# Pathogenesis of Plant Virus
# MIC 204
# (MSc Microbiology Semester II)

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# Plant Virus Diseases and Symptoms


https://www.bighaat.com/blogs/kb/viral-diseases-in-plants-and-its-control

# Virus taxonomy and nomenclature

- Modified binomial is used
- Taxonomy depends on particle properties, nucleic acid properties and especially sequence
- Family is the highest taxonomic level that is commonly used; ends in *viridae*, e.g., *Bromoviridae*
- Genus ends in suffix *virus*, e.g., *Bromomovirus*
- Species is usually the commonly used virus name; it is italicized in formal usage, e.g., *Brome mosaic virus*
- Small genome sizes, gene shuffling make broad taxonomic schemes difficult (above Family level)

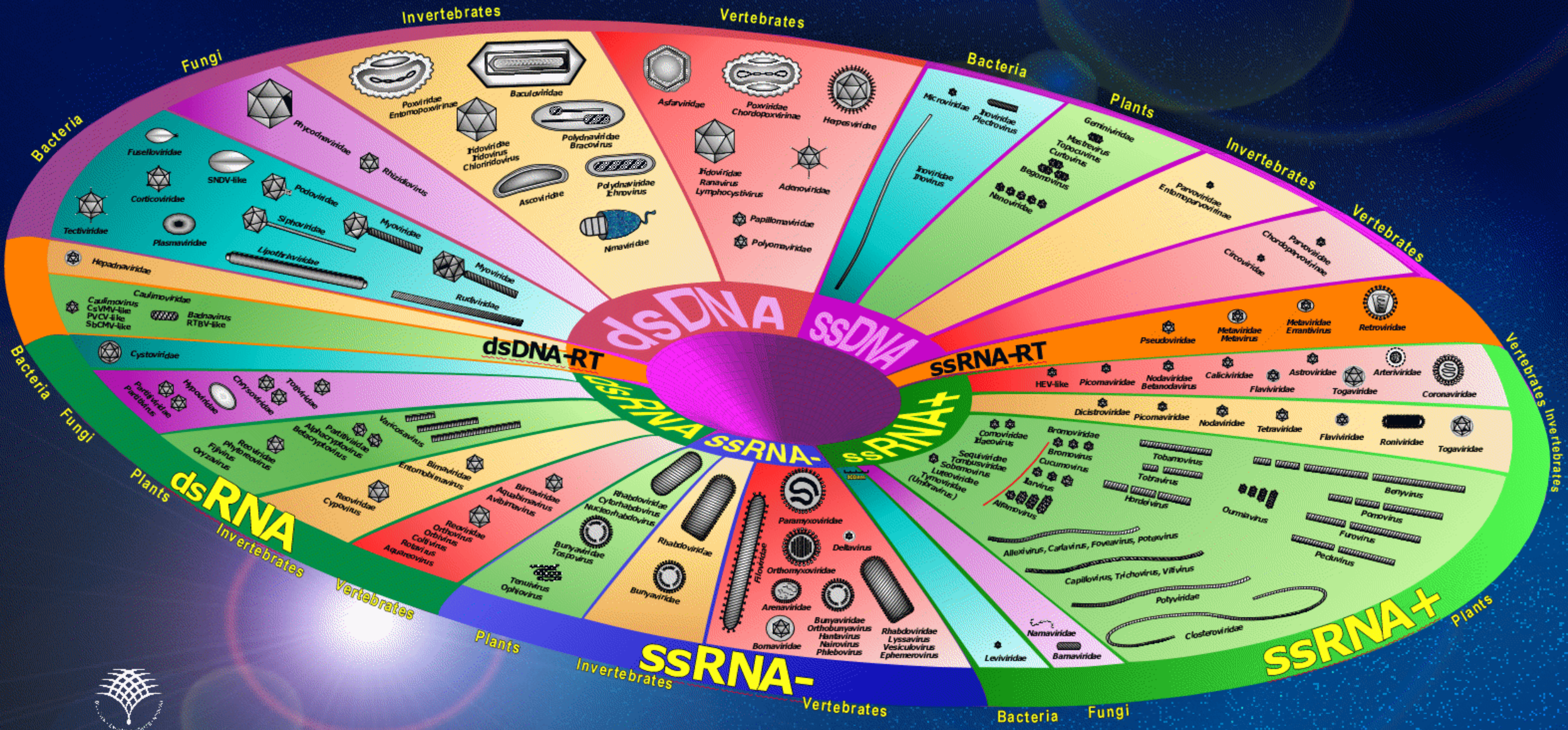
# Virus properties: Plant viruses are often simpler than animal viruses

- Genome sizes 0.3 - 300 kb; plant viruses 0.3-30 kb
- May have single-stranded or double-stranded RNA or DNA genome; most plant viruses ssRNA
- If RNA, may be + or – sense; most plant viruses + sense ssRNA
- May have one or many proteins in particles; most plant viruses have 1-2
- May or may not have lipid envelope; most plant viruses do not

# Types of plant virus genomes

- double-stranded (ds) DNA (rare)
- single-stranded (ss) DNA (rare)
- ssRNA, negative sense (rare)
- ssRNA, positive sense (common)
- dsRNA (rare)

