



## SHORT REPORT

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# Confusions in orbivirus protein classification

Meik Dilcher\* and Manfred Weidmann

**Abstract**

An extensive comparative analysis of orbivirus genomes revealed four cases of unclear numeration and protein designation, due to confused reference to protein size or segment size by which they are encoded. A concise nomenclature based on type species, sequence homology and functional characteristics independent of segment or protein size is suggested.

**Keywords:** *Reoviridae*, *Orbivirus*, Protein classification

**Background**

The genus *Orbivirus* is one of 15 in the family of *Reoviridae* containing 22 serogroups (species) and at least 160 different serotypes (strains) [1]. Orbiviruses are transmitted by insects (midges, flies, mosquitoes) or by ticks. Their double-stranded RNA (dsRNA) genomes consist of 10 segments coding for seven structural and at least three non-structural proteins. Orbiviruses have no envelope but a double-shelled icosahedral capsid [2] and include pathogenic agents of wild animals (Epizootic hemorrhagic disease virus (EHDV)), domestic animals (Bluetongue virus (BTV) and African horse sickness virus (AHSV)), and of man (Kemerovo virus (KEMV)) [3]. Type species of the genus is the *Culicoides* midge transmitted BTV. Insect-borne orbiviruses are much better characterized than tick-transmitted orbiviruses for which few sequences have been described: Broadhaven virus (BRDV, partial) [4], Sandy Bay virus (SBaV, partial (formerly Nugget virus)) [5-8], St Croix River virus (SCRV, complete genome) [9], Great Island virus (GIV, complete genome) [7].

Recently we determined the complete genomes of Tribeč virus (TRBV) and KEMV in a pyrosequencing approach [10] complementing available partial information on segments 1, 2 and 6 of these viruses and of Lipovnik virus (LIPV) [7].

During our extensive comparative analysis of orbivirus genomes we noticed four cases of unclear numeration and protein designation (see Tables 1 and 2). Some laboratories classify orbivirus proteins according to the

size of the proteins whereas others use the size of genome segments from which they are encoded.

- (i) The inner shell protein T2 for example can be encoded by segment 2 (tick- and mosquito-borne orbiviruses) or segment 3 (*Culicoides*-borne orbiviruses). This leads to some laboratories labeling this protein VP2(T2) (e.g. GIV), while others designate it VP3(T2) as in the type species BTV. For Peruvian horse sickness virus (PHSV) however, the segment 2 encoded protein is designated VP3 (T2) although it is larger (925 amino acids) than the segment 3 encoded VP2 protein (881 amino acids) [11]. To avoid confusion with the outer shell protein VP2 we suggest to exclusively use VP3(T2) for all T2 proteins.
- (ii) VP2 and VP2 homologous proteins can be encoded by segments 2, 3, 4 and 5 and are designated VP2, VP3 (YUOV, SCRIV) or VP4 (BRDV segment 4 ([12,13], sequence entry to GenBank missing)), GIV segment 5). Because of the location on the outer capsid and the described sequence similarity with other VP2 proteins, we suggest that the VP4 proteins (BRDV, GIV) as well as the VP3 proteins (YUOV, SCRIV) should be uniformly termed VP2, even though tick-borne VP2 proteins have only half the size of insect-borne VP2 proteins [13].
- (iii) The capping enzyme VP4(CaP) can be encoded by segment 4 (BTV, YUOV, SCRIV etc.) or segment 3 (TRBV, KEMV). In GIV this protein is designated VP3(CaP) [7] and should be renamed VP4(CaP) to avoid confusions with VP3(T2).
- (iv) In most cases VP5 is encoded by segment 6 and comprises a component of the outer shell that

\* Correspondence: [meik.dilcher@medizin.uni-goettingen.de](mailto:meik.dilcher@medizin.uni-goettingen.de)  
Department of Virology, University Medical Center Göttingen, Kreuzberggring 57, D-37075 Göttingen, Germany

