Virus Classification

 Acacia White Virology 4308

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# Virus Classification:

Animal viruses are classified according to their morphology, the specific host species, the nature of the disease, viral nucleic acids (DNA vs RNA), and the basis of taxonomy. There are approximately 26 different families, which can further be classified as DNA, RNA or reverse-transcribing viruses. DNA virus families include: *Poxviridae, Asfarviridae, Herpesviridae, Adenoviridae, Papovaviridae, Parvoviridae, and Circoviridae.*

*Poxviridae* genome consists of a linear double stranded molecule of over 100 genes, including DNA dependent RNA transcriptase. Surface tubules coat the somewhat rounded, brick-shaped, or ovoid nucleocapsid envelope. With both an outer and core envelope holding core fibrils inside the dumbbell-shaped core. Poxviruses, have DNA genomes ranging within 130–230 kb. The virion’s lateral bodies contain various enzymes essential for virus replication. *Poxviridae* encodes for several different proteins including: DNA polymerase (Pol), helicase–primase, uracil DNA glycosylase, protein kinase, processivity factor, single-stranded DNA-binding protein, and DNA ligase. Poxvirus DNA synthesis can usually be detected within two hours after an infection, in the cytoplasm, within factories that can be visually analyzed using a fluorescent dye and these viruses have a low-fidelity DNA polymerase. Some diseases caused by this family of virus are: cowpox virus, monkey pox virus, and smallpox.

*Asfarviridae* viruses contain a linear, double stranded structure of DNA, with the genome ranging about 170-190 kb in size. This virions are enclosed in an icosahedral capsid (icosahedral symmetry correlating to adjacent capsomeres) inside an external lipid-containing envelope that makes this virus sensitive to chloroform and deoxycholate, and are inactivated at 60 °C after 30 minutes of exposure. Virions contain more than 50 different proteins including structural proteins: J5R (transmembrane protein), P72 (major capsid protein), and P32 (phosphoprotein) just to name a few. Other proteins encoded by the genome include ribonucleotide reductase, thymidine kinase, thymidylate kinase and deoxyuridine (enzymes involved in nucleotide metabolism). DNA replication and repair or transcription involve DNA polymerase, DNA polymerase X, DNA ligase, topoisomerase II, guanylyl transferase, three members of DNA helicase superfamily II, and AP endonuclease proteins coded by *Asfarviridae* (ASFV) viruses. ASFV infects ticks and swine but has not been reported to infect humans. The incubation period is 5 to 21 days after direct contact with infected pigs, which can be diagnosed by virus isolation, but it can be less than 5 days after exposure to ticks. Acute disease typically appears in 3 to 7 days. Many studies show low-fidelity values obtained for DNA polymerase Pol X in ASFV.

*Herpesviridae* viruses’ genome (~120-250 kb/ 150-200 nm in diameter) consists of a non-segmented, linear, double-stranded DNA molecule encoding for 70 to 200 genes. Herpesviruses consist of an envelope, tegument (between the envelope and the nucleocapsid), a round nucleoscapsid with icosahedral symmetry and core containing viral nucleic acids. Each viral transcript usually encodes a single protein and has a promoter/regulatory sequence, a TATA box, a transcription initiation site, a 5’ leader sequence of 30-300 bp (not translated), a 3’ non-translated sequence of 10-30 bp, and a poly A signal. Lytic replication is accomplished through the initial attachment of the viral proteins GB, GC, GD and GH to host receptors mediates endocytosis of the virus into the host cell. This virus has a low-fidelity for DNA polymerase. Some diseases associated with *Herpesviridae* are: encephalitis, chickenpox and herpes (1, 2, 3).

*Adenoviridae* viruses have a genome containing a non-segmented, linear double-stranded DNA (35-36kb) with terminally redundant sequences which have inverted terminal repetitions (ITR). The terminal protein (TP) is covalently attached to each end of the genome. The capsid diameter is about 90 nm. The capsid shell consists of 720 hexon subunits arranged as 240 trimers and 12 vertex penton capsomers each with a fiber protruding, with a non-enveloped capsid depicting pseudo T=25 icosahedral symmetry. To initiate replication viral fiber glycoproteins bind to host receptors to mediate the endocytosis of the virus into the host cell and fiber shedding. Diseases associated with this virus include mainly respiratory diseases, croup, and bronchitis, pneumonia, and also keratoconjunctivitis, cystitis and gastroenteritis.

