Supplementary Figure 1
Genes showing multiple signs of adaptation (MSA)

Locus Name: Folate receptor 1 alpha (FOLR1)

ENSBTAT00000027602 FOLR1-201   folate receptor   embryogenesis, folate homeostasis
mouse: growth retardation, neural and cranofacial defects die at E10

PSG: (Giraffe) G47S|GGC/AGC; P48S|CCA/TCT; K61E|AAG/GAG; E222K|GAG/AAG; G235Q|GGG/CAG

PP2: (Giraffe) P49S, E223K;(Giraffe/Okapi) D51S, A22Q

Giraffe: P48S UPS, E54G UPS, R122T UPS, E222K UIS, G235Q UPS
Okapi: A20S UPS

Protein sequence Alignment of Cow, Giraffe and Okapi FOLR1

```
Cow          1      MAWQMTQLLLLALVAAAWGAQAPRTPRARTDLLNVCMDAKHHKAEPGPEDSLHEQCSPWR  60
Giraffe      1      ...K.................V.G.............N........SS.S...G......  60
Okapi        1      ...K...............S.V.G.............N...........S..........  60

Cow          61     KNACCSVNTSIEAHKDISYLYRFNWDHCGKMEPACKRHFIQDTCLYECSPNLGPWIREVN  120
Giraffe      61     E...........................................................  120
Okapi        61     ............................................................  120

Cow          121    QRWRKERVLGVPLCKEDCQSWWEDCRTSYTCKSNWHKGWNWTSGYNQCPVKAACHRFDFY  180
Giraffe      121    .T.......N.........I................R..D....................  180
Okapi        121    .S.......N.........I................R..D....................  180

Cow          181    FPTPAALCNEIWSHSYKVSNYSRGSGRCIQMWFDPFQGNPNEEVARFYAENPTSGSTPQG  240
Giraffe      181    .....................G...................K..........N.Q.....  240
Okapi        181    .....................G..............................N.......  240

Cow          241    I
Giraffe      241    .
Okapi        241    .
```

Newick Tree of Mammalian FOLR1

```
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(rhino:0.0803279, ((walrus:0.00727225, weddel_seal:0.0126104):0.065253,
cat:0.0713098):0.0423044):0.00400162):0.0122881, elephant:0.118106):0.0159987,
((dolphin:0.0509221, (orca:0.0171223, ((sperm_whale:0.0137419,
baiji_dolphin:0.0138767):0.000462631, minke_whale:0.041772):0.0109803):0.0150048):0.0134242,
((cow:0.00287772, yak:0.00545576):0.00515902, ((tibetan_antelope:0.00599731,
sheep:0.00962865):0.013353, (giraffe:0.0273562,
okapi:0.00815797):0.0355917):0.00359502):0.0559345):0.0372389):0.0352274):0.0517348):0.0053625):0
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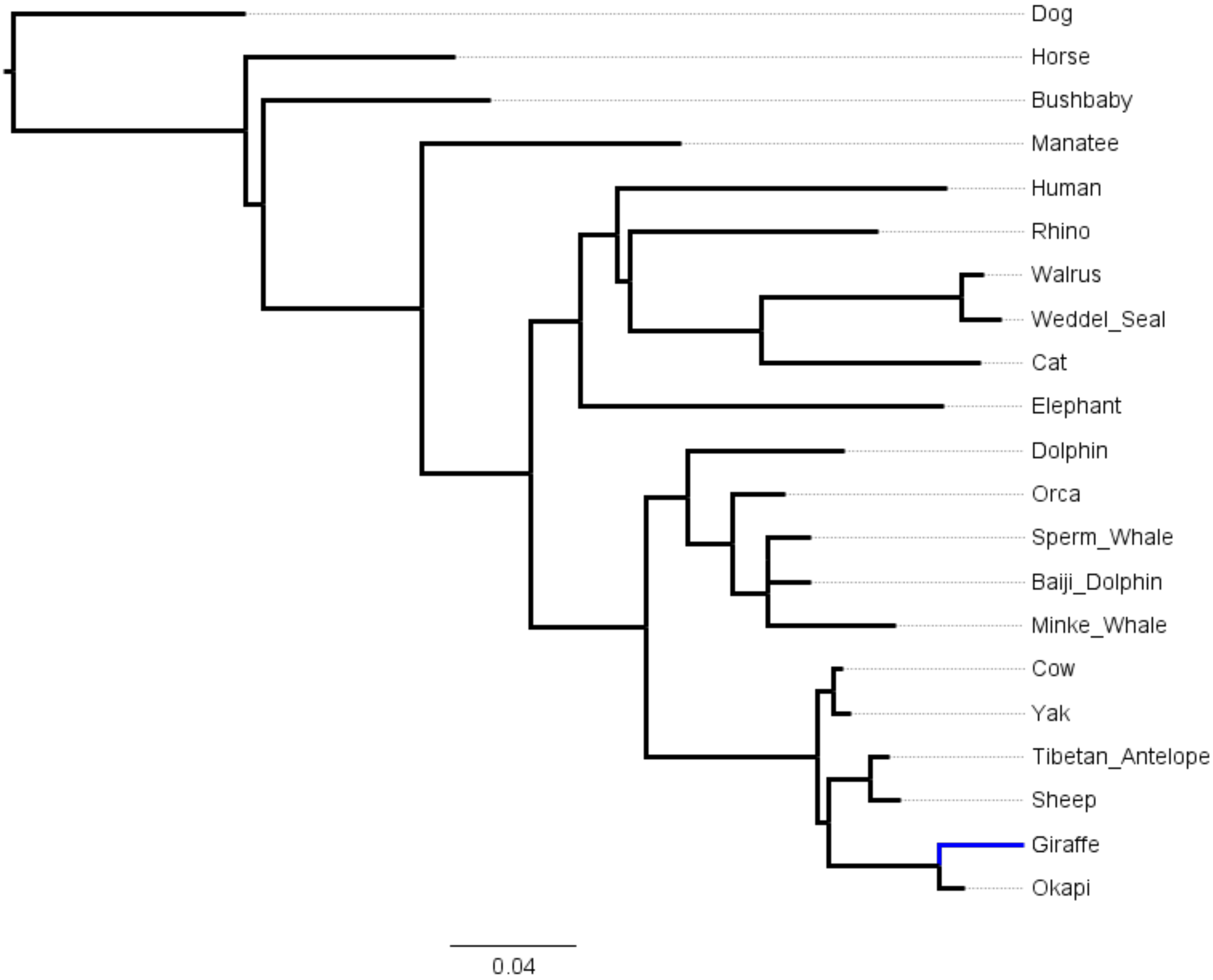


Locus Name: Folate receptor 1 alpha (FOLR1)

Locus Name: Homeobox B3 (HoxB3)

ENSBTAT00000028563 HOXB3-201 homeobox transcription factor segmental identity, anterior axial skeleton, angiogenesis
mouse: defects in cervical vertebrae, atlas, formation of IXth cranial nerve

PP2: (Giraffe) S98I; (Giraffe/Okapi) M282I, P403A

Giraffe: S98I UIS, G113S UPS,
Giraffe/Okapi: P115S UIS, M77I UIS, P398A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi HoxB3