**Table 1 Comparison of the genome segments and encoded proteins of BTV, YUOV, TRBV, KEMV and GIV**

| BTV (insect-transmitted) |                  |         |                                     | YUOV (insect-transmitted) |                  |         |                                     | TRBV (tick-transmitted) |                  |         |                                     |
|--------------------------|------------------|---------|-------------------------------------|---------------------------|------------------|---------|-------------------------------------|-------------------------|------------------|---------|-------------------------------------|
| Segment 1                | VP1 (Pol)        | 150 kDa | RNA-dep.-RNA-Polymerase             | Segment 1                 | VP1 (Pol)        | 151 kDa | RNA-dep.-RNA-Polymerase             | Segment 1               | VP1 (Pol)        | 146 kDa | RNA-dep.-RNA-Polymerase             |
| 3944 bp                  | ACR58458         | 1302 AA |                                     | 3393 bp                   | YP_443925        | 1315 AA |                                     | 3892 bp                 | HQ266581         | 1284 AA |                                     |
| Segment 2                | <b>VP2</b>       | 111 kDa | <b>Outer shell</b>                  | Segment 2                 | <b>VP2 (T2)</b>  | 107 kDa | <b>Inner shell</b>                  | Segment 2               | <b>VP3 (T2)</b>  | 102 kDa | <b>Inner shell</b>                  |
| 2953 bp                  | ACR58459         | 956 AA  |                                     | 2900 bp                   | YP_443926        | 940 AA  |                                     | 2793 bp                 | HQ266582         | 908 AA  |                                     |
| Segment 3                | <b>VP3 (T2)</b>  | 103 kDa | <b>Inner shell</b>                  | Segment 3                 | <b>VP3</b>       | 100 kDa | <b>Outer shell</b>                  | Segment 3               | VP4 (CaP)        | 72 kDa  | Capping Enzyme                      |
| 2772 bp                  | ACR58460         | 901 AA  |                                     | 2688 bp                   | YP_443927        | 873 AA  |                                     | 1935 bp                 | HQ266583         | 628 AA  |                                     |
| Segment 4                | VP4 (CaP)        | 75 kDa  | Capping Enzyme                      | Segment 4                 | VP4 (CaP)        | 74 kDa  | Capping Enzyme                      | Segment 4               | NS1 (TuP)        | 62 kDa  | Formes Tubules                      |
| 1980 bp                  | ACR58461         | 644 AA  |                                     | 1993 bp                   | YP_443928        | 645 AA  |                                     | 1734 bp                 | HQ266584         | 529 AA  |                                     |
| Segment 5                | NS1 (TuP)        | 64 kDa  | Forms Tubules                       | Segment 5                 | NS1 (TuP)        | 67 kDa  | Forms Tubules                       | Segment 5               | <b>VP2</b>       | 62 kDa  | <b>Outer shell</b>                  |
| 1769 bp                  | ACR58463         | 552 AA  |                                     | 1957 bp                   | YP_443929        | 574 AA  |                                     | 1730 bp                 | HQ266585         | 554 AA  |                                     |
| Segment 6                | <b>VP5</b>       | 59 kDa  | <b>Outer shell</b>                  | Segment 6                 | <b>VP5</b>       | 59 kDa  | <b>Outer shell</b>                  | Segment 6               | <b>VP5</b>       | 59 kDa  | <b>Outer shell</b>                  |
| 1638 bp                  | ACR58462         | 526 AA  |                                     | 1683 bp                   | YP_443930        | 535 AA  |                                     | 1668 bp                 | HQ266586         | 537 AA  |                                     |
| Segment 7                | <b>VP7 (T13)</b> | 39 kDa  | <b>Inner shell</b>                  | Segment 7                 | NS2 (ViP)        | 48 kDa  | Viral inclusion body matrix protein | Segment 7               | NS2 (ViP)        | 41 kDa  | Viral inclusion body matrix protein |
| 1156 bp                  | ACR58464         | 349 AA  |                                     | 1504 bp                   | YP_443931        | 435 AA  |                                     | 1196 bp                 | HQ266587         | 368 AA  |                                     |
| Segment 8                | NS2 (ViP)        | 41 kDa  | Viral inclusion body matrix protein | Segment 8                 | <b>VP7 (T13)</b> | 40 kDa  | <b>Inner shell</b>                  | Segment 8               | <b>VP7 (T13)</b> | 40 kDa  | <b>Inner shell</b>                  |
| 1125 bp                  | ACR58465         | 354 AA  |                                     | 1191 bp                   | YP_443932        | 355 AA  |                                     | 1184 bp                 | HQ266588         | 357 AA  |                                     |
| Segment 9                | VP6 (Hel)        | 36 kDa  | ssRNA and dsRNA binding helicase    | Segment 9                 | VP6 (Hel)        | 37 kDa  | ssRNA and dsRNA binding helicase    | Segment 9               | VP6 (Hel)        | 33 kDa  | ssRNA and dsRNA binding helicase    |
| 1049 bp                  | ACR58466         | 329 AA  |                                     | 1082 bp                   | YP_443933        | 338 AA  |                                     | 1034 bp                 | HQ266589         | 312 AA  |                                     |
| Segment 10               | NS3              | 26 kDa  | Glycoprotein                        | Segment 10                | NS3              | 28 kDa  | Glycoprotein                        | Segment 10              | NS3              | 23 kDa  | Glycoprotein                        |
| 822 bp                   | ACR58467         | 229 AA  |                                     | 825 bp                    | YP_443934        | 253 AA  |                                     | 705 bp                  | HQ266590         | 214 AA  |                                     |