# Virosphere 2002




DONALD DANFORTH
PLANT SCIENCE CENTER



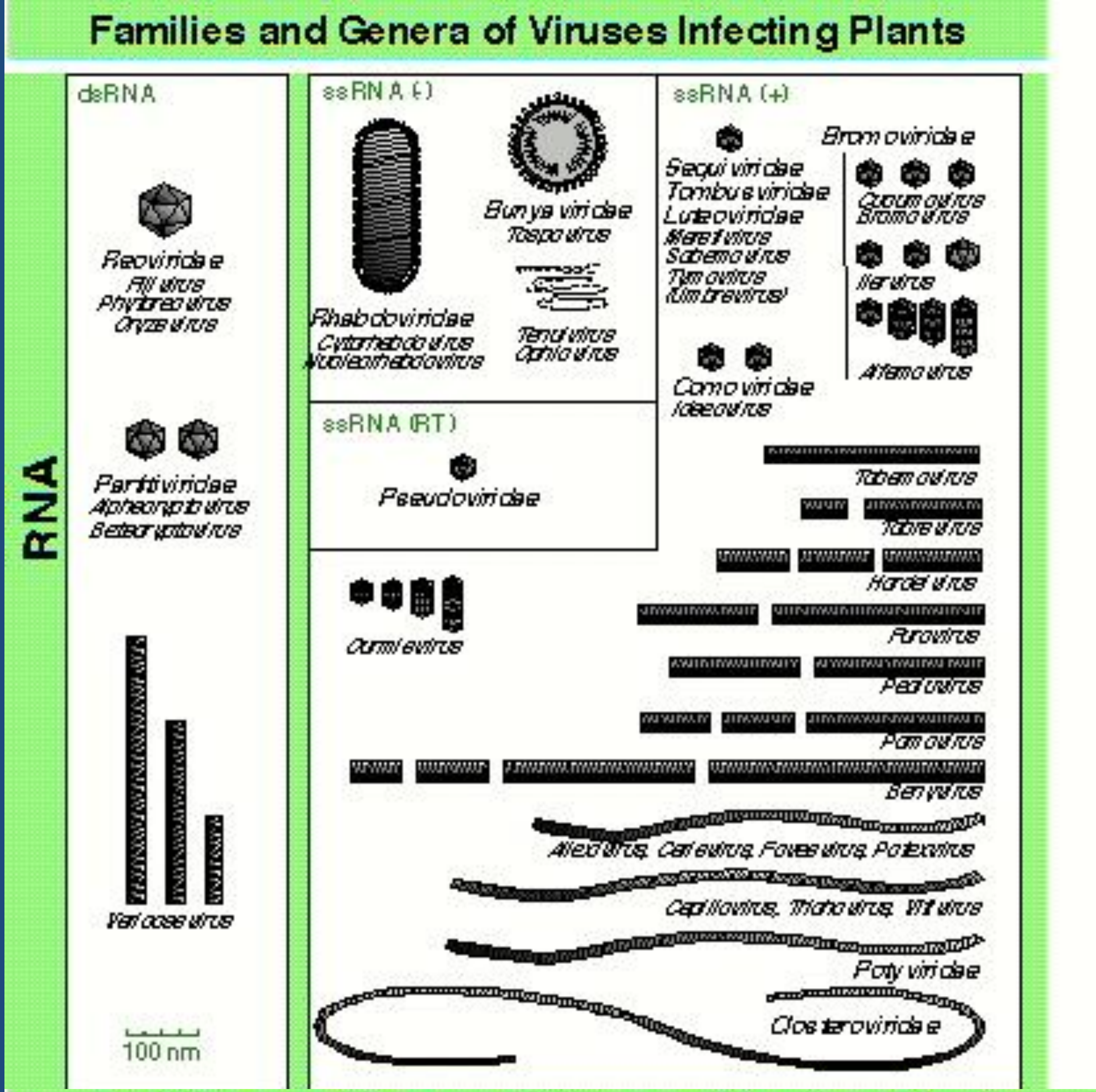
# International Committee on Taxonomy of Viruses

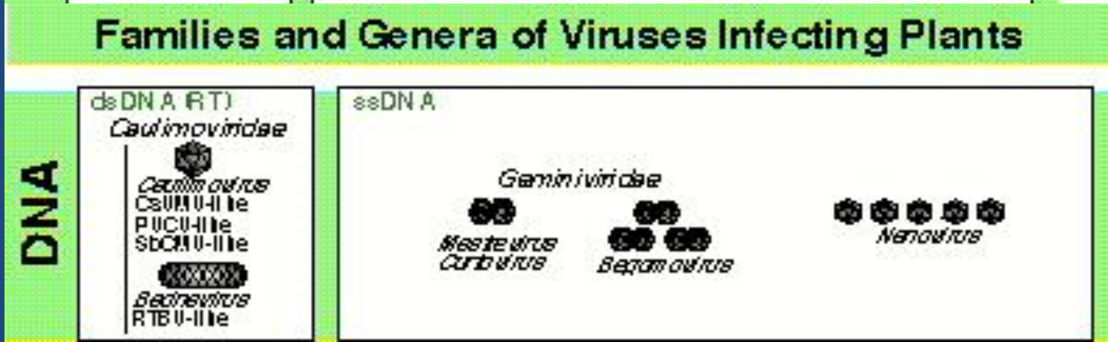
# Virus types, by nucleic acid

| | DNA | | | | RNA | | | |
|---|---|---|---|---|---|---|---|---|
| | ss | | ds | | ss | | ds | |
| | env | naked | env | naked | env | naked | env | naked |
| Families | 0 | 5 | 9 | 12 | 9 | 14 | 2 | 5 |
| Species | 0 | 100 | 200 | 300 | 200 | 600 | 10 | 300 |
| **Host type** | | | | | | | | |
| Vertebrate | - | + | ++ | ++ | ++ | ++ | - | ++ |
| Invertebrate | - | + | ++ | - | ++ | ++ | - | ++ |
| **Plant** | **-** | **++** | **-** | **+** | **+** | **+++** | **-** | **+** |
| Fungus | - | - | - | + | + | + | + | +++ |
| Bacteria | - | + | + | +++ | - | + | + | - |

