



Anelloviridae taxonomy update 2023

Arvind Varsani^{1,2} · Simona Kraberger¹ · Tanja Opriessnig^{3,4} · Fabrizio Maggi⁵ · Vladimir Celer⁶ · Hiroaki Okamoto⁷ · Philippe Biagini⁸

Published online: 21 October 2023

© The Author(s), under exclusive licence to Springer-Verlag GmbH Austria, part of Springer Nature 2023

Abstract

The family *Anelloviridae* comprises negative single-stranded circular DNA viruses. Within this family, there are 30 established genera. Anelloviruses in the genus *Gyrovirus* have been identified infecting various avian species, whereas those in the remaining 29 genera have been found primarily infecting various mammal species. We renamed the 146 anellovirus species with binomial species names, as required by the International Committee on Taxonomy of Viruses (ICTV) using a “genus + freeform epithet” format.

Anelloviruses have circular negative-sense single-stranded genomes ranging in size from 1.6 to 3.9 kb. In general, anelloviruses have one large open reading frame (ORF), generally referred to as ORF1 or VP1, and a few smaller ORFs [1–3]. There are currently 30 genera in the family *Anelloviridae* (Table 1) [4, 5]. Members of the genus *Gyrovirus* have been identified infecting various avian species and detected in fecal samples of various mammals [4], and a report discusses their identification in reptiles [6], whereas those in the remaining 29 genera have been identified in mammal species samples [4, 5].

The ORF1/VP1 protein is the most conserved protein, a single jelly-roll capsid protein, encoded by anelloviruses, despite a size variation, which is attributed to insertions of varying length in the conserved jelly-roll domain (between

β -strands H and I) [7]. Based on the phylogeny of this conserved ORF1/VP1, 30 genera have been established to classify various anelloviruses (Table 1, Fig. 1). Furthermore, based on the analysis of the nucleotide pairwise identities of the *orf1* gene of anelloviruses, a 69% species demarcation threshold has been established [4, 5]. Within the 30 genera in the family *Anelloviridae*, there are currently 155 established species (Table 1), which are listed on the International Committee on Taxonomy of Viruses (ICTV) site within the master species list (<https://ictv.global/msl>) and virus metadata resources (<https://ictv.global/vmr>) [8].

In 2021, the International Committee on Taxonomy of Viruses (ICTV) [8] proposal TaxoProp 2018.001G.R.binomial_species was ratified [9]. This requires all species names to be in binomial format comprising a “genus + epithet” with various style options for the epithets (as either freeform or Latinized; see Siddell *et*

Handling Editor: Sead Sabanadzovic.

✉ Arvind Varsani
arvind.varsani@asu.edu

¹ The Biodesign Center for Fundamental and Applied Microbiomics, Center for Evolution and Medicine, School of Life Sciences, Arizona State University, 1001 S. McAllister Ave, Tempe, AZ 85287-5001, USA

² Structural Biology Research Unit, Department of Integrative Biomedical Sciences, University of Cape Town, Cape Town 7925, South Africa

³ Moredun Research Institute, Pentland Science Park, Bush Loan, Penicuik, Midlothian EH26 0PZ, United Kingdom

⁴ Department of Veterinary Diagnostic and Production Animal Medicine, College of Veterinary Medicine, Iowa State University, Ames, Iowa, USA

⁵ National Institute for Infectious Diseases Lazzaro Spallanzani—IRCCS, Rome, Italy

⁶ Faculty of Veterinary Medicine, University of Veterinary Sciences Brno, Palackeho 1946, 612 42 Brno, Czech Republic

⁷ Division of Virology, Department of Infection and Immunity, Jichi Medical University School of Medicine, 3311-1 Yakushiji, Shimotsuke-shi, Tochigi 329-0498, Japan

⁸ Equipe Biologie des Groupes Sanguins, UMR 7268 ADES, Aix-Marseille Université, CNRS, EFS, 27 Bd. Jean Moulin, 13005 Marseille, France

Table 1 Summary of the changes to the species names in the family *Anelloviridae*