*Papovaviridae* viruses are also known as HPV viruses, are double stranded circular DNA viruses, with non-enveloped isohedral capsids (72 capsomers) roughly 45-55 nm in diameter. The genome codes for 3 structural proteins (VP1-3) and 3 nonstructural proteins (small, middle and large T antigens). During the lytic cycle the “minichromsomes” or the mass of cellular histones H2A, H2B, H3 and H4 are used as templates for DNA replication for the transcription of early/late genes. This virus has a low-fidelity of DNA polymerase. Some diseases associated with this virus include: Papilloma virus, BK virus, and the JC virus.

*Parvoviridae* are the smallest of the DNA-containing viruses (18-26 nm). The linear DNA is single stranded and contains three to four genes NS1, NS2P, NS2Y, NS2L. The virion is a naked icosahedron with 32 capsomers and 60 copies of CP protein within the capsid. Diseases associated with this virus are: progressive multifocal leukoencephalopathy (PML), ureteral stenosis. And hemorrhagic cystitis. These viruses have a low- fidelity of DNA polymerase. Following acute infection, many of the DNA viruses have the ability to remain latent. This virus and associated viruses most routinely show latency and reactivation.

Virions of the *Circoviridae* family are small (approximately 20–25 nm in diameter), non-enveloped, spherical in outline, with icosahedral symmetry. Virions are made up of 60 capsid subunits which package the viral circular single-stranded DNA which is approximately 1.7–2.3 kb in size. The genome of viruses in the genus Circovirus contains two major open reading frames (ORFs). The ORF1 encodes the VP1 capsid protein that is present in virions, and ORF2 and ORF3 encode the VP2 and VP3 nonstructural proteins, respectively. These viruses also have a low-fidelity for DNA polymerases. Diseases associated with *Circoviridae* include: postweaning multisystemic wasting syndrome (PCV-2), chicken infectious anemia (CAV), and porcine dermatitis and nephropathy syndrome (PDNS).

RNA virus families include: *Reoviridae, Birmaviridae, Paramyxoviridae, Rhabdoviridae, Bornaviridae, Orthomyoviridae, Bunyaviridae, Filoviridae, Coronaviridae, Arteiviridae, Picornaviridae, Caliciviradae, Astroviridae, Togaviridae, and Flaviviridae*.

*Reoviridae* viruses are non-enveloped, icosahedral virion with a double capsid structure. The outer capsid has a T=13 icosahedral symmetry and the inner capsid has a T=2 icosahedral symmetry. This virion has a segmented linear double stranded RNA genome with 10 to 12 segments coding for 10 to 14 proteins. Segments size range from 0.2 to 3.0 kb; the entire genome size ranges from 18.2 to 30.5 kb. Viral polymerases involved in this virion, synthesize mRNA from each of the double stranded RNA segments that are then translocated to the cell cytoplasm for translation. Proteins of this virus are produced by leaky scanning and protein processing, leading to a low fidelity of RNA polymerase. Positive sense RNAs are encapsidated in a sub-viral particle, they are transcribed to give negative RNA molecules, and they become base-paired to produce the double stranded RNA genome. The capsid is assembled on the sub-viral particle. Diagnosis depends on detecting virus in feces for example by and immunoassay or on demonstrating a serum antibody response. Diseases associated with this virus include: mammalian orthoreovirus (MRV), bluetongue virus (BTV), rotavirus A (RV-A), and the Colorado tick fever virus (CTFV).

*Birnaviridae* viruses have a double segmented linear double stranded RNA viral genome: encoding for about 5-6 proteins. The segments A and B together are about 2.3-3 kb with the entire genome at roughly 6 kb. The capsid is 70 nm in diameter, non-enveloped, and single-shelled with T=13 icosahedral symmetry and includes 260 trimers of structural VP2 protein forming spikes protruding from the capsid. A VP3 protein forms a ribonucleoprotein complex with the genomic RNA. Minor amounts of VP1 are also incorporated in the virion. Mature virions are released by budding and the replication of *Birnaviridae* viruses occur in the cytoplasm of host cells. The amount of recombinant-expressed VP1 is highly active for RNA polymerase during reverse transcriptase, *Birnaviridae* viruses have a low-fidelity. Diseases caused by this virus include: infectious pancreatic necrosis virus (IPNV), oyster virus (OV), tellina virus (TV), infectious bursal disease virus (IBDV), and the *Drosophila* X virus (DXV).