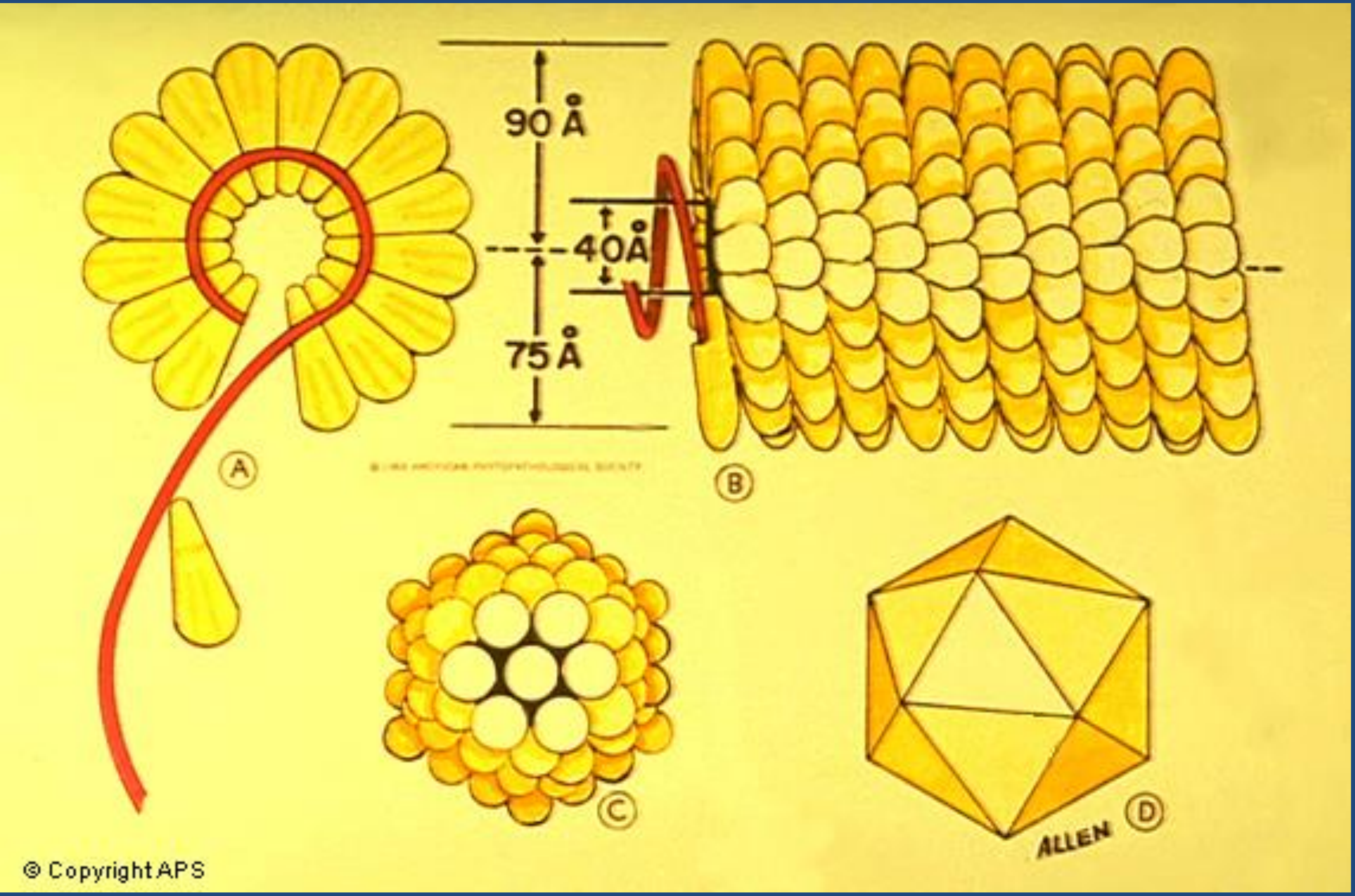
Plant viruses are diverse, but not as diverse as animal viruses – probably because of size constraints imposed by requirement to move cell-to-cell through plasmodesmata of host plants

