nutrients are hard to recycle. [L22 p51]

Phage lysis occurs at the surface and releases organic matter for use by other organisms. [L22 p51]

Viral shunt *(organic matter released by lysis)*: taken up by autotrophs and heterotrophs. [L22 p51]

Phages help control populations of Vibrio cholera bacteria and phototrophs *(organisms that use light for energy)*. [L22 p51]

G. Atypical Bacteria and Viruses

Typical bacteria vs typical viruses

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

⚠ **Do not mix up: Typical bacteria reproduce BY THEMSELVES; typical viruses only reproduce INSIDE cells.** [L22 p53]

Typical bacteria are free-living and reproduce by themselves. [L22 p53]

Typical viruses are obligate intracellular parasites: they **only** reproduce inside cells. [L22 p53]

Viruses have nucleic acids but no chromosomes *(one long DNA molecule)*, nucleus, ribosomes *(protein building machine)*, mitochondria or flagella *(whip tails that spin)*. [L22 p52]

Viruses lack mitosis, binary fission and independent biosynthesis. [L22 p52]

No cell wall *(stiff layer around the cell membrane)* in viruses: capsids instead. [L22 p52]

Sizes: viruses under **0.2 um**; bacteria **0.5** to **3 um**; eukaryotes **2** to **100 um**. [L22 p52]

Outside host cells, viruses cannot carry out metabolic or genetic activity. [L22 p52]

Typical bacteria vs typical viruses

Property	Typical bacteria	Typical viruses
Size	**1** to **3 um**	**0.02** to **0.2 um**
Genome	**500** to **10,000** kB; **1,000** to **10,000** genes	**1.8** to **100** kB; **1** to **100 proteins**
Lifestyle	Free-living; reproduces by itself	Obligate intracellular parasite; **only** reproduces inside cells

Table source: [L22 p53]

Atypical small bacteria: how they were found

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

⚠ **Do not mix up: Passing a 1 micron *(one millionth of a meter)* filter did NOT make them viruses: they had ribosomes *(protein building machine)* and metabolic enzymes.** [L22 p54]

Atypical small bacteria: originally identified in searches for the causes of certain diseases. [L22 p54]

First observation: no bacteria seen in a Gram stain *(stain that sorts bacteria purple or pink)*; agent too small or does not stain. [L22 p54]

Not removed by 1 micron filters, so the size is under **1 um**. [L22 p54]

Some material was seen inside some host cells (obligate intracellular parasitism?). [L22 p54]

Some concluded the diseases must be caused by a virus. [L22 p54]

Later observations: the agent contained DNA *(cell genetic instruction molecule)*, RNA and protein. [L22 p54]

The agent also contained ribosomes and metabolic enzymes. [L22 p54]

1. Rickettsia

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

⚠ **Do not mix up: Rickettsia are ENERGY PARASITES: they lack glycolysis and steal ATP *(cell energy molecule)* with a translocase.** [L22 p55]

Rickettsia size: **0.3** x **1 um**. [L22 p55]

Rickettsia genome: about **1,000** kB, about **830** genes. [L22 p55]

Multiplication only inside host cells. [L22 p55]

Gram-negative *(thin wall plus outer membrane)* **morphology**, but they stain poorly. [L22 p55]

Energy parasites: lack full metabolic systems (no glycolysis, no biosynthetic pathways). [L22 p55]

They will steal ATP if available, using a translocase transporter *(protein that carries molecules across)*. [L22 p55]

Gimenez stain of tick hemolymph: host cells packed with small red-stained rods. [L22 p55]

Infection: phagocytosis *(immune cells eating germs)* is induced; the bacterium escapes from the phagosome. [L22 p55]

Exit: lysis (R. prowazekii), filopodium focal lysis (R. rickettsii) or budding (R. tsutsugamushi). [L22 p55]

2. Chlamydia

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

⚠ **Do not mix up: EB is the DORMANT *(inactive, not growing)*, infectious form outside cells; RB is the GROWING form inside.** [L22 p56]

Chlamydia EB form: **only 0.3 um**. [L22 p56]

Chlamydia genome: **1,000** kB, about **900** genes. [L22 p56]

Multiplication only inside host cells: an obligate intracellular parasite. [L22 p56]

Two forms: RB *(reticulate body)* and EB *(elementary body)*. [L22 p56]

RB: the growing form, inside the cell. [L22 p56]

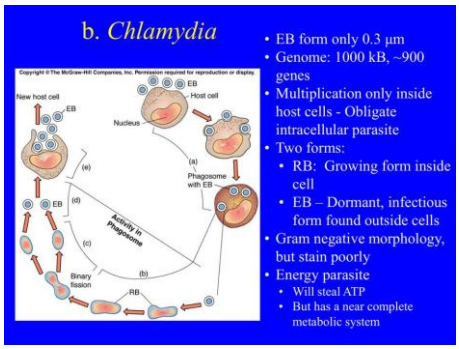
EB: the dormant, infectious form, found outside cells. [L22 p56]