```
Cow          1      MQKATYYDNTAAALFGGYPSYPGSNGFGYDGPPQPPFQAATHLESDYQRSACSLQSLGNA  60
Giraffe      1      .............................E.............................G  60
Okapi        1      ............................................................  60

Cow          61     APHAKGKELNGSCMRPGLASEPLPAPPGSPPPSAAPTSTTSNSSNGGGPSKSGPPKCGAG  120
14540        61     .....S...............................I..............S.S.....  120
14541        61     .....S................................................S.....  120

Cow          121    SNSTLTKQIFPWMKESRQTSKLKNSSPGTAEGCGSGGGGGGGSGSSGGGGGGGDKSPPGS  180
14540        121    ..................................G.........G...............  183
14541        121    ..................................G.........G...............  184

Cow          181    AASKRARTAYTSAQLVELEKEFHFNRYLCRPRRVEMANLLNLSERQIKIWFQNRRMKYKK  240
14540        184    ............................................................  243
14541        185    ............................................................  244

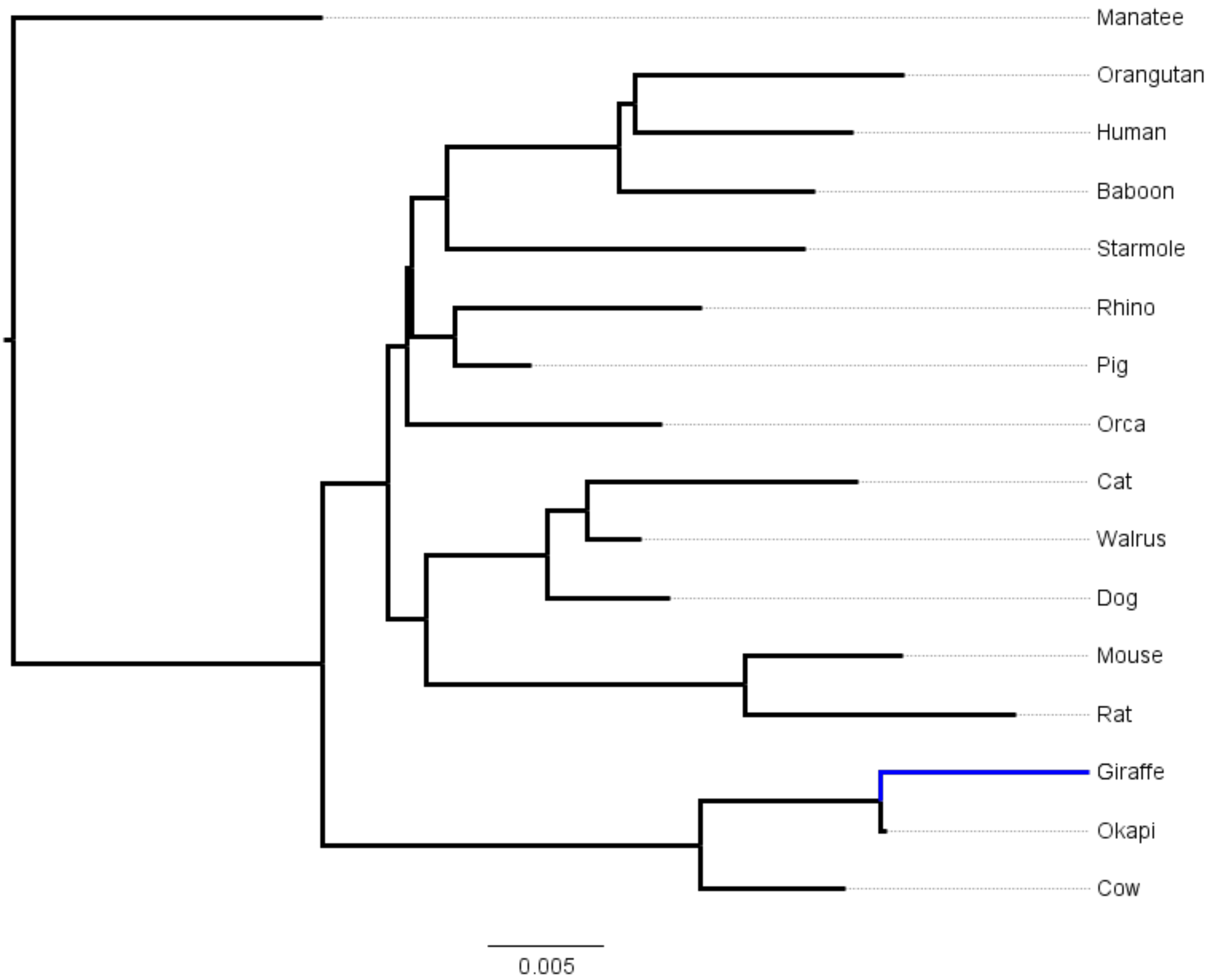
Cow          241    DQKAKGLASSSGGPSPAGSPSQPMQSTAGFMNALHSMTPSYESPSPPAFGKAHQNAYALP  300
14540        244    ....................................I.......................  303
14541        245    ....................................I.......................  304

Cow          301    SNYQPPLKGCGAPQKYPQTPAPDYEPHVLQTNGGAYGTPTMQGSPVYVGGGGYADPLPPP  360
14540        304    ............................................................  363
14541        305    ............................................................  364

Cow          361    AGPSLYGLNHLSHHPSGNLDYNGAPPMAPSQHHGPCDPHPTYTDLSSHHAPPPQGRIQEA  420