| <b>KEMV (tick-transmitted)</b> |                  |         |                                     | <b>GIV (tick-transmitted)</b> |                  |         |                                     |
|--------------------------------|------------------|---------|-------------------------------------|-------------------------------|------------------|---------|-------------------------------------|
| Segment 1                      | VP1 (Pol)        | 146 kDa | RNA-dep.-RNA-Polymerase             | Segment 1                     | VP1 (Pol)        | 147 kDa | RNA-dep.-RNA-Polymerase             |
| 3896 bp                        | HQ266591         | 1285 AA |                                     | 3897 bp                       | ADM88592         | 1285 AA |                                     |
| Segment 2                      | <b>VP3 (T2)</b>  | 103 kDa | <b>Inner shell</b>                  | Segment 2                     | <b>VP2 (T2)</b>  | 103 kDa | <b>Inner shell</b>                  |
| 2792 bp                        | HQ266592         | 908 AA  |                                     | 2794 bp                       | ADM88593         | 908 AA  |                                     |
| Segment 3                      | VP4 (CaP)        | 72 kDa  | Capping Enzyme                      | Segment 3                     | VP3 (CaP)        | 73 kDa  | Capping Enzyme                      |
| 1934 bp                        | HQ266593         | 632 AA  |                                     | 1936 bp                       | ADM88594         | 635 AA  |                                     |
| Segment 4                      | <b>VP2</b>       | 63 kDa  | <b>Outer shell</b>                  | Segment 4                     | NS1 (TuP)        | 60 kDa  | Formes Tubules                      |
| 1730 bp                        | HQ266594         | 554 AA  |                                     | 1731 bp                       | ADM88595         | 531 AA  |                                     |
| Segment 5                      | NS1 (TuP)        | 60 kDa  | Formes Tubules                      | Segment 5                     | <b>VP4</b>       | 62 kDa  | <b>Outer shell</b>                  |
| 1719 bp                        | HQ266595         | 529 AA  |                                     | 1722 bp                       | ADM88596         | 551 AA  |                                     |
| Segment 6                      | <b>VP5</b>       | 59 kDa  | <b>Outer shell</b>                  | Segment 6                     | <b>VP5</b>       | 60 kDa  | <b>Outer shell</b>                  |
| 1668 bp                        | HQ266596         | 537 AA  |                                     | 1666 bp                       | ADM88597         | 537 AA  |                                     |
| Segment 7                      | NS2 (ViP)        | 41 kDa  | Viral inclusion body matrix protein | Segment 7                     | <b>VP7 (T13)</b> | 40 kDa  | <b>Inner shell</b>                  |
| 1197 bp                        | HQ266597         | 368 AA  |                                     | 1181 bp                       | ADM88598         | 357 AA  |                                     |
| Segment 8                      | <b>VP7 (T13)</b> | 40 kDa  | <b>Inner shell</b>                  | Segment 8                     | NS2 (ViP)        | 39 kDa  | Viral inclusion body matrix protein |
| 1183 bp                        | HQ266598         | 357 AA  |                                     | 1172 bp                       | ADM88599         | 359 AA  |                                     |
| Segment 9                      | VP6 (Hel)        | 34 kDa  | ssRNA and dsRNA binding helicase    | Segment 9                     | VP6 (Hel)        | 34 kDa  | ssRNA and dsRNA binding helicase    |
| 1049 bp                        | HQ266599         | 317 AA  |                                     | 1056 bp                       | AMD88600         | 321 AA  |                                     |
| Segment 10                     | NS3              | 23 kDa  | Glycoprotein                        | Segment 10                    | NS3              | 19 kDa  | Glycoprotein                        |
| 707 bp                         | HQ266600         | 214AA   |                                     | 703 bp                        | ADM88602         | 171 AA  |                                     |

Outer and inner shell proteins are labeled in bold. GenBank and SwissProt accession numbers are indicated.

