Tikrit University/ Science College/ Biology Department

Forth class/ Microbiology / Virology

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Lecture 2

● Structure of Viruses:

A complete virus particle is called a **virion**. Virion morphology has been intensely studied over the past decades because of the importance of viruses and the realization that virion structure is simple enough to be understood in detail. Progress has come from the use of several different techniques: electron microscopy, X-ray diffraction, biochemical analysis, and immunology. Although our knowledge is incomplete due to the large number of different viruses, we can discuss the general nature of virion structure.

●General Structural Properties:

Virions range in size from about 10 to 400 nm in diameter. The smallest are a little larger than ribosomes, whereas mimiviruses, the largest viruses known, have virions larger than some of the smallest bacteria and can be seen in the light microscope. However, most virus particles must be viewed with electron microscopes.

The simplest virions consist only of a **nucleocapsid**, which is composed of a nucleic acid, either DNA or RNA, and a protein coat called a **capsid**. The capsid surrounds the viral nucleic acid, protects the viral genome, and often aids in its transfer between host cells. Among the proteins encoded by the viral genome are the capsid proteins, which are called

protomers. Capsids self-assemble by a process that is not fully understood. Some viruses use noncapsid proteins as scaffolding upon which the capsids are assembled. Probably the most important advantage of this design strategy is that the viral genome is used with maximum efficiency.

The various morphological types of virions primarily result from the combination of a particular type of capsid symmetry with the presence or absence of an envelope—a lipid layer external to the nucleocapsid. There are three types of capsid symmetry: helical, icosahedral, and complex. Viruses with virions having an envelope are called **enveloped viruses**, whereas those lacking an envelope are called **nonenveloped** or **naked viruses**.

●**Helical Capsids**:

Helical capsids are shaped like hollow tubes with protein walls. Tobacco mosaic virus is a well-studied example of helical capsid structure. The self-assembly of TMV protomers into a helical arrangement produces a rigid tube. The capsid encloses an RNA genome, which is wound in a spiral and lies within a groove formed by the protein subunits. Not all helical capsids are as rigid as the TMV capsid. The nucleocapsids of influenza viruses are thin and flexible and are enclosed within an envelope.

The size of a helical capsid is influenced by both its protomers and the viral genome. The diameter of the capsid is a function of the size, shape, and interactions of the protomers. The length of the capsid appears to be determined by the nucleic acid because a helical capsid does not extend much beyond the end of the viral genome.

●**Icosahedral Capsids:**

An icosahedron is a regular polyhedron with 20 equilateral triangular faces and 12 vertices. **Icosahedral capsids** are the most efficient way to enclose a space. They are constructed from ring- or knob-shaped assemblages of five or six protomers; the assemblages are called **capsomers**. Capsomers composed of five protomers are called pentamers (pentons); hexamers (hexons) are capsomers that possess six protomers. Pentamers are usually at the vertices of the icosahedron, whereas hexamers generally form its edges and triangular faces.

●**Capsids of Complex Symmetry**:

Most viruses have either icosahedral or helical capsids, but some viruses do not fit into either category. Poxviruses and large bacteriophages are two important examples.

Poxvirus virions are among the largest of the animal viruses (about 400 by 240 by 200 nm in size) and can be seen with a light microscope. They possess an exceptionally complex internal structure with an ovoid- to brick-shaped exterior. Vaccinia virus consist of doublestranded DNA genome is associated with proteins and contained in the core, a central structure shaped like a biconcave disk and surrounded by a membrane. Two lateral bodies lie between the core and the virion's outer envelope.

Some large bacteriophages have virions that are even more elaborate than those of poxviruses. The virions of T2, T4, and T6 phages (T-even phages) that infect Escherichia coli are said to have **binal symmetry**

because they have a head that resembles an icosahedron and a tail that is helical. The icosahedral head is elongated by one or two rows of hexamers in the middle and contains the DNA genome. The tail is composed of a collar joining it to the head, a central hollow tube, a sheath surrounding the tube, and a complex baseplate. In T-even phages, the baseplate is hexagonal and has a pin and a jointed tail fiber at each corner.