14540        364    .....................................A......................  423
14541        365    .....................................A......................  424

Cow          421    PKLTHL  427
14540        424    ......  430
14541        425    ......  431
```

Newick Tree of Mammalian HoxB3
(manatee:0.0134567, ((cow:0.00638513, (giraffe:0.00908205,
okapi:0.00026395):0.0078677):0.0164519, (((rat:0.011867, mouse:0.00691398):0.0138423,
(dog:0.00532972, (walrus:0.00233832, cat:0.0118133):0.00175755):0.00524476):0.00171903,
(orca:0.0111089, ((pig:0.00334083, rhino:0.0107775):0.00188319, (starmole:0.0156363,
(baboon:0.0085923, (human:0.00948222,
orangutan:0.0117216):0.000754308):0.00750944):0.00152221):0.000185431):0.000854271):0.00283764):0
.0134567);



Locus Name: Homeobox B3 (HoxB3)

Locus name Homeobox B13 (HOXB13)

ENSBTAT00000019523 HOXB13-201   homeobox transcription factor   segmental identity, posterior axial skeleton, angiogenesis
mouse: caudal vertebrae and angiogenesis impaired and overgrowth in all major structures derived from the tail bud

PP2 (Giraffe/Okapi): S122I, H160R, W195C

Giraffe: A108G UPS
Giraffe/Okapi: S123I unique, APVP deletion unique, H160R UIS, W196C UIS,

Protein sequence Alignment of Cow, Giraffe and Okapi HOXB13

```
Cow       1  MEPSNYTTLDGAKEIEGLLGAGGSRNLVTHSPLTSHPTSAPTLMPAVNYAPLDLPGSAEP  60
Giraffe   1  ...G.......T.........................AA.....................  60
Okapi     1  ...G.................................AA....L................  60

Cow      61  PKQCHPCPGVPQGASPAPVPYGYFGGGYYSCRVSRSSLKPCAQAATLAAYPAETPTSGEE  120
Giraffe  61  ................----...........................G.......A....  116
Okapi    61  ..........T.....----...................................A....  116