**Table 2 Comparison of the genome segments and encoded proteins of SCRIV, PHSV, BRDV and LIPV**

| SCRIV (tick-transmitted) |                  |         |                                     | PHSV (isolates only known from horses) |                  |         |                                     |
|--------------------------|------------------|---------|-------------------------------------|--|------------------|---------|-------------------------------------|
| Segment 1                | VP1 (Pol)        | 151 kDa | RNA-dep.-RNA-Polymerase             | Segment 1                              | VP1 (Pol)        | 151 kDa | RNA-dep.-RNA-Polymerase             |
| 4089 bp                  | YP_052942        | 1345 AA |                                     | 3987 bp                                | YP_460038        | 1311 AA |                                     |
| Segment 2                | <b>VP2 (T2)</b>  | 98 kDa  | <b>Inner shell</b>                  | Segment 2                              | <b>VP3 (T2)</b>  | 105 kDa | <b>Inner shell</b>                  |
| 2747 bp                  | YP_052943        | 890 AA  |                                     | 2856 bp                                | YP_460039        | 925 AA  |                                     |
| Segment 3                | <b>VP3</b>       | 74 kDa  | <b>Outer shell</b>                  | Segment 3                              | <b>VP2</b>       | 104 kDa | <b>Outer shell</b>                  |
| 2024 bp                  | YP_052944        | 654 AA  |                                     | 2747 bp                                | YP_460040        | 881 AA  |                                     |
| Segment 4                | VP4 (CaP)        | 74 kDa  | Capping Enzyme                      | Segment 4                              | VP4 (CaP)        | 74 kDa  | Capping Enzyme                      |
| 2017 bp                  | YP_052945        | 643 AA  |                                     | 1996 bp                                | YP_460041        | 646 AA  |                                     |
| Segment 5                | <b>VP5</b>       | 57 kDa  | <b>Outer shell</b>                  | Segment 5                              | NS1 (TuP)        | 64 kDa  | Forms Tubules                       |
| 1664 bp                  | YP_052946        | 517 AA  |                                     | 1784 bp                                | YP_460045        | 554 AA  |                                     |
| Segment 6                | NS1 (TuP)        | 58 kDa  | Forms Tubules                       | Segment 6                              | <b>VP5</b>       | 59 kDa  | <b>Outer shell</b>                  |
| 1657 bp                  | YP_052947        | 517 AA  |                                     | 1695 bp                                | YP_460042        | 529 AA  |                                     |
| Segment 7                | NS2 (ViP)        | 51 kDa  | Viral inclusion body matrix protein | Segment 7                              | NS2 (ViP)        | 48 kDa  | Viral inclusion body matrix protein |
| 1463 bp                  | YP_052948        | 462 AA  |                                     | 1613 bp                                | YP_460046        | 435 AA  |                                     |
| Segment 8                | <b>VP7 (T13)</b> | 41 kDa  | <b>Inner shell</b>                  | Segment 8                              | <b>VP7 (T13)</b> | 40 kDa  | <b>Inner shell</b>                  |
| 1256 bp                  | YP_052949        | 379 AA  |                                     | 1180 bp                                | YP_460044        | 353 AA  |                                     |
| Segment 9                | VP6 (Hel)        | 26 kDa  | ssRNA and dsRNA binding helicase    | Segment 9                              | VP6 (Hel)        | 37 kDa  | ssRNA and dsRNA binding helicase    |
| 764 bp                   | YP_052950        | 232 AA  |                                     | 1071 bp                                | YP_460043        | 334 AA  |                                     |
| Segment 10               | NS3              | 24 kDa  | Glycoprotein                        | Segment 10                             | NS3              | 28 kDa  | Glycoprotein                        |
| 764 bp                   | YP_052951        | 224 AA  |                                     | 819 bp                                 | YP_460047        | 255 AA  |                                     |