*Paramyxoviridae* viruses have a negative stranded RNA linear genome, about 15 kb in size encoding for eight proteins. This virion has a spherical shape and enveloped nucleocapsid, about 150 nm in diameter. *Paramyxoviridae* express a C protein by [leaky scanning](http://viralzone.expasy.org/all_by_species/1976.html) and V/W proteins by [mRNA editing](http://viralzone.expasy.org/all_by_species/857.html) along with HN, H and G glycoproteins involved in cytoplasmic replication. The RNA polymerase (L) protein yields a low-fidelity. Replication presumably starts when enough nucleoprotein is present to encapsidate neo-synthesized antigenomes and genomes. The ribonucleocapsid interacts with the matrix protein under the plasma membrane and budding begins. Diseases associated with this virion include: the measles, mumps, respiratory tract infections (RTI).

The *Rhabdoviridae* virion nucleocapsid is enveloped, about 180 nm long and 75 nm wide, and bullet shaped. Certain plant Rhabdoviruses species are bacilliform in shape and double in length. The genome of the virus is a linear, negative-stranded piece of RNA, about 11-15 kb in size which encodes for 5 to 6 proteins: G, M, P, L, N, and a ribonucleocapsid protein. The attachment of the viral G glycoproteins to host receptors mediates Clathrin-mediated endocytosis of the virus into the host cell. The viral DNA dependent RNA polymerase binds the encapsidated genome at the leader region, then sequentially transcribes each gene by recognizing start and stop signals and flanking viral genes. Thus a high fidelity rate of RNA polymerases. Diseases associated with this virion includes: Vesiculovirus, rabies and Bovine ephemeral fever virus.

*Bornaviridae* virions range from 70 to 130 nm in diameter. These viruses have enveloped nucleocapsids spherical in shape. Negative stranded linear RNA house the genome, which is 8.9 kb in size and encodes for six proteins to nine proteins. The viral RNA dependent RNA polymerase transcribes each of the genes by recognizing start and stop signals flanking viral genes. The messenger RNAs are capped and polyadenylated by the L protein during synthesis and the third transcript encodes M, G and L by alternative splicing. These L proteins show a high fidelity polymerase. Diseases associated with these virions include: encephalitis and [proventricular dilatation disease](http://en.wikipedia.org/wiki/Proventricular_Dilatation_Disease) in birds and Borna disease in mammals.

*Orthomyoviridae* viruses are usually rounded but can be filamentous and sizes are about 80-120 nm in diameter. These virions have enveloped nucleocapsid (nucleoproteins) with a linear single stranded RNA genome. The genome is cleaved in eight segments, 13.5kb in size, which code for eleven proteins. Segments sizes can range from 890 to 2,341nt in size. Some proteins made by this virion are viral RNA polymerase (PB1, PB2 and PA), M2, NEP, and PB1-F2. Translation by leaky scanning from the PB1 mRNA and the ribosomal frameshift during protein synthesis results from a low fidelity RNA polymerase. Virus attaches to sialic acid receptor though HA protein and is endocytosed by Clathrins in the host cell and fuses with the viral membrane with the vesicle membrane. Diseases associated with this virion includes: H1N1, Spanish flu, Swine flu, and Asian flu.

The *Bunyaviridae* virion has an enveloped capsid, spherical in shape with a diameter ranging from 80 to 120 nm. The virus contains a linear, segmented, single stranded (negative-stranded) RNA genome encoding for four to six proteins. The L segment is between 6.8 and 12 kb, M segment between 3.2 and 4.9 kb and the S segment between 1 and 3 kb. The viral RNA dependent RNA polymerase (L) bind to a promoter on each encapsidated segment, and transcribes the mRNA. Transcription is terminated by a strong hairpin sequence at the end of each gene. mRNAs are capped by L protein during synthesis. *Orthobunyavirus* and *Hantavirus* express alternative ORF by leaky scanning *Phlebovirus* and *Tospovirus* have ambience segment(s), and a low fidelity RNA polymerase. Diseases related to this virion include: Viral hemorrhagic fever, Crimean–Congo hemorrhagic fever, and Hantavirus hemorrhagic fever with renal syndrome.