Cow     121  YPSRPTEFAFYPGYPGPYQPMASYLDVSVVQTLGAPGEPRHDSLLPVDSYQPWALTGGWN  180
Giraffe 117  ..I...........S.....V...................R..........S....S...  176
Okapi   117  ..I...........S.....V...................R..........S....S...  176

Cow     181  SQMCCQGEQNPPGPFWKAAFADSSSQHPPEGCTFRRGRKKRIPYSKGQLRELEREYSANK  240
Giraffe 177  .............S.C........V....D..A...........................  236
Okapi   177  .............S.C........V....D..AL..........................  236

Cow     241  FITKDKRRKISAATSLSERQITIWFQNRRVKEKKVLAKVKTS 282
Giraffe 237  ......................................L... 278
Okapi   237  ......................................L... 278
```

Newick Tree of Mammalian HOXB13

(rabbit:0.0180279, ((dog:0.00423827, (walrus:0.00170297, cat:0.0124487):0.002849):0.00610416,
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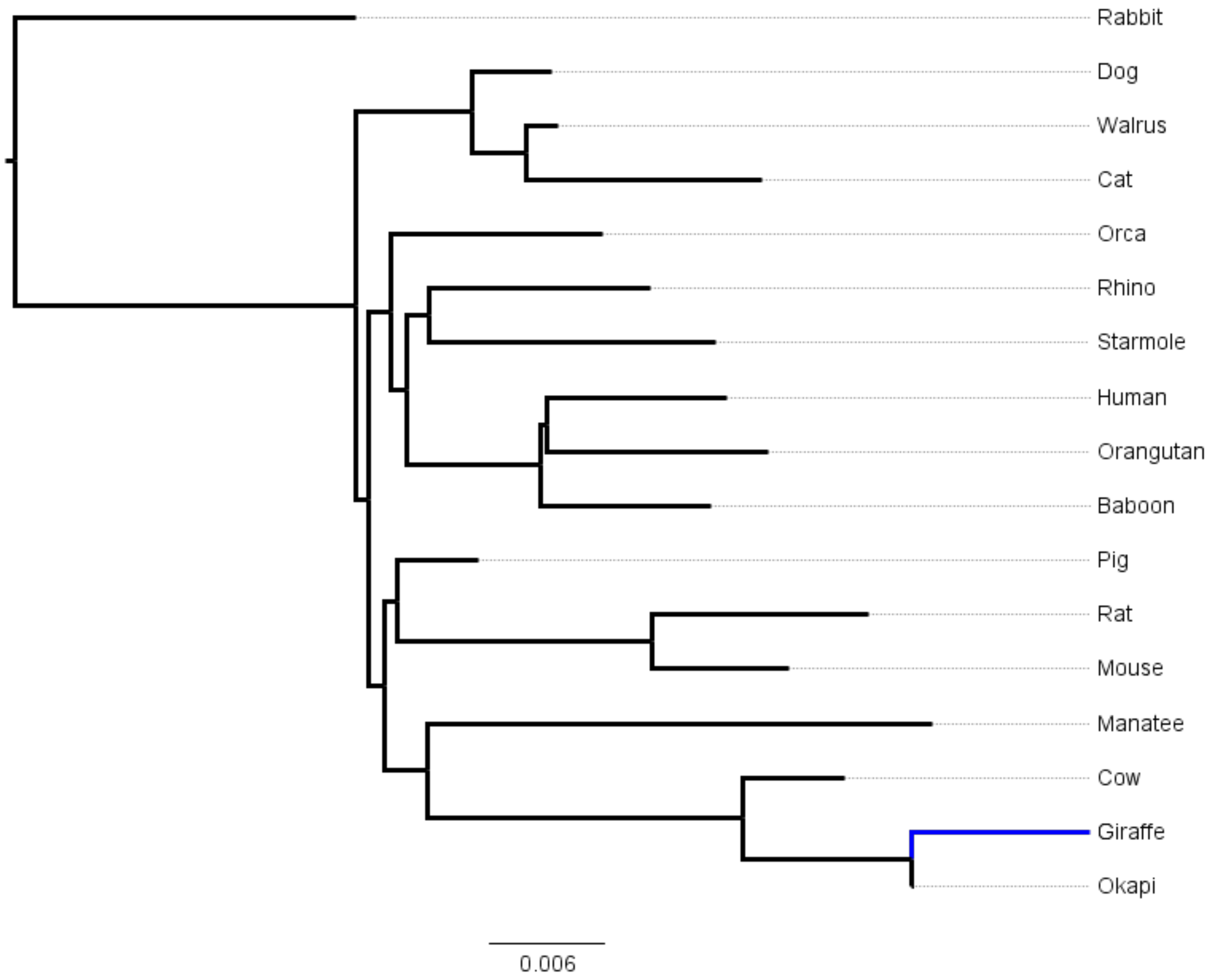
orangutan:0.0116872):0.000328021, baboon:0.00901859):0.00711139):0.000839773):0.00113203,
((pig:0.00433482, (rat:0.0115056, mouse:0.00727538):0.013488):0.000606871, (manatee:0.0266819,
(cow:0.00537304, (giraffe:0.00941327,
okapi:0):0.00887979):0.0166834):0.00225322):0.000864063):0.000653822):0.0180279);



Locus name Homeobox B13 (HOXB13)

Locus Name: Homeobox D9 (HOXD9)

ENSBTAT00000021336 HOXD9-201   HoxD9 homeobox transcription factor   segmental identity, mid axial skeleton, forelimb development, angiogenesis
mouse: abnormalities in forelimb, lumbar, sacral, caudal vertebrae

Giraffe: G124S UIS, GAGIGSGS deletion 219-226 UIS in cetartiodacytls
Okapi: S255L UPS

Protein sequence Alignment of Cow, Giraffe and Okapi HOXD9