| BRDV (tick-transmitted) |                  |          |                    | LIPV (tick-transmitted) |                 |           |                         |
|-------------------------|------------------|----------|--------------------|-------------------------|-----------------|-----------|-------------------------|
| Segment 1               |                  |          |                    | Segment 1               | VP1 (Pol)       | 146 kDa   | RNA-dep.-RNA-Polymerase |
|                         |                  |          |                    | 3892 bp                 | ADM88603        | 1284 AA   |                         |
| Segment 2               | <b>VP2 (T2)</b>  | 103 kDa  | <b>Inner shell</b> | Segment 2               | <b>VP2 (T2)</b> | 103 kDa   | <b>Inner shell</b>      |
|                         | P35934           | 908 AA   |                    | 2793 bp                 | ADM88604        | 908 AA    |                         |
| Segment 3               |                  |          |                    | Segment 3               |                 |           |                         |
| Segment 4               | <b>VP4 †</b>     | 63 kDa † | <b>Outer shell</b> | Segment 4               |                 |           |                         |
| Segment 5               | <b>VP5</b>       | 53 kDa   | <b>Outer shell</b> | Segment 5               |                 |           |                         |
| 1658 bp                 | P21230           | 480 AA   |                    |                         |                 |           |                         |
| Segment 6               | NS1 (TuP)        | 60 kDa   | Formes Tubules     | Segment 6               | <b>VP5</b>      | 502 AA †† | <b>Outer shell</b>      |
| 1714 bp                 | 2115436A         | 537 AA   |                    | 1509 bp ††              | ADM88605        |           |                         |
| Segment 7               | <b>VP7 (T13)</b> | 40 kDa   | <b>Inner shell</b> | Segment 7               |                 |           |                         |
|                         | P35935           | 356 AA   |                    |                         |                 |           |                         |
| Segment 8               |                  |          |                    | Segment 8               |                 |           |                         |
| Segment 9               |                  |          |                    | Segment 9               |                 |           |                         |
| Segment 10              | NS3              | 22 kDa   | Glycoprotein       | Segment 10              |                 |           |                         |
|                         | P32555           | 205 AA   |                    |                         |                 |           |                         |

Outer and inner shell proteins are labeled in bold. GenBank and SwissProt accession numbers are indicated.

†: [12,13], GenBank entry missing.

††: partial sequence.

might be involved in membrane fusion and penetration [14]. TRBV and KEMV also encode VP5 on segment 6. The highest similarity of TRBV VP5 is to LIPV VP5 (95.6%), again encoded by segment 6 [7]. However, VP5 of BRDV is described as encoded by segment 5 [15]. Since in the classification of the viral genome segments bigger segments have smaller segment numbers, and the size of BRDV segment 6 (1714 bp) encoding the NS1(TuP) [16] is larger than the size of BRDV segment 5 (1658 bp) encoding VP5, a reassignment of BRDV segment 5 and 6 (a vice versa switch) seems necessary.

To summarize, it would be much more helpful if the nomenclature of the viral proteins in orbiviruses would reflect the sequence homology and functional relationship rather than protein size or encoding segment size, since the sizes of the orbivirus genome segments sometimes only differ slightly, which leads to even closely related viruses such as TRBV and KEMV encoding VP2 and NS1 (TuP) on different genome segments. We therefore suggest the following concise nomenclature based on the type species BTV and on sequence homology and functional characteristics independent of segment or protein size: VP1(Pol), VP2, VP3(T2), VP4(CaP), VP5, VP6(Hel), VP7 (T13), NS1(TuP), NS2(ViP), NS3.

#### Competing interests

The authors declare that they have no competing interests.

#### Author's contributions

MD and MW wrote the paper. Both authors read and approved the final manuscript.