New species name	Previous species name	Representative virus name	Accession	Host/source	Host/ source family
<i>Aleptorquevirus culic1</i>	<i>Torque teno arthrovec virus 1</i>	mosquito VEM Anellovirus SDBVL A	HQ335082	Mosquitoes (mixed species)	Culicidae
<i>Aleptorquevirus lepor1</i>	<i>Torque teno lepid virus 1</i>	Lepus torque teno virus 1 Lag01_EL_Anello4	MN994854	<i>Lepus granatensis</i>	Leporidae
<i>Alphatorquevirus homin31</i>	<i>Torque teno virus 31</i>	torque teno virus TTV-Hebei-1	KJ082064	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin1</i>	<i>Torque teno virus 1</i>	torque teno virus 1 VT416	AB041007	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin4</i>	<i>Torque teno virus 4</i>	torque teno virus 4 Pt-TTV6	AB041957	<i>Pan troglodytes</i>	Hominidae
<i>Alphatorquevirus homin10</i>	<i>Torque teno virus 10</i>	torque teno virus 10 JT34F	AB064607	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin14</i>	<i>Torque teno virus 14</i>	torque teno virus 14 s-TTV CH65-1	AB037926	<i>Pan troglodytes</i>	Hominidae
<i>Alphatorquevirus homin19</i>	<i>Torque teno virus 19</i>	torque teno virus 19 TTV SANBAN	AB025946	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus cerco6</i>	<i>Torque teno virus 26</i>	torque teno virus 26 Mf-TTV3	AB041958	<i>Macaca fuscata</i>	Cercopithecidae
<i>Alphatorquevirus homin7</i>	<i>Torque teno virus 7</i>	torque teno virus 7 PMV	AF261761	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin3</i>	<i>Torque teno virus 3</i>	torque teno virus 3 HEL32	AY666122	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus cerco7</i>	<i>Torque teno virus 25</i>	torque teno virus 25 Mf-TTV9	AB041959	<i>Macaca fuscata</i>	Cercopithecidae
<i>Alphatorquevirus homin6</i>	<i>Torque teno virus 6</i>	torque teno virus 6 KAV	AF435014	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin15</i>	<i>Torque teno virus 15</i>	torque teno virus 15 TJN01	AB028668	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin2</i>	<i>Torque teno virus 2</i>	torque teno virus 2 s-TTV CH71	AB049608	<i>Pan troglodytes</i>	Hominidae
<i>Alphatorquevirus cerco3</i>	<i>Torque teno chlorocebus virus 3</i>	simian torque teno virus 31 VGA00123.3	KP296853	<i>Chlorocebus sabaeus</i>	Cercopithecidae
<i>Alphatorquevirus cerco1</i>	<i>Torque teno chlorocebus virus 1</i>	simian torque teno virus 30 VWP00522.2	KP296857	<i>Chlorocebus sabaeus</i>	Cercopithecidae
<i>Alphatorquevirus cerco5</i>	<i>Torque teno chlorocebus virus 5</i>	simian torque teno virus 32 VGA00154.2	KP296854	<i>Chlorocebus sabaeus</i>	Cercopithecidae
<i>Alphatorquevirus cerco2</i>	<i>Torque teno chlorocebus virus 2</i>	simian torque teno virus 34 VGA00120.1	KP296856	<i>Chlorocebus sabaeus</i>	Cercopithecidae
<i>Alphatorquevirus homin5</i>	<i>Torque teno virus 5</i>	torque teno virus 5 TCHN-C1	AF345523	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin9</i>	<i>Torque teno virus 9</i>	torque teno virus 9 BM1C-18	DQ187006	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin13</i>	<i>Torque teno virus 13</i>	torque teno virus 13 TCHN-A	AF345526	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin20</i>	<i>Torque teno virus 20</i>	torque teno virus 20 SAa-10	AB060594	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin21</i>	<i>Torque teno virus 21</i>	torque teno virus 21 TCHN-B	AF348409	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin24</i>	<i>Torque teno virus 24</i>	torque teno virus 24 SAa-01	AB060597	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin29</i>	<i>Torque teno virus 29</i>	torque teno virus 29 TTVyon-KC009	AB038621	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin17</i>	<i>Torque teno virus 17</i>	torque teno virus 17	AX025830	<i>Homo sapiens</i>	Hominidae
<i>Alphatorquevirus homin18</i>	<i>Torque teno virus 18</i>	torque teno virus 18	AX025718	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini13</i>	<i>Torque teno mini virus 13</i>	TTV-like mini virus zhenjiang	KY856742	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini14</i>	<i>Torque teno mini virus 14</i>	torque teno mini virus 10 BNI-700620-G1-CSF	MH017546	<i>Homo sapiens</i>	Hominidae

Table 1 (continued)