```
Cow        1  MSSSGTLSNYYVDSLIGHEGDEVFAGRFGPPGPGAQGRPAGVADSPAAAAAEFASCSFAP  60
Giraffe    1  ............................................................  60
Okapi      1  ............................................................  60

Cow       61  KSAVFSASWSAVPAQPPAAAAMSGLYHPYVPPPPLAASASEPGRYMRSWMEPLPGFPGGA  120
Giraffe   61  ............................................................  120
Okapi     61  ............................................................  120

Cow      121  GGGGGGGGSGGGPGPGPSPGPSGPPNGRHYGIKPESGAAPTPAAASTTSTSSTSSSSSSK  180
Giraffe  121  ...SS...G....................................-..............  179
Okapi    121  .S..S...G....................................-..............  179

Cow      181  RTECSAARESQGSGGPEFSCNSFLRDKVAAAAAGGTGPGAGIGSGSGAGGTSEPSACSDH  240
Giraffe  180  ......................................--------....S.........  231
Okapi    180  ..................................................S.........  239

Cow      241  PSPGCPLKEEEKQHSQAPQQQLDPNNPAANWIHARSTRKKRCPYTKYQTLELEKEFLFNM  300
Giraffe  232  ............................................................  291
Okapi    240  ..............L.............................................  299

Cow      301  YLTRDRRYEVARILNLTERQVKIWFQNRRMKMKKMSKEKCPKGD  345
Giraffe  292  .............................................  336
Okapi    300  .............................................  344
```

Newick Tree of Mammalian HOXD9

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rat:0.000698627):0.0322236, rabbit:0.0241599):0.00187279):0.00376309):0.00384313,
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(((sperm_whale:0.00335994, (orca:0, dolphin:0.00353369):0.000161231):0.000527845,
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alpaca:0.0194144):0.0316376, ((Giraffe:0.00771686, Okapi:0.0102379):0.0404145, ((sheep:0.0109289,
tibet_antelope:0.00677159):0.00652728, (water_buffalo:0.00528391, (Cow:0.00713736,
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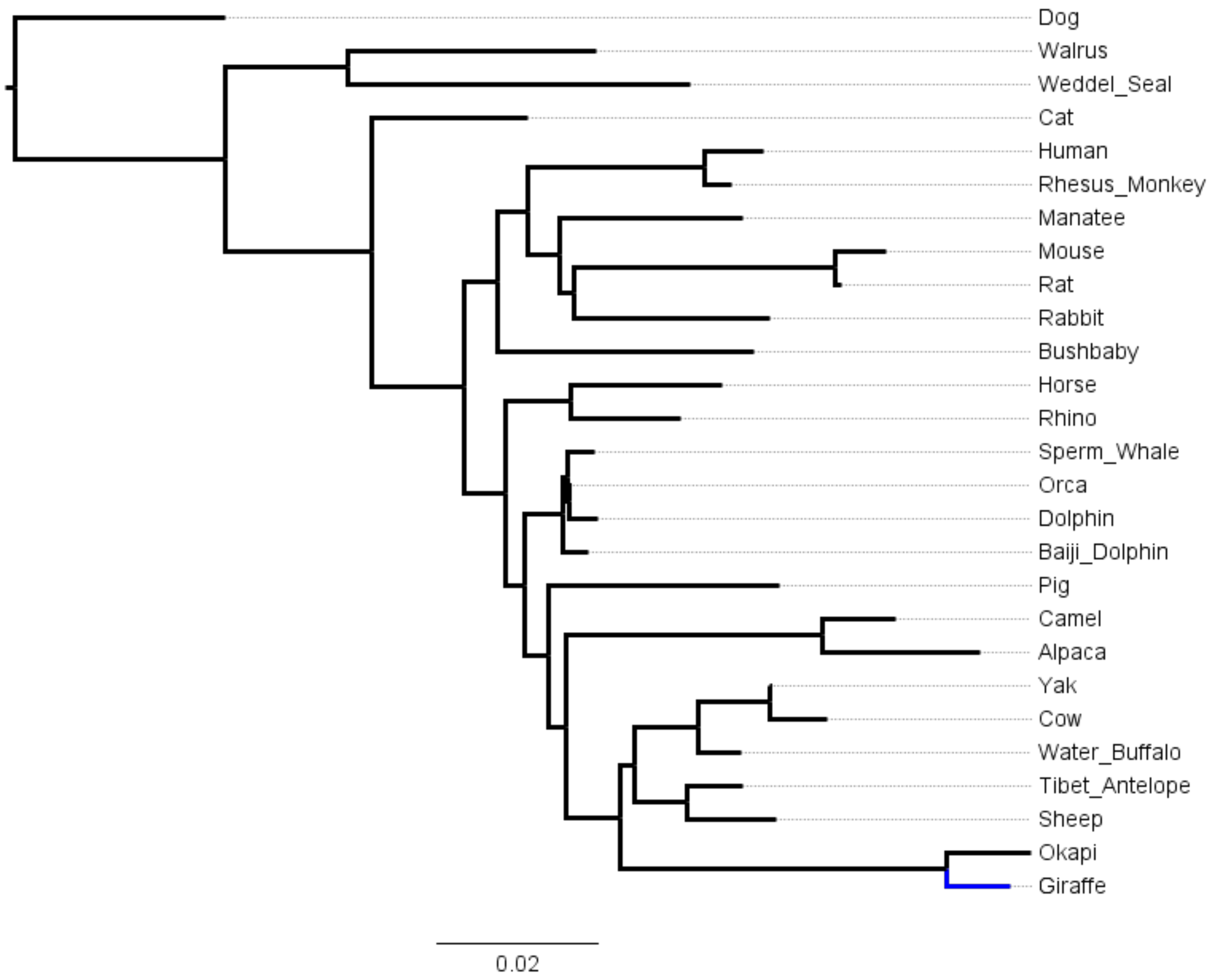

Locus Name: Homeobox D9 (HOXD9)

Locus Name: Caudal Type Homeobox 4 (CDX4)

ENSBTAT00000002260 CDX4-201 homeobox transcription factor segmental identity, posterior axial skeleton, heart development mouse: defects in axial skeleton development

PP2: (Giraffe) S250C; (Giraffe/Okapi) D140N; (Okapi) V246M

Giraffe: M93T UPS, S251C UIS
Giraffe/Okapi: T130P UPS, N140D UIS

Protein sequence Alignment of Cow, Giraffe and Okapi CDX4