*Filoviridae* viruses are enveloped in a lipid (fatty) membrane and glycoprotein filaments, and are 790 nm long for Marburg virus and about 970 nm long for Ebolavirus with a diameter of 80 nm. The negative-stranded RNA linear genome, about 18-19 kb in size, encodes for seven proteins. The viral RNA dependent RNA polymerase binds the genome at the leader region, then transcribes each of the genes by recognizing start and stop signals flanking viral genes. Then the mRNAs are capped and polyadenylated by the L protein (polymerase) during synthesis. During replication the attachment to host receptors, via GP glycoproteins, mediates endocytosis into vesicles in the host cell by apoptotic mimicry. This virus as a low fidelity RNA polymerase. Ebola (Ebola Virus Disease) and Marburg Hemorrhagic Fever are associated with this disease.

*Coronaviridae* viruses are enveloped and spherical at about 120 nm in. The single stranded RNA genome is associated with the N protein, which forms the nucleocapsid. This monopartite, linear, positive sense RNA genome, is 27-32kb in size, and one of the largest genomes of all RNA viruses. The viral RNA encodes for ORF1a and ORF1b, which is translated by [ribosomal frameshifting](http://viralzone.expasy.org/all_by_protein/860.html). Resulting proteins pp1a and pp1ab, being processed into the viral polymerase (RdRp) along with other non-structural proteins involved in RNA synthesis. Structural proteins within this virion are expressed as subgenomic RNAs, with each RNA (genomic & subgenomic) translated to yield only the protein encoded by the ORF. The binding of the viral S protein to [host receptors](http://viralzone.expasy.org/all_by_protein/958.html) mediates [endocytosis of the virus into the host cell](http://viralzone.expasy.org/all_by_protein/977.html). [Fusion of virus membrane with the endosomal membrane](http://viralzone.expasy.org/all_by_protein/992.html) (mediated by S2), then the positive sense RNA genome is released into the cytoplasm. Diseases associated with this virion includes: Severe Acute Respiratory Syndrome (SARS), pneumonia, and gastroenteritis.

*Arteiviridae* viruses areenveloped and spherical about 45-60 nm in diameter, with an isometric core, 20-30 nm surrounded by a lipid-containing envelope. This monopartite, linear, [single, positive sense RNA has a genome](http://viralzone.expasy.org/all_by_protein/245.html) of 12-16kb in size is capped and polyadenylated. The genpme codes for an N protein, which forms the nucleocapsid. ORF1b is translated by a [ribosomal frameshifting](http://viralzone.expasy.org/all_by_protein/860.html). Polyproteins pp1a and pp1ab are processed into the viral polymerase (RdRp) and other non-structural proteins involved in RNA synthesis. Structural proteins are expressed as subgenomic RNAs. Proteins PRRSV, LDV, SHFV, and polyprotein 1aTF are due to a [ribosomal frameshifting](http://viralzone.expasy.org/all_by_protein/860.html) in the nsp2 gene in *Arteiviridae* viruses. The 3’ proximal region of SHFV contains in addition a large insertion that may encode three additional glycoproteins. Protein GP2 and 5a are produced by leaky scanning from the E and gp5 subgenomic mRNA. This shows low fidelity for this RNA polymerase. Diseases associated with this virion includes: equine arteritis virus (EAV), porcine reproductive and respiratory syndrome virus (PRRSV), lactate dehydrogenase elevating virus (LDV) of mice and simian haemorrhagic fever virus (SHFV).

*Picornaviridae* viruses has no outer envelope, spherical in shape, and about 30 nm in diameter with a [T=pseudo 3 icosahedral symmetry capsid](http://viralzone.expasy.org/all_by_protein/809.html) surrounding the naked RNA genome. The capsid further, consists of a densely-packed icosahedral arrangement of 60 protomers, each consisting of four polypeptides: VP1, VP2, VP3 and VP4 inside the capsid. This monopartite, linear, single stranded, positive [RNA genome](http://viralzone.expasy.org/all_by_protein/245.html) is about 7.1-8.9 kb in size, polyadenylated, and composed of a single ORF encoding a polyprotein. The P1 region of the genome encodes for structural polypeptides, while the P2 and P3 regions encode the nonstructural proteins associated with replication. The internal ribosomal entry site or [IRES](http://viralzone.expasy.org/all_by_species/867.html) allows the direct translation of the polyprotein. The polyprotein is initially processed by the viral protease(s) into various precursor and mature proteins to yield the structural proteins, replicase, VPg, and a number of proteins that modify the host cell leading to [cell lysis](http://viralzone.expasy.org/all_by_species/1077.html). This virus has a low fidelity RNA polymerase. Disease associated with this virion includes: myocarditis, Rhinoviruses, and Hepatoviruses.