Plant viruses often contain divided genomes spread among several particles



# Basic Plant Virus Structures

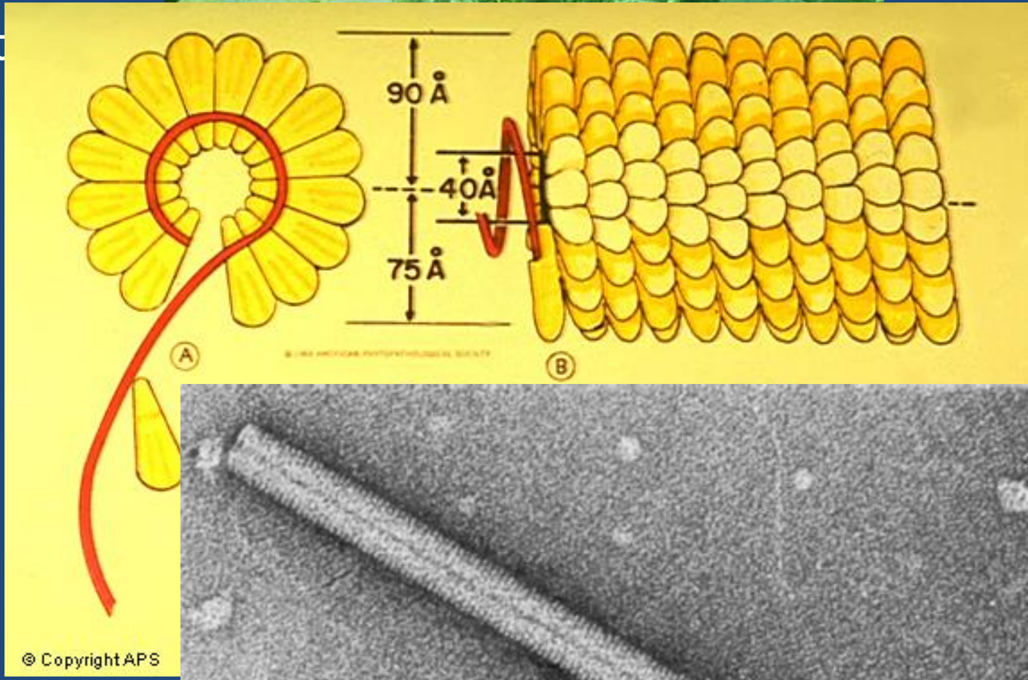


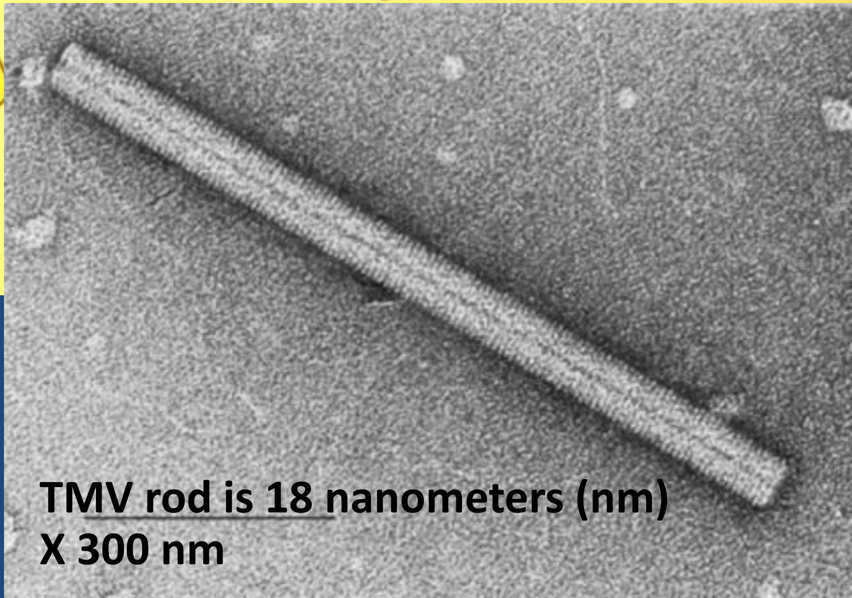

Helix (rod)
e.g., **TMV**

Icosahedron
(sphere)
e.g., **BMV**

# Helical symmetry

- ***Tobacco mosaic virus*** is typical, well-studied example
- Each particle contains only a single molecule of RNA (6395 nucleotide residues) and 2130 copies of the coat protein subunit (158 amino acid residues; 17.3 kilodaltons)
  - 3 nt/subunit
  - 16.33 subunits/turn
  - 49 subunits/3 turns
- TMV protein subunits + nucleic acid will self-assemble *in vitro* in an energy-independent fashion
- Self-assembly also occurs in the absence of RNA

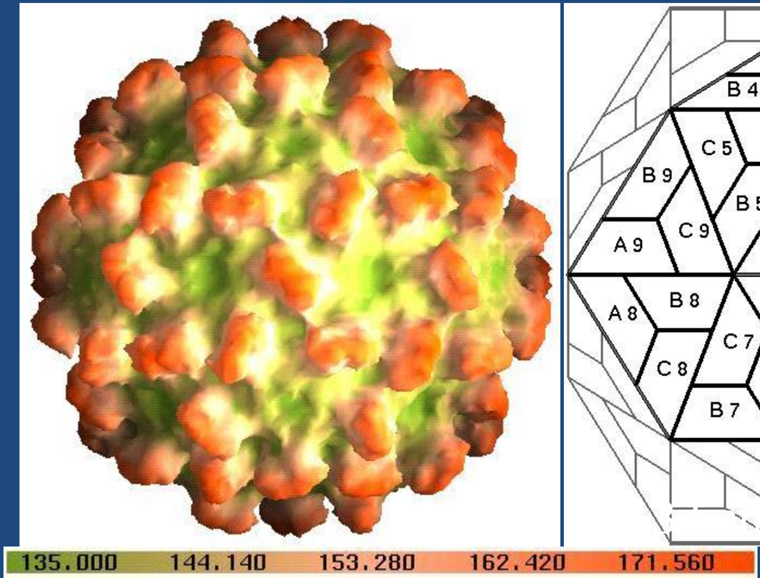



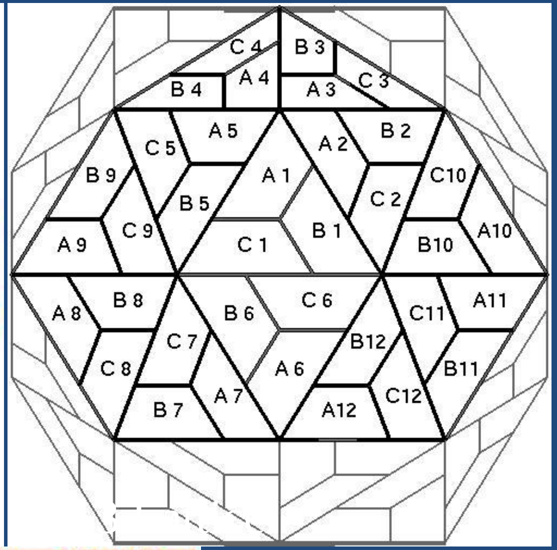



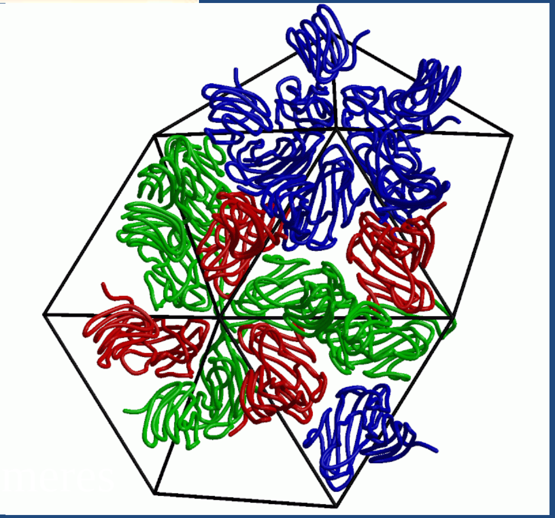
# Cubic (icosahedral) symmetry

**TBSV icosahedron is 35.4 nm in diameter**

- ***Tomato bushy stunt virus*** is typical, well-studied example
- Each particle contains only a single molecule of RNA (4800 nt) and 180 copies of the coat protein subunit (387 aa; 41 kd)
- Viruses similar to TBSV will self-assemble *in vitro* from protein subunits + nucleic acid in an energy-independent fashion