New species name	Previous species name	Representative virus name	Accession	Host/source	Host/ source family
<i>Betatorquevirus homini17</i>	<i>Torque teno mini virus 17</i>	Anelloviridae sp. ctcf040	MH648907	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini18</i>	<i>Torque teno mini virus 18</i>	TTV-like mini virus D11	KF764701	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini19</i>	<i>Torque teno mini virus 19</i>	TTV-like mini virus TTMV_LY3	JX134046	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini20</i>	<i>Torque teno mini virus 20</i>	Anelloviridae sp. ctga035	MH648989	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini21</i>	<i>Torque teno mini virus 21</i>	Anelloviridae sp. ctcd026	MH648910	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini22</i>	<i>Torque teno mini virus 22</i>	TTV-like mini virus vzttmv4	MK212031	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini23</i>	<i>Torque teno mini virus 23</i>	TTV-like mini virus Emory1	KX810063	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini24</i>	<i>Torque teno mini virus 24</i>	Anelloviridae sp. ctbc019	MH649141	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini25</i>	<i>Torque teno mini virus 25</i>	Anelloviridae sp. ctbd020	MH648986	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini26</i>	<i>Torque teno mini virus 26</i>	torque teno mini virus SHA	KY462770	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini28</i>	<i>Torque teno mini virus 28</i>	torque teno mini virus 10 BNI-700835-G3-CSF	MH017563	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini29</i>	<i>Torque teno mini virus 29</i>	TTV-like mini virus Emory2	KX810064	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini30</i>	<i>Torque teno mini virus 30</i>	Anelloviridae sp. ctea38	MH648912	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini31</i>	<i>Torque teno mini virus 31</i>	Anelloviridae sp. ctbb016	MH649017	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini33</i>	<i>Torque teno mini virus 33</i>	Anelloviridae sp. ctbi042	MH649029	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini34</i>	<i>Torque teno mini virus 34</i>	Anelloviridae sp. ctbf050	MH649114	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini35</i>	<i>Torque teno mini virus 35</i>	Anelloviridae sp. ctei055	MH648966	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini36</i>	<i>Torque teno mini virus 36</i>	torque teno virus Human/ Japan/KS025/2016	LC381845	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini37</i>	<i>Torque teno mini virus 37</i>	Anelloviridae sp. ctbg056	MH649209	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini38</i>	<i>Torque teno mini virus 38</i>	Anelloviridae sp. ctbf014	MH648982	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini9</i>	<i>Torque teno mini virus 9</i>	torque teno mini virus 9 TLMV-CLC062	AB038625	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini8</i>	<i>Torque teno mini virus 8</i>	torque teno mini virus 8 PB4TL	AF291073	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini7</i>	<i>Torque teno mini virus 7</i>	torque teno mini virus 7 TLMV-CLC156	AB038627	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini2</i>	<i>Torque teno mini virus 2</i>	torque teno mini virus 2 TLMV-NLC023	AB038629	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini3</i>	<i>Torque teno mini virus 3</i>	torque teno mini virus 3 TLMV-NLC026	AB038630	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini5</i>	<i>Torque teno mini virus 5</i>	torque teno mini virus 5 TGP96	AB041962	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini4</i>	<i>Torque teno mini virus 4</i>	torque teno mini virus 4 Pt-TTV8-II	AB041963	<i>Pan troglodytes</i>	Hominidae
<i>Betatorquevirus homini6</i>	<i>Torque teno mini virus 6</i>	torque teno mini virus 6 TLMV-CBD203	AB026929	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini1</i>	<i>Torque teno mini virus 1</i>	torque teno mini virus 1 TLMV-CBD279	AB026931	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini15</i>	<i>Torque teno mini virus 15</i>	TTV-like mini virus TTMV_LY1	JX134044	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini27</i>	<i>Torque teno mini virus 27</i>	torque teno mini virus ALA22	KM259873	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini16</i>	<i>Torque teno mini virus 16</i>	torque teno mini virus ALH8	KM259874	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini32</i>	<i>Torque teno mini virus 32</i>	torque teno mini virus 18 222	KU041847	<i>Homo sapiens</i>	Hominidae

Table 1 (continued)

New species name	Previous species name	Representative virus name	Accession	Host/source	Host/ source family
<i>Betatorquevirus homini10</i>	<i>Torque teno mini virus 10</i>	torque teno mini virus 10 LIL-y1	EF538880	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini11</i>	<i>Torque teno mini virus 11</i>	torque teno mini virus 11 LIL-y2	EF538881	<i>Homo sapiens</i>	Hominidae
<i>Betatorquevirus homini12</i>	<i>Torque teno mini virus 12</i>	torque teno mini virus 12 LIL-y3	EF538882	<i>Homo sapiens</i>	Hominidae
<i>Chitorquevirus indri1</i>	<i>Torque teno indriid virus 1</i>	torque teno indri virus 1 bet12.15	MF187212	<i>Indri indri</i>	Indriidae
<i>Dalettorquevirus ursid6</i>	<i>Torque teno ursid virus 6</i>	giant panda anellovirus gpan20793	MF327539	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Deltatorquevirus tupai1</i>	<i>Torque teno tupaia virus</i>	torque teno tupaia virus Tbc-TTV14	AB057358	<i>Tupaia belangeri chin- ensis</i>	Tupaiaidae
<i>Epsilontorquevirus calli1</i>	<i>Torque teno tamarin virus</i>	torque teno tamarin virus So-TTV2	AB041960	<i>Saguinus oedipus</i>	Callitrichidae
<i>Etatorquevirus felid1</i>	<i>Torque teno felid virus 1</i>	torque teno felis virus Fc-TTV4	AB076003	<i>Felis catus</i>	Felidae
<i>Etatorquevirus felid2</i>	<i>Torque teno felid virus 2</i>	torque teno felis virus 2 PRA1	EF538877	<i>Felis catus</i>	Felidae
<i>Etatorquevirus felid3</i>	<i>Torque teno felid virus 3</i>	torque teno ocelot virus WF10	MK069470	<i>Leopardus pardalis</i>	Felidae
<i>Etatorquevirus felid4</i>	<i>Torque teno felid virus 4</i>	torque teno felis virus-Fc- TTV2 VS4300008	JF304938	<i>Felis catus</i>	Felidae
<i>Etatorquevirus felid5</i>	<i>Torque teno felid virus 5</i>	torque teno felis virus-Fc- TTV1 VS4300006	JF304937	<i>Felis catus</i>	Felidae
<i>Etatorquevirus viver3</i>	<i>Torque teno viverrid virus 3</i>	Paguma larvata torque teno virus Pl-TTV3	LC387548	<i>Paguma larvata</i>	Viverridae
<i>Gammatorquevirus homidi1</i>	<i>Torque teno midi virus 1</i>	torque teno midi virus 1 MD1-032	AB290917	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi2</i>	<i>Torque teno midi virus 2</i>	torque teno midi virus 2 MD2-013	AB290919	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi3</i>	<i>Torque teno midi virus 3</i>	torque teno midi virus 3 2PoSMA	EF538875	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi4</i>	<i>Torque teno midi virus 4</i>	torque teno midi virus 4 6PoSMA	EF538876	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi5</i>	<i>Torque teno midi virus 5</i>	torque teno midi virus 5 MDJHem2	AB303552	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi6</i>	<i>Torque teno midi virus 6</i>	torque teno midi virus 6 MDJHem3-1	AB303553	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi7</i>	<i>Torque teno midi virus 7</i>	torque teno midi virus 7 MDJHem3-2	AB303554	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi8</i>	<i>Torque teno midi virus 8</i>	torque teno midi virus 8 MDJN1	AB303558	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi9</i>	<i>Torque teno midi virus 9</i>	torque teno midi virus 9 MDJN2	AB303559	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi10</i>	<i>Torque teno midi virus 10</i>	torque teno midi virus 10 MDJN14	AB303560	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi11</i>	<i>Torque teno midi virus 11</i>	torque teno midi virus 11 MDJN47	AB303561	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi12</i>	<i>Torque teno midi virus 12</i>	torque teno midi virus 12 MDJN51	AB303562	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi13</i>	<i>Torque teno midi virus 13</i>	torque teno midi virus 13 MDJN69	AB303564	<i>Homo sapiens</i>	Hominidae
<i>Gammatorquevirus homidi14</i>	<i>Torque teno midi virus 14</i>	torque teno midi virus 14 MDJN97	AB303566	<i>Homo sapiens</i>	Hominidae