●Viral Envelopes and Enzymes:

The nucleocapsids of many animal viruses, some plant viruses, and at least one bacterial virus are surrounded by an outer membranous layer called an **envelope**. Animal virus envelopes usually arise from the plasma or nuclear membranes of the host cell. Envelope lipids and carbohydrates are therefore acquired from the host. In contrast, envelope proteins are coded for by viral genes and may even project from the envelope surface as spikes, which are also called **peplomers**. In many cases, spikes are involved in virion attachment to the host cell surface. Because spikes differ among viruses, they also can be used to identify some viruses. Many enveloped viruses have virions with a somewhat variable shape and are called pleomorphic. However, the envelopes of viruses such as the bulletshaped rabies viruses are firmly attached to the underlying nucleocapsid and endow the virion with a constant, characteristic shape. Influenza virus is a well-studied enveloped virus with two types of spikes. Some spikes consist of the enzyme neuraminidase, which functions in the release of mature virions from the host cell. Other spikes are hemagglutinin proteins. Influenza virus's hemagglutinins participate in virion attachment to host cells. Most of its envelope proteins are glycoproteins— proteins that have carbohydrate attached to them. A nonglycosylated protein, the M (matrix) protein, is

found on the inner surface of the envelope and helps stabilize it. In addition to enzymes associated with the envelope or capsid (e.g., influenza neuraminidase), some viruses have enzymes within their capsids. Such enzymes are usually involved in nucleic acid replication. For example, influenza virus virions have an RNA genome and carry an enzyme that synthesizes RNA using an RNA template. Thus, although viruses lack true metabolism and cannot reproduce independently of living cells, their virions may carry one or more enzymes essential to the completion of their life cycles.

●Viral Genomes Are Structurally Diverse:

One clear distinction between cellular organisms and viruses is the nature of their genomes. Cellular genomes are always doublestranded (ds) DNA. Viruses, on the other hand, employ all four possible nucleic acid types: dsDNA, single-stranded (ss) DNA, ssRNA, and dsRNA. All four types are used by animal viruses. Most plant viruses have ssRNA genomes, and most bacterial viruses have dsDNA. The size of viral genomes also varies greatly. Very small genomes are around 4,000 nucleotides—just large enough to code for three or four proteins. Some viruses save additional space by using overlapping genes. At the other extreme are the genomes of mimiviruses, which infect protists. They are about $1.2 \times 10_6$ nucleotides long, rivaling some bacteria and archaea in coding capacity.

Most DNA viruses use dsDNA as their genetic material. However, some have ssDNA genomes. In both cases, the genomes may be either linear or circular. Some DNA genomes can switch from one form to the other. For

instance, the *E. coli* phage lambda has a linear genome in its capsid, but it becomes circular once it enters the host cell.

Relatively few RNA viruses have dsRNA genomes. More common are viruses with ssRNA genomes. Polio, tobacco mosaic, SARS, rabies, mumps, measles, influenza, human immunodeficiency, and brome mosaic viruses are all ssRNA viruses.

Some RNA viruses have segmented genomes—genomes that consist of more than one piece (segment) of RNA. In many cases, each segment codes for one protein and there may be as many as 10 to 12 segments. Usually, all segments are enclosed in the same capsid; however, this is not always the case. For example, the genome of brome mosaic virus, a virus that infects certain grasses, is composed of three segments distributed among three different virions.

●Evolutionary origin of Viruses:

The origin of viruses is not known. There are profound differences among the DNA viruses, the RNA viruses, and viruses that use both DNA and RNA as their genetic material during different stages of their life cycle. It is possible that different types of agents are of different origins. Two theories of viral origin can be summarized as follows:

1. Viruses may be derived from DNA or RNA nucleic acid components of host cells that became able to replicate autonomously and evolve independently. They resemble genes that have acquired the capacity to exist independently of the cell. Some viral sequences are related to portions of cellular genes encoding protein functional domains. It seems likely that at least some viruses evolved in this fashion.

2. Viruses may be degenerate forms of intracellular parasites. There is no evidence that viruses evolved from bacteria, although other obligately intracellular organisms (eg, rickettsiae and chlamydiae) presumably did so. However, poxviruses are so large and complex that they might represent evolutionary products of some cellular ancestor.

Definition statement:

●**Capsid**: The protein shell, or coat, that encloses the nucleic acid genome.
●**Capsomeres**: Morphologic units seen in the electron microscope on the surface of icosahedral virus particles. Capsomeres represent clusters of polypeptides, but the morphologic units do not necessarily correspond to the chemically defined structural units.

● **Envelope**: A lipid-containing membrane that surrounds some virus particles. It is acquired during viral maturation by a budding process through a cellular membrane. Virus encoded glycoproteins are exposed on the surface of the envelope. These projections are called **peplomers**.
●**Nucleocapsid**: The protein–nucleic acid complex representing the packaged form of the viral genome. The term is commonly used in cases in which the nucleocapsid is a substructure of a more complex virus particle.
●**Structural units**: The basic protein building blocks of the coat. They are usually a collection of more than one nonidentical protein subunit. The structural unit is often referred to as a protomer.

●**Virion:** The complete virus particle. In some instances (eg,papillomaviruses, picornaviruses), the virion is identical with the nucleocapsid. In more complex virions (herpesviruses, orthomyxoviruses), this includes the nucleocapsid plus a surrounding envelope. This structure, the virion, serves to transfer the viral nucleic acid from one cell to another.