# GENOME ORGANIZATIONS

# Plant virus genome organizations

- Very compact
- Most are +sense RNA viruses, so translation regulation very important
- Use various strategies for genome expression
- Only a few genes absolutely required:
  - Replicase
  - Coat protein
  - Cell-to-cell movement protein
- Other genes present in some viruses

# Genome expression of + strand RNA viruses

- Most use more than one strategy
  - Polyprotein processing
  - Subgenomic RNA
  - Segmented genome
  - Translational readthrough
  - Frameshift
  - Internal initiation of translation (without scanning)
  - Scanning to alternative start site (truncated product)
  - Alternative reading frame (gene-within-a-gene)

# Polyprotein processing

- Post-translational cleavage of viral proteins may occur *in cis* or *in trans*
- Some viruses use polyprotein processing exclusively to regulate gene expression
- Many viruses use polyprotein processing as one of several regulation mechanisms
- Examples:
  - Potyviruses*
  - Comoviruses*
  - Closteroviruses
  - Carlaviruses

# Subgenomic RNA

- Similar to traditional mRNA, but synthesized from an RNA template
- Many viruses use polyprotein processing as one of several regulation mechanisms
- Examples:
  - Tobamoviruses (TMV)*
  - Bromoviruses (BMV)*
  - Tombusviruses (TBSV)
  - Potexviruses (PVX)

# Segmented genome

- Positive sense RNA genomes are usually encapsidated in separate particles
- Segmented genomes lend themselves to recombination
- Examples:
  - Bromoviruses (*Brome mosaic virus*, BMV)*
  - Dianthoviruses (*Red clover necrotic mosaic virus*, RCNMV)*
  - Hordeiviruses (*Barley stripe mosaic virus,* BSMV)

# Translational readthrough

- Usually UAG codon is read through using suppressor tyrosine tRNA
- Common mechanism in plant viruses
- Examples:
  - Tobamoviruses (*Tobacco mosaic virus*, TMV)*
  - Dianthoviruses (*Red clover necrotic mosaic virus*, RCNMV)*
  - Hordeiviruses (*Barley stripe mosaic virus,* BSMV)