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#### References

1. Attoui H, Mertens PPC, Becnel J, Belaganahalli S, Bergoin M, Brussaard CP, Chappell JD, Ciarlet M, del Vas M, Dermody TS, et al: **Orbiviruses, Reoviridae**. In *Virus taxonomy ninth report of the international committee on taxonomy of viruses*. Edited by King AMQ, Adams MJ, Carstens EB, Lefkowitz EJ. Elsevier: Academic Press; 2011:592–603.
2. Attoui H, Jaafar FM, Belhouchet M, Aldrovandi N, Tao SJ, Chen BQ, Liang GD, Tesh RB, de Micco P, de Lamballerie X: **Yunnan orbivirus, a new orbivirus species isolated from Culex tritaeniorhynchus mosquitoes in China**. *J Gen Virol* 2005, **86**:3409–3417.
3. Gorman BM: **Variation in orbiviruses**. *J Gen Virol* 1979, **44**:1–15.
4. Moss SR, Jones LD, Nuttall PA: **Comparison of the major structural core proteins of tick-borne and culicoides-borne orbiviruses**. *J Gen Virol* 1992, **73**:2585–2590.
5. Doherty RL, Carley JG, Murray MD, Main AJ, Kay BH, Domrow R: **Isolation of arboviruses (Kemerovo-Group, Sakhalin-Group) from ixodes-uriae**

collected at Macquarie Island, Southern Ocean. *Am J Trop Med Hyg* 1975, **24**:521–526.

6. Gorman BM, Taylor J, Morton HC, Melzer AJ, Young PR: **Characterization of nugget virus, a serotype of the kemerovo group of orbiviruses**. *Aust J Exp Biol Med Sci* 1984, **62**:101–115.
7. Belhouchet M, Jaafar FM, Tesh RB, Grimes J, Maan S, Mertens P, Attoui H: **Complete sequence of the Great Island virus and comparison with the T2 and outer-capsid proteins of Kemerovo, Lipovnik and Tribec viruses (genus Orbivirus, family Reoviridae)**. *J Gen Virol* 2010, **91**:2985–2993.
8. Major L, Linn ML, Slade RW, Schroder WA, Hyatt AD, et al: **Ticks associated with Macquarie Island penguins carry arboviruses from four genera**. *PLoS One* 2009, **4**:e4375.
9. Attoui H, Stirling JM, Munderloh UG, Billoir F, Brookes SM, Burroughs JN, de Micco P, Mertens PPC, de Lamballerie X: **Complete sequence characterization of the genome of the St Croix River virus, a new orbivirus isolated from cells of Ixodes scapularis**. *J Gen Virol* 2001, **82**:795–804.
10. Dilcher M, Hasib L, Lechner M, Wieseke N, Middendorf M, Marz M, Koch A, Spiegel M, Dobler G, Hufert FT, Weidmann M: **Genetic characterization of Tribec virus and Kemerovo virus, two tick-transmitted human-pathogenic Orbiviruses**. *Virology* 2012, **423**:68–76.
11. Attoui H, Mendez-Lopez MR, Rao SJ, Hurtado-Alendes A, Lizaraso-Caparo F, Jaafar FM, Samuel AR, Belhouchet M, Pritchard LI, Melville L, et al: **Peruvian horse sickness virus and Yunnan orbivirus, isolated from vertebrates and mosquitoes in Peru and Australia**. *Virology* 2009, **394**:298–310.
12. Moss SR, Nuttall PA: **Subcore-like and core-like particles of Broadhaven Virus (Brdv), a tick-borne orbivirus, synthesized from baculovirus-expressed Vp2 and Vp7, the major core proteins of Brdv**. *Virus Res* 1994, **32**:401–407.
13. Schoehn G, Moss SR, Nuttall PA, Hewat EA: **Structure of Broadhaven virus by cryoelectron microscopy: Correlation of structural and antigenic properties of Broadhaven virus and bluetongue virus outer capsid proteins**. *Virology* 1997, **235**:191–200.
14. Zhang X, Boyce M, Bhattacharya B, Zhang XK, Schein S, Roy P, Zhou ZH: **Bluetongue virus coat protein VP2 contains sialic acid-binding domains, and VP5 resembles enveloped virus fusion proteins**. *Proc Natl Acad Sci U S A* 2010, **107**:6292–6297.
15. Moss SR, Fukusho A, Nuttall PA: **Rna segment 5 of Broadhaven virus, a tick-borne orbivirus, shows sequence homology with segment-5 of bluetongue virus**. *Virology* 1990, **179**:482–484.
16. Moss SR, Nuttall PA: **Comparison of the nonstructural protein, Ns1, of tick-borne and insect-borne orbiviruses**. *Virus Res* 1995, **36**:287–292.

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