Gram negative *(thin wall plus outer membrane)* **morphology**, but they stain poorly. [L22 p56]

Energy parasite: will steal ATP *(cell energy molecule)*, but has a near complete metabolic system. [L22 p56]

Cycle: EB attach and enter; EB become RB; RB divide by binary fission. [L22 p56]

Then RB turn back into EB, which are released to a new host cell. [L22 p56]



Chlamydia cycle: EB enter, become RB, divide, turn back into EB and leave [L22 p56]

3. Endosymbiotic bacteria

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

⚠ **Do not mix up: Endosymbionts have the SMALLEST bacterial genomes, yet still have their own DNA *(cell genetic instruction molecule)* and ribosomes *(protein building machine)*.** [L22 p57]

Endosymbiotic bacteria live inside cells or a body part of another organism. [L22 p57]

Some are obligate endosymbionts. [L22 p57]

Genome: as small as **150** kB, **182** genes, the smallest bacterial genomes. [L22 p57]

They have their own DNA, ribosomes and some metabolic enzymes. [L22 p57]

They grow independently by dividing. [L22 p57]

Mitochondria and chloroplasts

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

Mitochondria and chloroplasts *(plant part that does photosynthesis)*: obligate intracellular symbionts. [L22 p58]

Mitochondria genome: **6** to **300** kB, **30** to **60** genes. [L22 p58]

Chloroplast genome: **70** to **200** kB, about **120** genes. [L22 p58]

They grow independently by dividing and fusion. [L22 p58]

They synthesize their own DNA *(cell genetic instruction molecule)*, RNA, ribosomes *(protein building machine)*, tRNA *(adapter that carries amino acids)* and some metabolic enzymes. [L22 p58]

They generate ATP *(cell energy molecule)* **for their own use** but get many metabolites *(small working molecules of the cell)* from the host cell. [L22 p58]

Hypothesis: mitochondria came from an ancestor of Rickettsia; chloroplasts from a cyanobacterium. [L22 p58]

4. Giant viruses

Book: 6.3 Viral Genomes and Classification, Viral Genomes: Small or Large (chapter 6 PDF, p. 47).

⚠ **Do not mix up: Typical viruses have DNA *(cell genetic instruction molecule)* or RNA but NOT both; some giant viruses contain both.** [L22 p09, L22 p59]

Giant viruses: size over **0.15 um**. [L22 p59]

Giant virus genome: **100** to **1,000** kB, **100** to **1,100** genes. [L22 p59]

Some contain both DNA and RNA. [L22 p59]

Some produce enzymes involved in translation. [L22 p59]

Some can be infected by viruses. [L22 p59]

Giant viruses have been proposed as a fourth domain of life. [L22 p59]

Genome size: Mimivirus (about **1.2** million bp) is larger than Rickettsia, Chlamydia and Mycoplasma. [L22 p59]

Which would you consider a living organism?

Book: Not in Chapter 6; his outline marks this part "(notes)": study the slides.

Living or not: weigh each on reproducing by itself, ribosomes *(protein building machine)*, metabolism and genome size. [L22 p60]

Viruses have no ribosomes and are assembled from parts, not by splitting. [L22 p37, L22 p52]

Typical and atypical bacteria and viruses compared

Organism	How it reproduces	What it has	Genome
Typical bacteria	By itself; free-living	Ribosomes; independent biosynthesis	**500** to **10,000** kB
Rickettsia	Only inside host cells	DNA, RNA, ribosomes; lacks glycolysis, steals ATP	About **1,000** kB, **830** genes
Chlamydia	Only inside host cells; RB divide by binary fission	Near complete metabolic system; steals ATP	**1,000** kB, about **900** genes
Endosymbiotic bacteria	Grow independently by dividing	Own DNA, ribosomes, some metabolic enzymes	As small as **150** kB, **182** genes
Mitochondria and chloroplasts	Grow by dividing and fusion inside host cells	Own DNA, RNA, ribosomes; many metabolites from the host	**6** to **300** kB; **70** to **200** kB
Giant viruses	Viruses: no activity outside host cells	Some have DNA and RNA; some make translation enzymes	**100** to **1,000** kB
Typical viruses	Only inside cells; assembled from parts	No ribosomes; no metabolism outside host cells	**1.8** to **100** kB, **1** to **100 proteins**

Table source: [L22 p52, L22 p53, L22 p55, L22 p56, L22 p57, L22 p58, L22 p59, L22 p60]