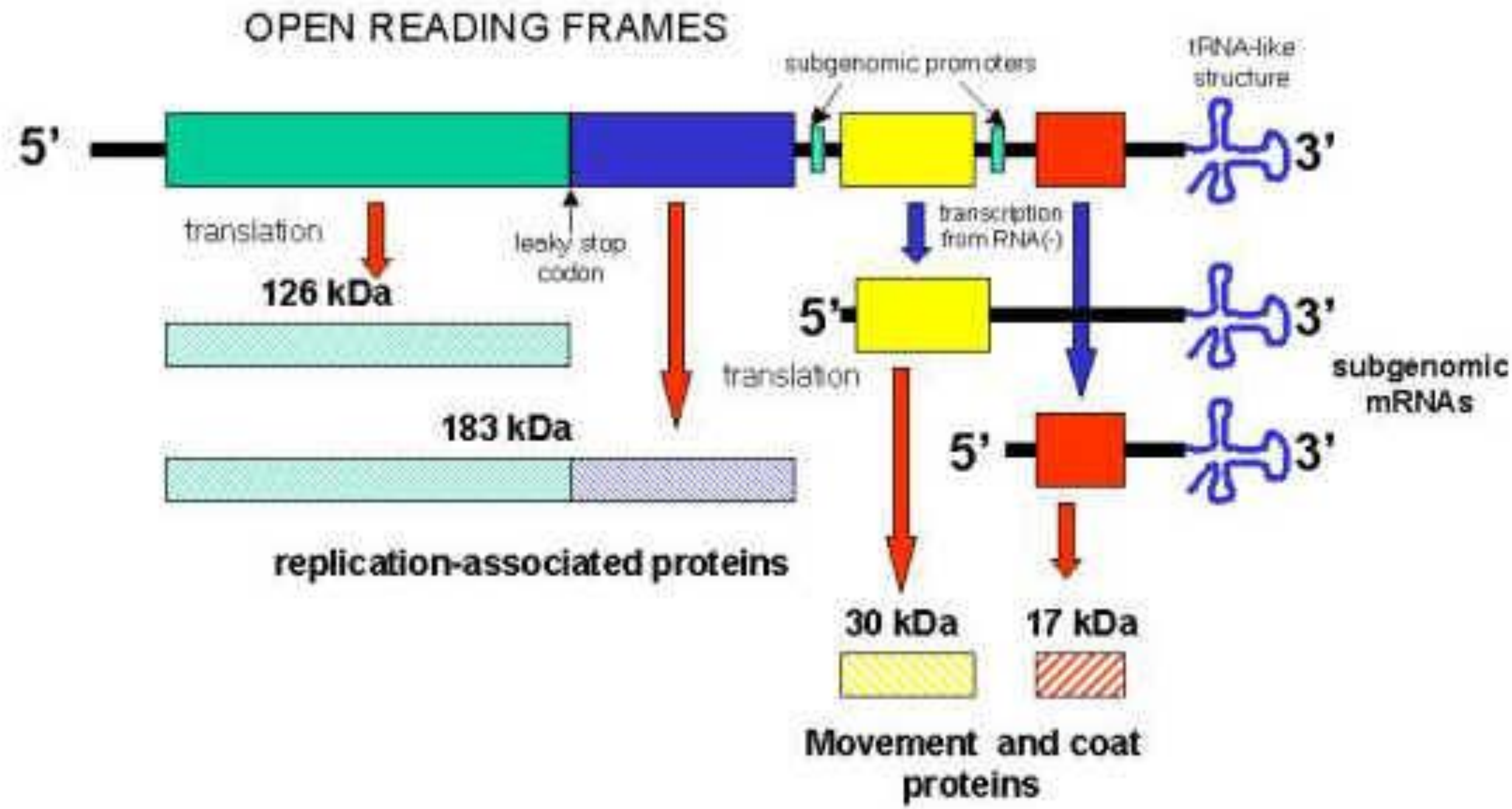
# Translational frameshift

- Typically +1 or -1
- Common mechanism in plant viruses
- Examples:
  - Luteoviruses (Barley yellow dwarf *virus*, BYBV)*
  - Dianthoviruses (*Red clover necrotic mosaic virus*, RCNMV)*
  - Closteroviruses (*Beet yellow vein virus,* BYVV)

# Internal initiation

- Cap-free translation
- Less complex in plant viruses than in animal viruses
- Examples:
  - Potyviruses (*Tobacco etch virus*, TEV)*
  - Sobemoviruses (*Southern bean mosaic virus*, (SBMV)*

# *Tobacco mosaic virus* is a typical positive-sense RNA plant virus with a 6.4 kilobase genome



# INFECTION CYCLE

# Plant Virus Life Cycle

- Virus entry into host
  - no attachment step with plant viruses
  - by vector, mechanical, etc. – must be forced
  - requires healable wound – delivery into cell
- Uncoating of viral nucleic acid
  - may be co-translational for + sense RNA viruses
  - poorly understood for many
- Replication
  - replication is a complex, multistep process
  - viruses encode their own replication enzymes

# Plant Virus Life Cycle 2

- Cell-to-cell movement
  - cell-to-cell movement through plasmodesmata
  - move as whole particles or as protein/nucleic acid complex (no coat protein required)
- Long distance movement in plant
  - through phloem
  - as particles or protein/nucleic acid complex (coat protein required)
- Transmission from plant to plant
  - requires whole particles

# Typical RNA-containing plant virus replication cycle

1. Virus particle enters first cell through <u>healable wound</u>

2. RNA is released; translates using host machinery

3. Replication in cytoplasm

4a. Infectious TMV RNA is shuttled to adjacent cell through plasmodesmata, by virus-coded movement protein