Table 1 (continued)

New species name	Previous species name	Representative virus name	Accession	Host/source	Host/ source family
<i>Gammatorquevirus homidi15</i>	<i>Torque teno midi virus 15</i>	torque teno midi virus 15 Pt-TTMDV210	AB449062	<i>Pan troglodytes</i>	Hominidae
<i>Gimeltorquevirus ursid13</i>	<i>Torque teno virus 30</i>	giant panda anellovirus gpan20806	MF327544	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Hetortorquevirus hominid2</i>	<i>Torque teno hominid virus 2</i>	Anelloviridae sp. vztm5	MK212032	<i>Homo sapiens</i>	Hominidae
<i>Iotatorquevirus suida1a</i>	<i>Torque teno sus virus 1a</i>	torque teno sus virus 1 Sd-TTV31	AB076001	<i>Sus scrofa</i>	Suidae
<i>Kappatorquevirus suidak2a</i>	<i>Torque teno sus virus k2a</i>	torque teno sus virus k2a 2p	AY823991	<i>Sus scrofa</i>	Suidae
<i>Kappatorquevirus suidak2b</i>	<i>Torque teno sus virus k2b</i>	torque teno sus virus k2b 38E23	JQ406846	<i>Sus scrofa</i>	Suidae
<i>Lambdatorquevirus phoci5</i>	<i>Torque teno pinniped virus 8</i>	torque teno Leptonychotes weddellii virus 1 TTLwV-1_gt16_wsp8	KY246582	<i>Leptonychotes weddellii</i>	Phocidae
<i>Lambdatorquevirus phoci1</i>	<i>Torque teno pinniped virus 1</i>	seal anellovirus TFFN/USA/2006	HQ287751	<i>Phoca vitulina</i>	Phocidae
<i>Lambdatorquevirus phoci3</i>	<i>Torque teno pinniped virus 3</i>	seal anellovirus 3 12-410	KF373758	<i>Phoca vitulina</i>	Phocidae
<i>Lambdatorquevirus phoci2</i>	<i>Torque teno pinniped virus 2</i>	seal anellovirus 2 12-410	KF373760	<i>Phoca vitulina</i>	Phocidae
<i>Lambdatorquevirus phoci6</i>	<i>Torque teno pinniped virus 9</i>	torque teno Leptonychotes weddellii virus-2 TTLwV-2_gt3_wsp24	KY246547	<i>Leptonychotes weddellii</i>	Phocidae
<i>Mutorquevirus equid1</i>	<i>Torque teno equid virus 1</i>	torque teno equus virus 1	KR902501	<i>Equus caballus</i>	Equidae
<i>Nutorquevirus phoci4</i>	<i>Torque teno pinniped virus 4</i>	seal anellovirus 5 SeAv5-PV13-431	KM262782	<i>Phoca vitulina</i>	Phocidae
<i>Omegatorquevirus hominid1</i>	<i>Torque teno hominid virus 1</i>	gorilla anellovirus GorF	KT027939	<i>Gorilla gorilla</i>	Hominidae
<i>Omicrontorquevirus ursid5</i>	<i>Torque teno ursid virus 5</i>	giant panda anellovirus gpan20684	MF327557	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Pitorquevirus ursid11</i>	<i>Torque teno ursid virus 11</i>	giant panda anellovirus gpan21066	MF327548	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Pitorquevirus ursid12</i>	<i>Torque teno ursid virus 12</i>	giant panda anellovirus gpan21031	MF327547	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Pitorquevirus ursid7</i>	<i>Torque teno ursid virus 7</i>	giant panda anellovirus gpan21094	MF327540	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Pitorquevirus ursid8</i>	<i>Torque teno ursid virus 8</i>	giant panda anellovirus gpan20859	MF327542	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Pitorquevirus ursid9</i>	<i>Torque teno ursid virus 9</i>	giant panda anellovirus gpan20868	MF327550	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Pitorquevirus ursid10</i>	<i>Torque teno ursid virus 10</i>	giant panda anellovirus gpan20688	MF327541	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Psitorquevirus procy4</i>	<i>Torque teno procyo virus 4</i>	Anelloviridae sp. ctf003	MK012516	<i>Procyon lotor</i>	Procyonidae
<i>Rhotorquevirus murid1</i>	<i>Torque teno rodent virus 1</i>	rodent torque teno virus 1 AS_WM1_Sp_1	KJ194617	<i>Apodemus sylvaticus</i>	Muridae
<i>Sigmatorquevirus otari1</i>	<i>Torque teno pinniped virus 5</i>	California sea lion anellovirus	FJ459582	<i>Zalophus californianus</i>	Otariidae
<i>Sigmatorquevirus otari2</i>	<i>Torque teno pinniped virus 6</i>	torque teno Arctocephalus gazella virus 1 ASV20_172	MG837569	<i>Arctocephalus gazella</i>	Otariidae
<i>Sigmatorquevirus otari3</i>	<i>Torque teno pinniped virus 7</i>	torque teno Arctocephalus gazella virus 2 ASV35_197	MG837571	<i>Arctocephalus gazella</i>	Otariidae