*Caliciviradae* non-enveloped, capsid of about 27-40 nm in diameter, with T=3 icosahedral symmetry. The virion is composed of 180 capsid proteins. The genome of the virion is a monopartite, linear, single positive sense [RNA](http://viralzone.expasy.org/all_by_protein/245.html), 7.3 to 8.3 kb in size. The 5’-terminus is linked to a VPg protein and the 3’-terminus has a poly(A) tract. The genome encodes a polyprotein (ORF1) and one or two smaller ORFs are expressed from a subgenomic RNA. The cleavage of an ORF1 polyprotein by the virus-encoded 3C-like cysteine proteinase, yields mature nonstructural proteins. The 3’-end terminal ORF encodes a basic protein and the capsid protein. Leaky scanning is a characteristic of this virus leading to a low fidelity RNA polymerase. The binding to [host receptors](http://viralzone.expasy.org/all_by_protein/958.html) mediates [endocytosis of the virus into the host cell](http://viralzone.expasy.org/all_by_protein/977.html) and the release of the viral genomic RNA into the cytoplasm. Protein VPg is removed from the viral RNA, which is then translated into a processed ORF1 polyprotein to yield the replication proteins. Diseases associated with this virion includes Feline calicivirus and acute gastroenteritis.

*Astroviridae* viruses are composed ofmonopartite (non-segmented), linear, single stranded (positive sense) [RNA, with a genome](http://viralzone.expasy.org/all_by_protein/245.html) size of 6.8-7kb. These virions are non-enveloped and spherical with a capsid of about 35 nm ([T=3 icosahedral symmetry](http://viralzone.expasy.org/all_by_protein/806.html)). Surface proteins are small and appears rough, the spikes protrude from the 30 vertices. The 5’-terminus is linked to a VPg protein and the 3’-terminus has a poly(A) tract.  The genome contains three overlapping open reading frames (ORF1a, ORF1b, and ORF2). ORF1a and ORF1b encode the viral protease and polymerase respectively. The nonstructural proteins are translated from the genomic RNA as two large polyproteins, nsP1a and nsP1a/1b. ORF2 is expressed from a subgenomic RNA and encodes the VP90 capsid precursor protein. [With the attachment](http://viralzone.expasy.org/all_by_protein/956.html) to [host receptors](http://viralzone.expasy.org/all_by_protein/958.html), mediates [endocytosis of the virus into the host cell](http://viralzone.expasy.org/all_by_protein/977.html). Replication occurs in [viral factories](http://viralzone.expasy.org/all_by_protein/1951.html) made of membrane vesicles derived from the ER. A double stranded RNA genome is synthesized from the genomic positive sense RNA, yielding a low fidelity of RNA polymerase. Diseases associated with this virion are gastroenteritis and [Avian Nephritis Virus (ANV)](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=18&cad=rja&uact=8&ved=0ahUKEwiT7N-wnI3SAhVkiFQKHcHmApEQFgh3MBE&url=http%3A%2F%2Fjvi.asm.org%2Fcontent%2F74%2F18%2F8487.full&usg=AFQjCNEOlJLRprJayEZGfi2fhU-6NrcDXA&sig2=F6WtovL1Y7SzcUaTVEHDsg&bvm=bv.146786187,d.cGw).