4b. New virus particles are assembled

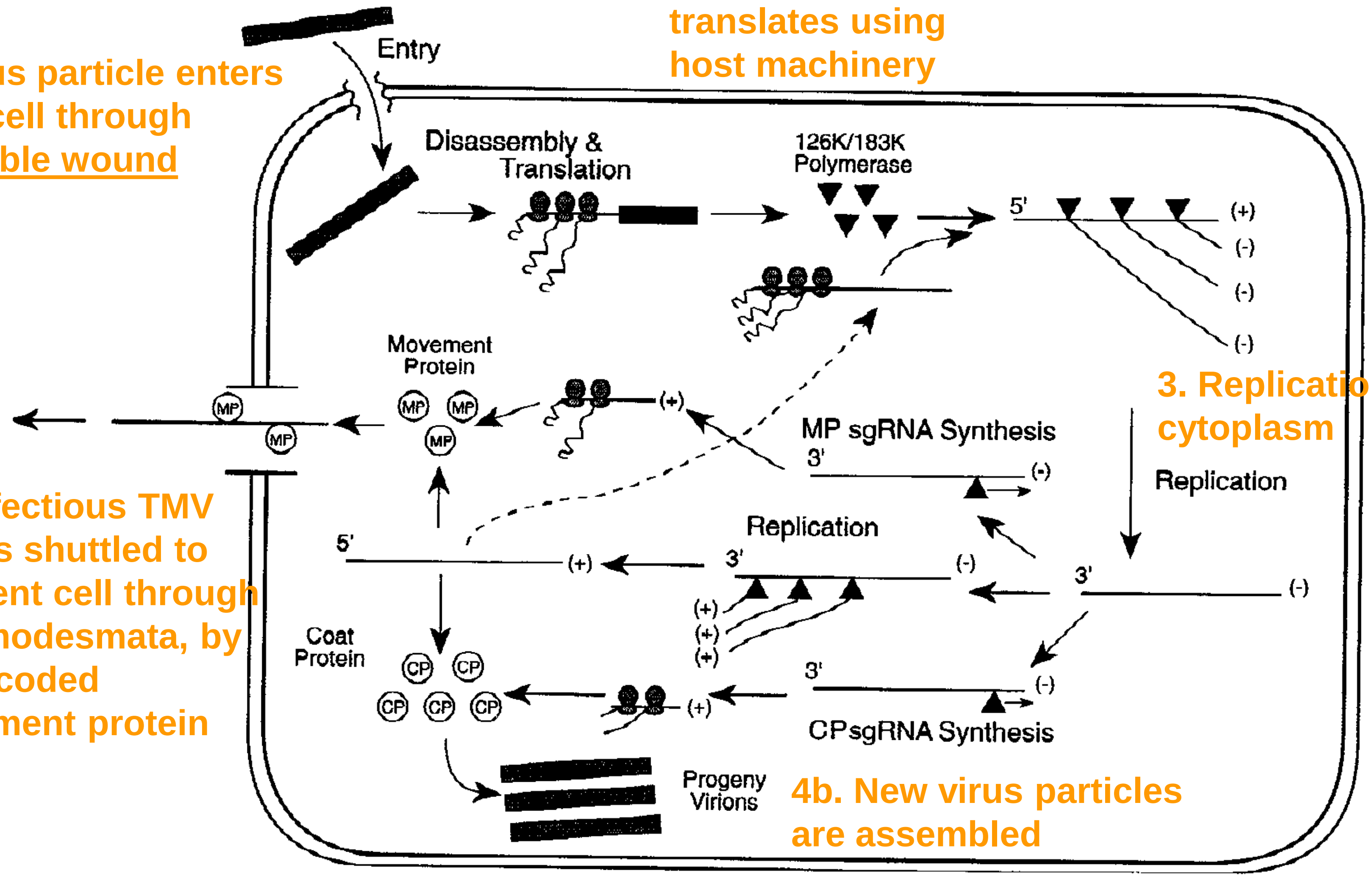



**FIG. 8.** Diagram of stages in TMV infections. All the events shown are presumed to occur in the cytoplasm of infected cells.

From Shaw, 1996 Ch. 12 in Fundamental Virology (Academic Press)

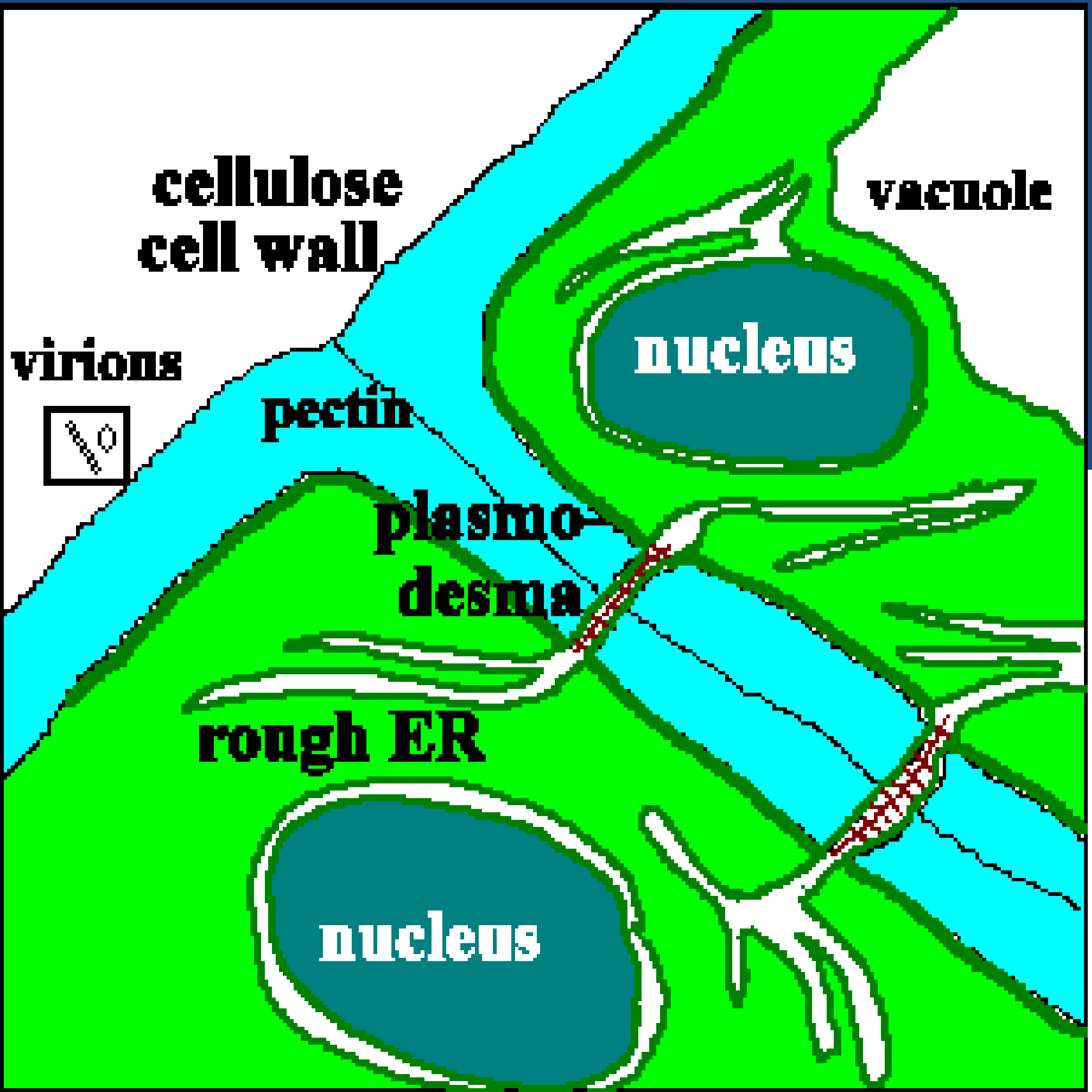
# Cell-to-Cell Movement of Plant Viruses

- Plant viruses move cell-to-cell slowly through plasmodesmata
- Most plant viruses move cell-to-cell as complexes of non-structural protein and genomic RNA
- The viral protein that facilitates movement is called the "movement protein" (MP)
- Coat protein is often dispensable for cell-to-cell movement