Table 1 (continued)

New species name	Previous species name	Representative virus name	Accession	Host/source	Host/ source family
<i>Tettorquevirus felid6</i>	<i>Torque teno felid virus 6</i>	feline anellovirus Felin-eAV621	KX262893	<i>Felis catus</i>	Felidae
<i>Thetatorquevirus ixodi1</i>	<i>Torque teno arthrovec virus 3</i>	tick associated torque teno virus tick24_1	MF173068	<i>Dermacentor variabilis</i>	Ixodidae
<i>Thetatorquevirus mustel1</i>	<i>Torque teno mustilid virus 1</i>	pine marten torque teno virus 1 VS4700004	JN704611	<i>Martes americana</i>	Mustelidae
<i>Thetatorquevirus procy5</i>	<i>Torque teno procyo virus 5</i>	Anelloviridae sp. ctdb009	MK012446	<i>Procyon lotor</i>	Procyonidae
<i>Thetatorquevirus procy6</i>	<i>Torque teno procyo virus 6</i>	Anelloviridae sp. cthe000	MK012439	<i>Procyon lotor</i>	Procyonidae
<i>Thetatorquevirus ursid2</i>	<i>Torque teno ursid virus 2</i>	giant panda anellovirus gpan20783	MF327551	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Thetatorquevirus ursid3</i>	<i>Torque teno ursid virus 3</i>	giant panda anellovirus gpan20682	MF327552	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Thetatorquevirus ursid4</i>	<i>Torque teno ursid virus 4</i>	giant panda anellovirus gpan20724	MF327554	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Thetatorquevirus viver4</i>	<i>Torque teno viverrid virus 4</i>	Paguma larvata torque teno virus Pl-TTV9-2	LC387543	<i>Paguma larvata</i>	Viverridae
<i>Thetatorquevirus canid1</i>	<i>Torque teno canid virus 1</i>	torque teno canis virus Cf-TTV10	AB076002	<i>Canis lupus familiaris</i>	Canidae
<i>Thetatorquevirus ursid1</i>	<i>Torque teno ursid virus 1</i>	lesser panda anellovirus chengdu-1	KX611132	<i>Ailuropoda melanoleuca</i>	Ursidae
<i>Upsilontorquevirus procy1</i>	<i>Torque teno procyo virus 1</i>	Anelloviridae sp. ctcf003	MK012447	<i>Procyon lotor</i>	Procyonidae
<i>Upsilontorquevirus procy2</i>	<i>Torque teno procyo virus 2</i>	Anelloviridae sp. ctcf007	MK012527	<i>Procyon lotor</i>	Procyonidae
<i>Upsilontorquevirus procy3</i>	<i>Torque teno procyo virus 3</i>	Anelloviridae sp. ctdc005	MK012497	<i>Procyon lotor</i>	Procyonidae
<i>Upsilontorquevirus procy7</i>	<i>Torque teno procyo virus 7</i>	Anelloviridae sp. ctbd010	MK012464	<i>Procyon lotor</i>	Procyonidae
<i>Upsilontorquevirus procy8</i>	<i>Torque teno procyo virus 8</i>	Anelloviridae sp. ctbb008	MK012467	<i>Procyon lotor</i>	Procyonidae
<i>Upsilontorquevirus procy9</i>	<i>Torque teno procyo virus 9</i>	Anelloviridae sp. ctbb005	MK012471	<i>Procyon lotor</i>	Procyonidae
<i>Upsilontorquevirus viver2</i>	<i>Torque teno viverrid virus 2</i>	Paguma larvata torque teno virus Pl-TTV9-1	LC387546	<i>Paguma larvata</i>	Viverridae
<i>Wawtorquevirus crice1</i>	<i>Torque teno rodent virus 6</i>	rodent torque teno virus 8 2252	MF541389	<i>Oligoryzomys nigripes</i>	Cricetidae
<i>Wawtorquevirus culic2</i>	<i>Torque teno arthrovec virus 2</i>	mosquito VEM Anellovirus SDRB A	HQ335084	Mosquitoes (mixed species)	Culicidae
<i>Wawtorquevirus murid2</i>	<i>Torque teno rodent virus 4</i>	rodent torque teno virus 2 AS_WM1_Se_4	KJ194604	<i>Apodemus sylvaticus</i>	Muridae
<i>Wawtorquevirus murid3</i>	<i>Torque teno rodent virus 5</i>	rodent torque teno virus 2 RN_8_Se11	KM609325	<i>Rattus norvegicus</i>	Muridae
<i>Wawtorquevirus crice2</i>	<i>Torque teno rodent virus 2</i>	rodent torque teno virus 3 2	MF541374	<i>Akodon montensis</i>	Cricetidae
<i>Wawtorquevirus crice3</i>	<i>Torque teno rodent virus 3</i>	rodent torque teno virus 7 15	MF541388	<i>Akodon montensis</i>	Cricetidae
<i>Xitorquevirus didel1</i>	<i>Torque teno didelphi virus 1</i>	torque teno didelphis albiventris virus 3470	MF541378	<i>Didelphis albiventris</i>	Didelphidae
<i>Xitorquevirus molos1</i>	<i>Torque teno chiroptera virus 1</i>	torque teno Tadarida brasiliensis virus	KM434181	<i>Tadarida brasiliensis</i>	Molossidae
<i>Zayintorquevirus viver1</i>	<i>Torque teno viverrid virus 1</i>	Paguma larvata torque teno virus Pl-TTV5-2	LC387540	<i>Paguma larvata</i>	Viverridae
<i>Zayintorquevirus viver5</i>	<i>Torque teno viverrid virus 5</i>	Paguma larvata torque teno virus Pl-TTV1-1	LC387536	<i>Paguma larvata</i>	Viverridae
<i>Zetatorquevirus aotid1</i>	<i>Torque teno douroucouli virus</i>	torque teno douroucouli virus At-TTV3	AB041961	<i>Aotus trivirgatus</i>	Aotidae
<i>Gyrovirus chickenanemia</i>	<i>Chicken anemia virus</i>	chicken anemia virus Cuxhaven-1	M55918	<i>Gallus gallus domesticus</i>	Phasianidae
<i>Gyrovirus fulglal</i>	-	gyrovirus GyV8	KR137527	<i>Fulmarus glacialis</i>	Procellariidae