*Togaviridae* viruses are monopartite, linear, [positive, singled stranded RNA. The genome](http://viralzone.expasy.org/all_by_protein/245.html) is approximately 9.7-11.8 kb in size, it is capped and polyadenylated. This virus is enveloped, spherical and 65-70 nm in diameter. Nucleocapsids have a [T=4 icosahedral symmetry](http://viralzone.expasy.org/all_by_protein/808.html) made of 240 monomers enclosed in the envelope, which has 80 trimer spikes protruding from the surface.  The entire genome is translated into non-structural polyproteins, that are processed by host and viral proteases. A structural polyprotein is expressed through a subgenomic mRNA, but in alphaviruses, RdRp is expressed by [suppression of termination](http://viralzone.expasy.org/all_by_protein/859.html) at the end of 10% of nsP polyproteins. Also a [ribosomal frameshifting](http://viralzone.expasy.org/all_by_protein/860.html) in the 6K region induces the translation of the TF protein in alphaviruses. These viruses have a high fidelity of RNA polymerases. [To begin replication, the attachment](http://viralzone.expasy.org/all_by_protein/956.html) of the viral E glycoprotein to [host receptors](http://viralzone.expasy.org/all_by_protein/958.html) mediates [Clathrin-mediated endocytosis of virus into the host cell](http://viralzone.expasy.org/all_by_species/957.html), resulting in [the fusion of virus membrane with host endosomal membrane](http://viralzone.expasy.org/all_by_species/992.html). Then, the RNA genome is released into the cytoplasm. Some diseases associated with this virion are, arthritis, encephalitis, and congenital rubella syndrome.

*Flaviviridae* viruses are enveloped and spherical, about 50 nm in diameter. The surface of these envelopes consist of proteins arranged in an icosahedral-like symmetry (surface dimers). The genome of this virus is monopartite, linear, single/positive sense RNA of about 9.7-12 kb in size. The genome 3’ terminus is not polyadenylated but forms a loop structure, while the 5’ end has a methylated nucleotide cap (to allow translation) or a genome-linked protein (VPg). The whole genome is translated into a polyprotein, which is processed co- and post-translationally by host and viral proteases. Replication takes place at the surface of endoplasmic reticulum in [cytoplasmic viral factories](http://viralzone.expasy.org/all_by_protein/1951.html). A double stranded RNA genome is synthesized from the genomic positive sense RNA, yielding a low fidelity polymerase. Diseases related to this virion includes [Viral Hemorrhagic Fevers (VHFs)](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwivuLDEpI3SAhVLllQKHbOpCLYQFggaMAA&url=http%3A%2F%2Fwww.cdc.gov%2Fvhf%2Fvirus-families%2Fflaviviridae.html&usg=AFQjCNHxNvmwhJcCM51y8mxjXhvMNuxCvw&sig2=tB3CxmBYKp92jHc0xPgZkw&bvm=bv.146786187,d.amc), encephalitis, and fatal mucosal disease.

*Hepadnaviridae* viruses are enveloped and spherical with a diameter of about 42 nm. The capsid is [icosahedral in structure with a T=4 symmetry](http://viralzone.expasy.org/all_by_protein/808.html). The virion itself is a circular, partially double stranded DNA molecule about 3.2 kb in size it encodes for seven proteins. Due to a low fidelity of polymerases, non-specific recombination, in the viral genome leads to the virus being [integrated in host chromosome](http://viralzone.expasy.org/all_by_species/980.html). The ‘[minichromosome](http://viralzone.expasy.org/all_by_protein/1282.html)’ is transcribed by cellular RNA polymerase II under the control of three to four promoters (the core, pre-S1, pre-S2/S promoters, and the X promoter) and two enhancer regions (ENH1 and ENH2). The pre-genomic RNA is [alternatively spliced](http://viralzone.expasy.org/all_by_species/1943.html); the unspliced form is [exported from the nucleus](http://viralzone.expasy.org/all_by_protein/1953.html) through a PRE capsid protein. The polymerase and short S proteins are expressed by [leaky scanning](http://viralzone.expasy.org/all_by_species/1976.html) from the pgmRNA and the smRNA. Diseases associated with this virion includes: hepatitis, hepatocellular carcinomas (chronic infections), and cirrhosis.

 *Retroviridae* viruses are enveloped and spherical in shape, 80-100 nm in diameter. This virion is a retrovirus with a single stranded positive-sense RNA virus with a DNA intermediate end. The genome itself is monopartite, linear and dimeric, and range to about 7-11kb in size. Diseases associated with this virion are HIV-1 and Adult T-cell leukemia. These virions are associated with Gag, Pol, and Env proteins. These viruses have a low fidelity of RNA polymerase.