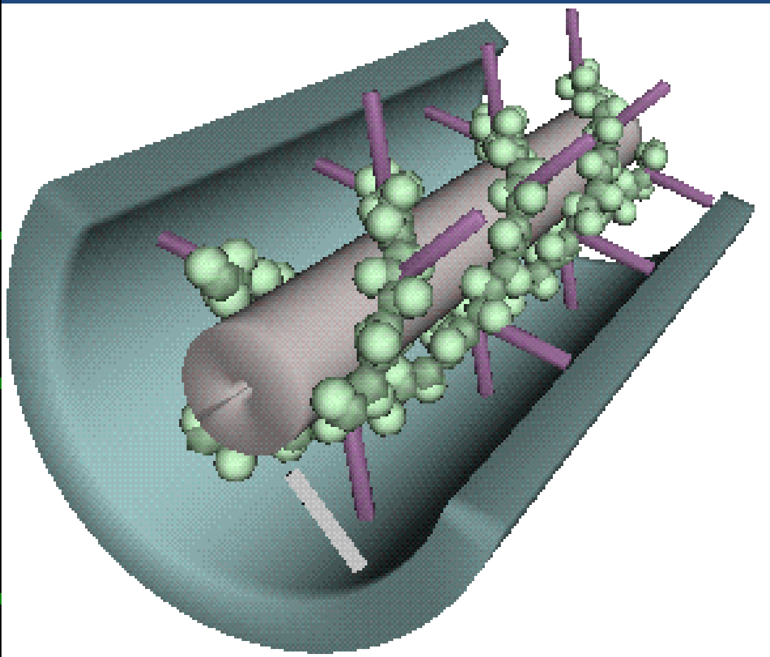
# Cell-to-Cell Movement of Plant Viruses

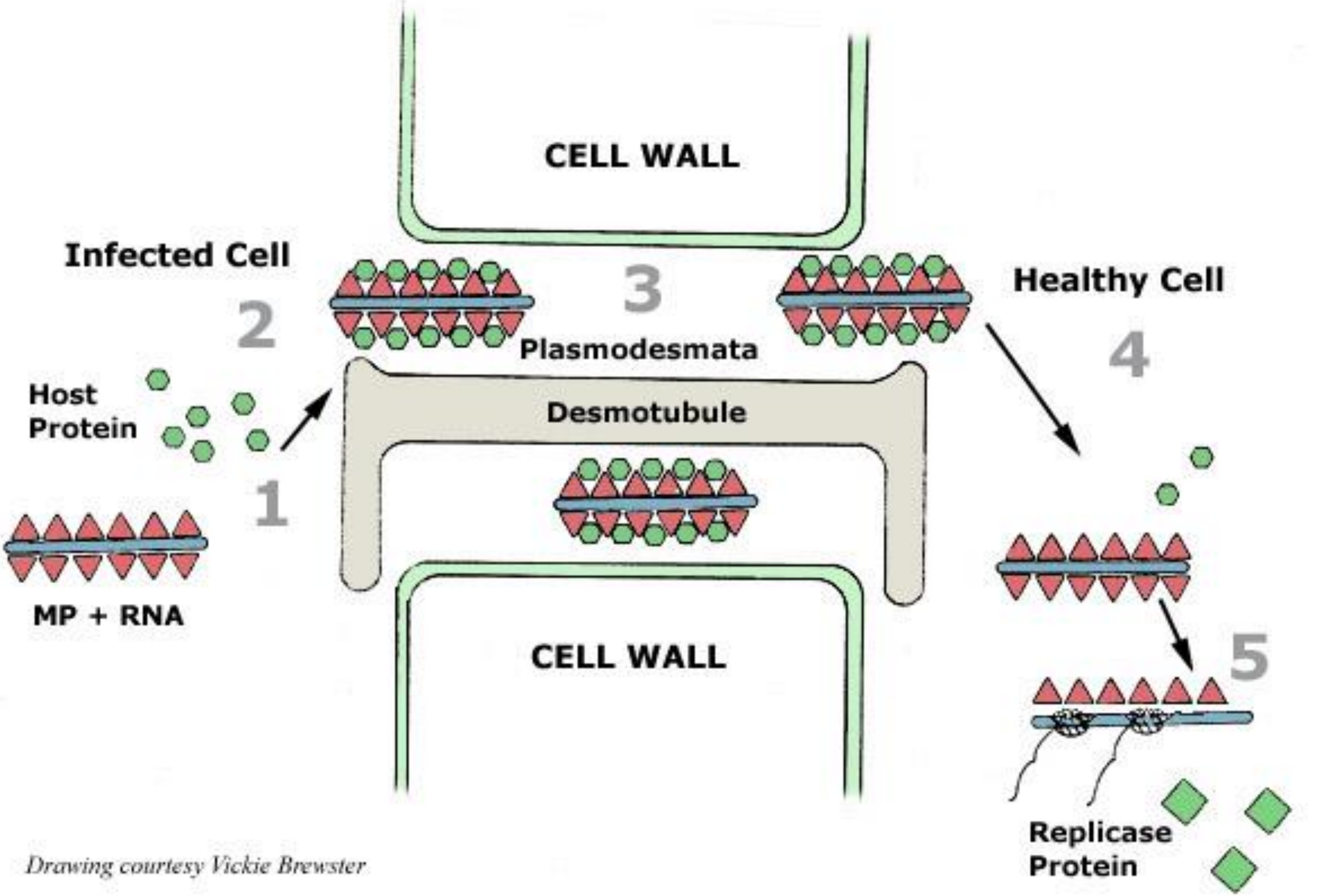
- Several unrelated lineages of MP proteins have been described
- MPs act as host range determinants
- MP alone causes expansion of normally constricted plasmodesmata pores; MPs then traffic through rapidly
- MPs are homologs of proteins that naturally traffic mRNAs between cells
- MPs may act as suppressors of gene silencing

**Plant cells are bound by rigid cell walls and are interconnected by plasmodesmata, which are too small to allow passage of whole virus particles.**




Plasmodesma




CELL WALL
Infected Cell
2
3
Healthy Cell
Plasmodesmata
4
Host
Protein
Desmotubule
1
MP + RNA
CELL WALL
5
Replicase
Protein
Drawing courtesy Vickie Brewster

Systemic spread of plant viruses is primarily through vascular tissue, especially phloem