Table 1 (continued)

New species name	Previous species name	Representative virus name	Accession	Host/source	Host/ source family
<i>Gyrovirus galga1</i>	-	avian gyrovirus 2	HM590588	<i>Gallus gallus</i>	Phasianidae
<i>Gyrovirus galga2</i>	-	gyrovirus GyV7-SF	KM111536	<i>Gallus gallus</i>	Phasianidae
<i>Gyrovirus homsa1</i>	-	gyrovirus GyV3	JQ308210	<i>Homo sapiens</i>	Hominidae
<i>Gyrovirus homsa2</i>	-	gyrovirus Tu789	KF294862	<i>Homo sapiens</i>	Hominidae
<i>Gyrovirus homsa3</i>	-	gyrovirus 4 D137	JX310702	<i>Homo sapiens</i>	Hominidae
<i>Gyrovirus homsa4</i>	-	gyrovirus Tu243	KF294861	<i>Homo sapiens</i>	Hominidae
<i>Gyrovirus hydho1</i>	-	ashy storm petrel gyrovirus a12a1_528	MH378452	<i>Hydrobates homochroa</i>	Hydrobatidae
<i>Gyrovirus myferr1</i>	-	gyrovirus 11	MH638372	<i>Myrmoderus ferrugineus</i>	Thamnophilidae

A representative virus has been chosen for each species. For nine species in the genus *Gyrovirus*, there is no species name change because binomial species names were assigned during the establishment of these species by Kraberger et al. [4].

al. [10] and Postler et al. [11]). The species name is different from the name of a virus [12].

Here, we provide an update on the revised species names (using a freeform alphanumeric epithet where possible) for all species in the family *Anelloviridae* (Table 1). Nine species in the genus *Gyrovirus* have previously been named in binomial freeform alphanumeric epithet format with the five-letter epithet derived from the host species followed by a number [4]. Given that viruses in the previous species "*Chicken anemia virus*" (genus *Gyrovirus*) have been associated with disease, we have renamed this species *Gyrovirus chickenanemia*.

In general, we have used the first five letters of the name of the host or the source family (e.g., "phoca" for Phocidae) followed by a number such that each epithet is unique. In the case of species in the genus *Betatorquevirus*, we have used the epithet "homini" followed by a number to reflect "mini" from the name torque teno mini virus, e.g., the previous species "*Torque teno mini virus 1*" has been renamed *Betatorquevirus homini1*. On the other hand, in the case of the species in the genus *Gammatorquevirus*, we have used the epithet "homidi" followed by a number to reflect "midi" from the name torque teno midi virus, e.g., the previous species name "*Torque teno midi virus 1*" has been changed to *Gammatorquevirus homidi1*.

A summary of the changes is provided in Table 1. In addition, we provide an ORF1/VP1-protein-sequence-based phylogeny in Figure 1 showing genera and species using representative virus sequences as a reference. The ORF1/VP1 protein of the representative anellovirus sequences detailed in the virus metadata resources (<https://ictv.global/vmr>) [8] were assembled and aligned using MAFFT [13], and the alignment was then trimmed using TrimAL [14] with a gap setting of 0.2. This trimmed alignment was used to infer a maximum-likelihood phylogenetic tree in PHYML 3 [15] with aLRT branch support and with VT+G+F as the best substitution model determined using ProtTest 3 [16]. The resulting phylogeny was visualized in iTOL 6 [17].