```
Cow          1      MYRSCLLEKEADMYSSTLRSPAGGGTAGAGATGDGGSPLPASNFAAAPSYAHYMGYPHMP  60
Giraffe      1      ............................................S....F..D.......  60
Okapi        1      .........................P...........................D.......  60

Cow          61     GMDPHGPPLGAWGSPYSPPREDWSVYPGPSSTMGTVPMNDMSSSPAAFSSLEYSNLGPAG  120
Giraffe      61     ............................Q...T........T........P.........  120
Okapi        61     .....................................V...T........P.........  120

Cow          121    GGNSGSSLPTPAGGSLFPIDAGIADADESSSRSRHSPYAWMRKTVQVTGKTRTKEKYRVV  180
Giraffe      121    .........P.........N...--...................................  178
Okapi        121    .........P.........N...--..V................................  178

Cow          181    YTDHQRLELEKEFHCNRYITIRRKSELAVNLGLSERQVKIWFQNRRAKERKMIKKKISQF  240
Giraffe      179    ............................I...............................  238
Okapi        181    ............................................................  238

Cow          241    ENSGGSVQSDSGSISPGELPNIFFTTPSAVRGFQPIEIQQVIVSE   285
Giraffe      239    ..........C..........T.......................   283
Okapi        241    ......M....D.........T.......................   283
```

Newick Tree of Mammalian CDX4