As more anellovirus genomes are identified from various hosts, coupled with more insights into their genomes and coding regions, we expect to see an increased number of new species and genera and a revision of species demarcation in the near future. Further, it is likely that the family *Anelloviridae*, which is currently not assigned to any phylum or higher ranks would be classified in a new phylum, "*Commensaviricota*", in the kingdom *Shotokuvirae* (realm *Monodnaviria*), as proposed by Butkovic et al. [7].

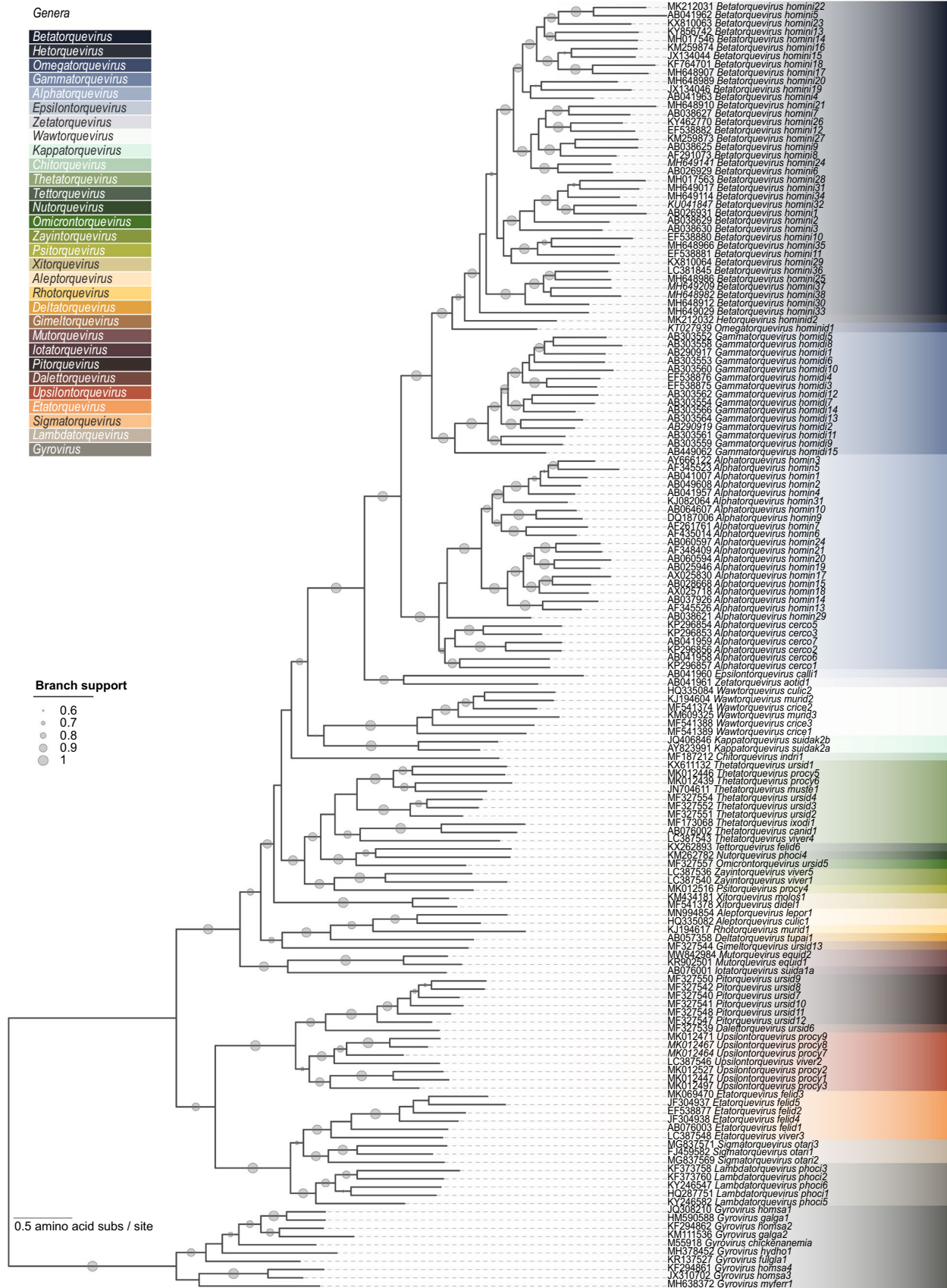


Fig. 1 Maximum-likelihood phylogenetic tree of the representative ORF1/VP1 protein sequences of anelloviruses from each species. The accession number of the representative sequence is provided next to the binomial species name. The phylogenetic tree is rooted with gyrovirus sequences. Branch support is shown for branches with >0.6 aLRT support.

Funding The authors have not disclosed any funding.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare there are no conflicts of interest.

Research involving human participants and/or animals The research did not involve human participants or animals.

References

- Biagini P (2009) Classification of TTV and related viruses (anelloviruses). *Curr Top Microbiol Immunol* 331:21–33
- Biagini P, Bendinelli M, Hino S, Kakkola L, Mankertz A, Niel C, Okamoto H, Raidal S, Teo CG, Todd D (2012) Family Anelloviridae. In: King AMQ, Adams EB, Carstens EB, E.J. L (eds) *Virus taxonomy : Ninth report of the International Committee on Taxonomy of Viruses*. Academic press, London ; Waltham, MA, pp 331–341
- Kato A, Fujino M, Nakamura T, Ishihama A, Otaki Y (1995) Gene organization of chicken anemia virus. *Virology* 209:480–488
- Kraberger S, Opriessnig T, Celer V, Maggi F, Okamoto H, Blomstrom AL, Cadar D, Harrach B, Biagini P, Varsani A (2021) Taxonomic updates for the genus Gyrovirus (family Anelloviridae): recognition of several new members and establishment of species demarcation criteria. *Arch Virol* 166:2937–2942
- Varsani A, Opriessnig T, Celer V, Maggi F, Okamoto H, Blomstrom AL, Cadar D, Harrach B, Biagini P, Kraberger S (2021) Taxonomic update for mammalian anelloviruses (family Anelloviridae). *Arch Virol* 166:2943–2953
- Wu Q, Xu X, Chen Q, Ji J, Kan Y, Yao L, Xie Q (2019) Genetic Analysis of Avian Gyrovirus 2 Variant-Related Gyrovirus Detected in Farmed King Ratsnake (*Elaphe carinata*): The First Report from China. *Pathogens* 8
- Butkovic A, Kraberger S, Smeele Z, Martin DP, Schmidlin K, Fontenele RS, Shero MR, Beltran RS, Kirkham AL, Aleamotu'a M, Burns JM, Koonin EV, Varsani A, Krupovic M (2023) Evolution of anelloviruses from a circovirus-like ancestor through gradual augmentation of the jelly-roll capsid protein. *Virus Evol* 9:vead035
- Siddell SG, Smith DB, Adriaenssens E, Alfenas-Zerbini P, Dutilh BE, Garcia ML, Junglen S, Krupovic M, Kuhn JH, Lambert AJ, Lefkowitz EJ, Lobočka M, Mushegian AR, Oksanen HM, Robertson DL, Rubino L, Sabanadzovic S, Simmonds P, Suzuki N, Van Doorslaer K, Vandamme AM, Varsani A, Zerbini FM (2023) Virus taxonomy and the role of the International Committee on Taxonomy of Viruses (ICTV). *J Gen Virol* 104
- Walker PJ, Siddell SG, Lefkowitz EJ, Mushegian AR, Adriaenssens EM, Alfenas-Zerbini P, Davison AJ, Dempsey DM, Dutilh BE, Garcia ML, Harrach B, Harrison RL, Hendrickson RC, Junglen S, Knowles NJ, Krupovic M, Kuhn JH, Lambert AJ, Lobočka M, Nibert ML, Oksanen HM, Orton RJ, Robertson DL, Rubino L, Sabanadzovic S, Simmonds P, Smith DB, Suzuki N, Van Doorslaer K, Vandamme AM, Varsani A, Zerbini FM (2021) Changes to virus taxonomy and to the International Code of Virus Classification and Nomenclature ratified by the International Committee on Taxonomy of Viruses (2021). *Arch Virol* 166:2633–2648
- Siddell SG, Walker PJ, Lefkowitz EJ, Mushegian AR, Dutilh BE, Harrach B, Harrison RL, Junglen S, Knowles NJ, Kropinski AM, Krupovic M, Kuhn JH, Nibert ML, Rubino L, Sabanadzovic S, Simmonds P, Varsani A, Zerbini FM, Davison AJ (2020) Binomial nomenclature for virus species: a consultation. *Arch Virol* 165:519–525
- Postler TS, Rubino L, Adriaenssens EM, Dutilh BE, Harrach B, Junglen S, Kropinski AM, Krupovic M, Wada J, Crane A, Kuhn JH, Mushegian A, Rumnieks J, Sabanadzovic S, Simmonds P, Varsani A, Zerbini FM, Callanan J, Draper LA, Hill C, Stockdale SR (2022) Guidance for creating individual and batch latinized binomial virus species names. *J Gen Virol* 103
- Zerbini FM, Siddell SG, Mushegian AR, Walker PJ, Lefkowitz EJ, Adriaenssens EM, Alfenas-Zerbini P, Dutilh BE, Garcia ML, Junglen S, Krupovic M, Kuhn JH, Lambert AJ, Lobočka M, Oksanen HM, Robertson DL, Rubino L, Sabanadzovic S, Simmonds P, Suzuki N, Van Doorslaer K, Vandamme AM, Varsani A (2022) Differentiating between viruses and virus species by writing their names correctly. *Arch Virol* 167:1231–1234
- Katoh K, Standley DM (2016) A simple method to control over-alignment in the MAFFT multiple sequence alignment program. *Bioinformatics* 32:1933–1942
- Capella-Gutierrez S, Silla-Martinez JM, Gabaldon T (2009) trimAl: a tool for automated alignment trimming in large-scale phylogenetic analyses. *Bioinformatics* 25:1972–1973
- Guindon S, Dufayard JF, Lefort V, Anisimova M, Hordijk W, Gascuel O (2010) New algorithms and methods to estimate maximum-likelihood phylogenies: assessing the performance of PhyML 3.0. *Syst Biol* 59:307–321
- Darriba D, Taboada GL, Doallo R, Posada D (2011) ProtTest 3: fast selection of best-fit models of protein evolution. *Bioinformatics* 27:1164–1165
- Letunic I, Bork P (2021) Interactive Tree Of Life (iTOL) v5: an online tool for phylogenetic tree display and annotation. *Nucleic Acids Res* 49:W293–W296

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.