```
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horse:0.0229299):0.0149351, (((Macaque:0.0334678, (orangutan:0.0167002,
human:0.0228125):0.0104206):0.0451086, ((mouse:0.0197583, rat:0.0126827):0.0823364,
(walrus:0.0141256, weddell_seal:0.0108337):0.0598136):0.00930766):0.00360017,
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okapi:0.0175872):0.00900926, ((tibetan_antelope:0.00264641, (sheep:0.00257207,
goat:0.00096776):0.00267596):0.000454067, (water_buffalo:0.00355976, (cow:0,
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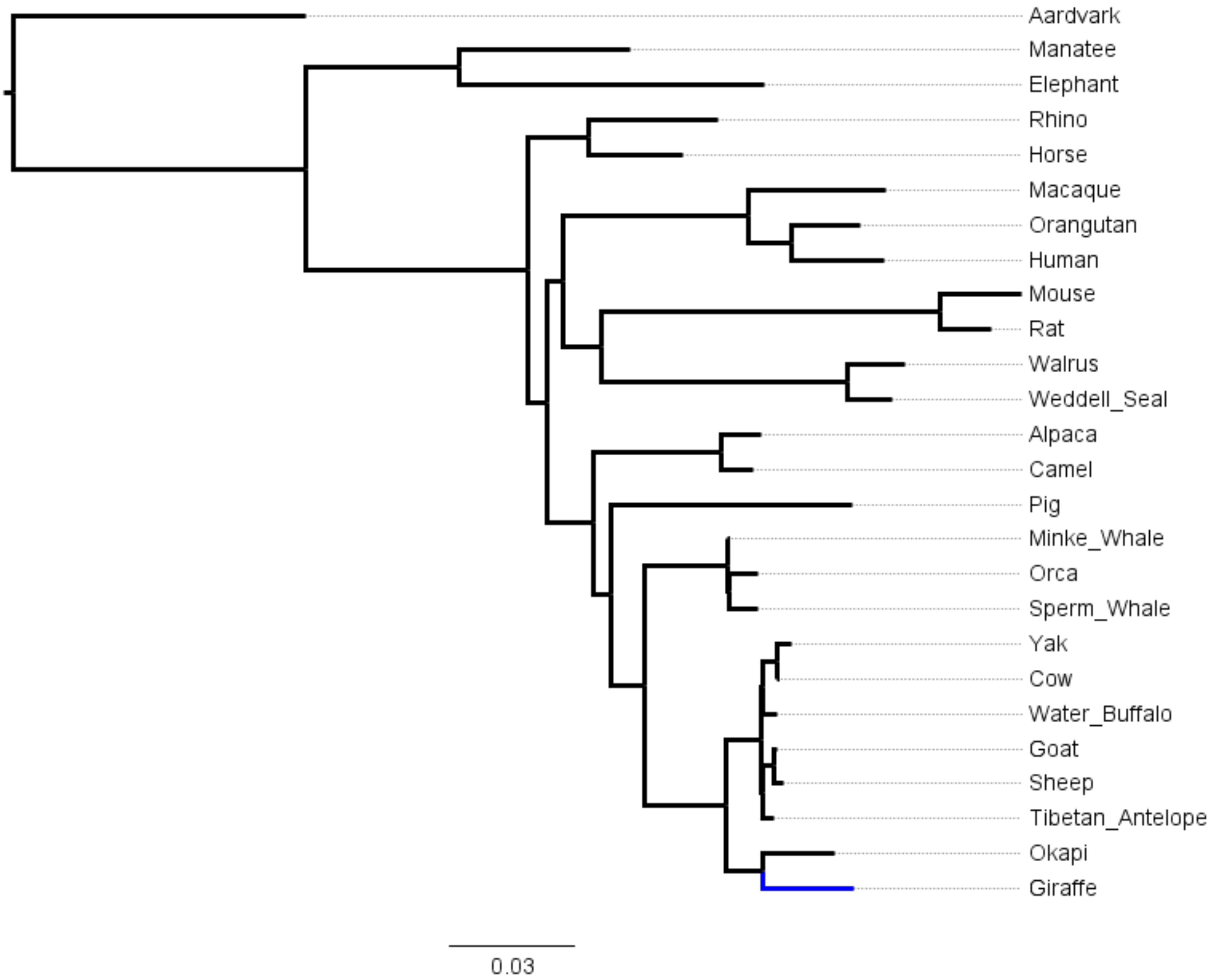

Locus Name: Caudal Type Homeobox 4 (CDX4)

Locus Name: Homeobox protein notochord (NOTO)

ENSBTAT00000047327 NOTO-202 homeobox transcription factor embryonic somitogenesis, mouse: notochord, axial skeleton, axial vs paraxial cell fate

PP2: (Giraffe) G98R, Y223H

Giraffe: Q115R UPS, D162G UIS, Y223H UIS, A257S UPS
Giraffe/Okapi: R23H UPS, H81Y UPS, LP105-106PR UIS, H191Q UIS

Protein sequence Alignment of Cow, Giraffe and Okapi NOTO

```
Cow          1     MPSPGPRGCRPLPLSGAGVQPQRSSRSPRPASPALPRGSANPGPARAPGRLASSFSVEAI  60
Giraffe      1     ..........L.....V....PH..G..G..........V....P......V........  60
Okapi        1     ..........L..........PH.....G..........S....PC..............  60

Cow          61    LARPDPRAPTTSPLSVSAGAHGDLWNVPSRPPAQALPGACPPTWLPPCLSAGLHQPRPQP  120
Giraffe      61    ....................Y................R......PRA.......R.C...  120
Okapi        61    ....................Y................W......PRA....R....C...  120

Cow          121   PALRPLASHFCGLQGLSVTGLELVHCLGLWDPRDWAQAQDLQDTERSPKRIRTMFNLEQL  180
Giraffe      121   ................................Q.........G....Q............  180
Okapi        121   ................................Q..............Q............  180

Cow          181   EELEKVFAKQHNIVGKKRAQLAAQLNLTENQVRVWFQNRRVKYQKQQRLKLPAASAMAAS  240
Giraffe      181   ..........Q...............................H.............V...  240
Okapi        181   ..........Q.............................................V...  240

Cow          241   PDEPSSSSDTSIQREDAESGMDS                                       263
Giraffe      241   ................S......                                       263
Okapi        241   .......................                                       263
```

Newick Tree of Mammalian NOTO

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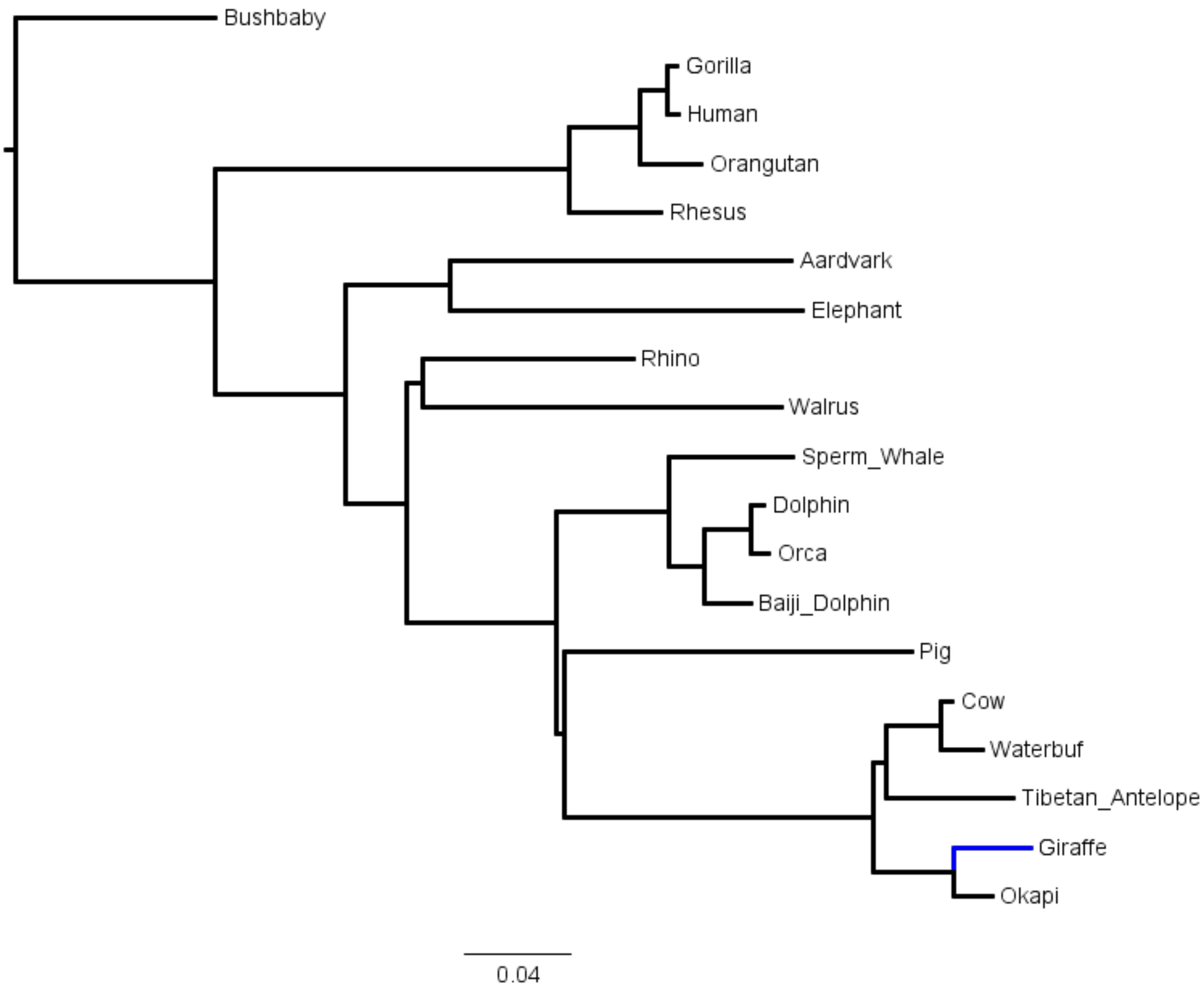


Locus Name: Homeobox protein notochord (NOTO)

Locus Name: Jagged 1 homolog to Drosophila Serrate (JAG1)

ENSBTAT00000009631 JAG1-201 Notch ligand vertebrae development, cardiovascular, eye, kidney human: Alagille syndrome defects in heart and vertebrae abnormalities. mouse: right ventricular hypertrophy, overriding aorta, ventricular septal defects, coronary vessel abnormalities and valve defects

PP2: L134F

Giraffe: S916T UIS, S939P UIS
Giraffe/Okapi: V45P UPS, D72N UIS, L135F UIS, K854T UPS, SE909-910NQ UIS, K944R UIS, E995K UIS, A1015T UIS

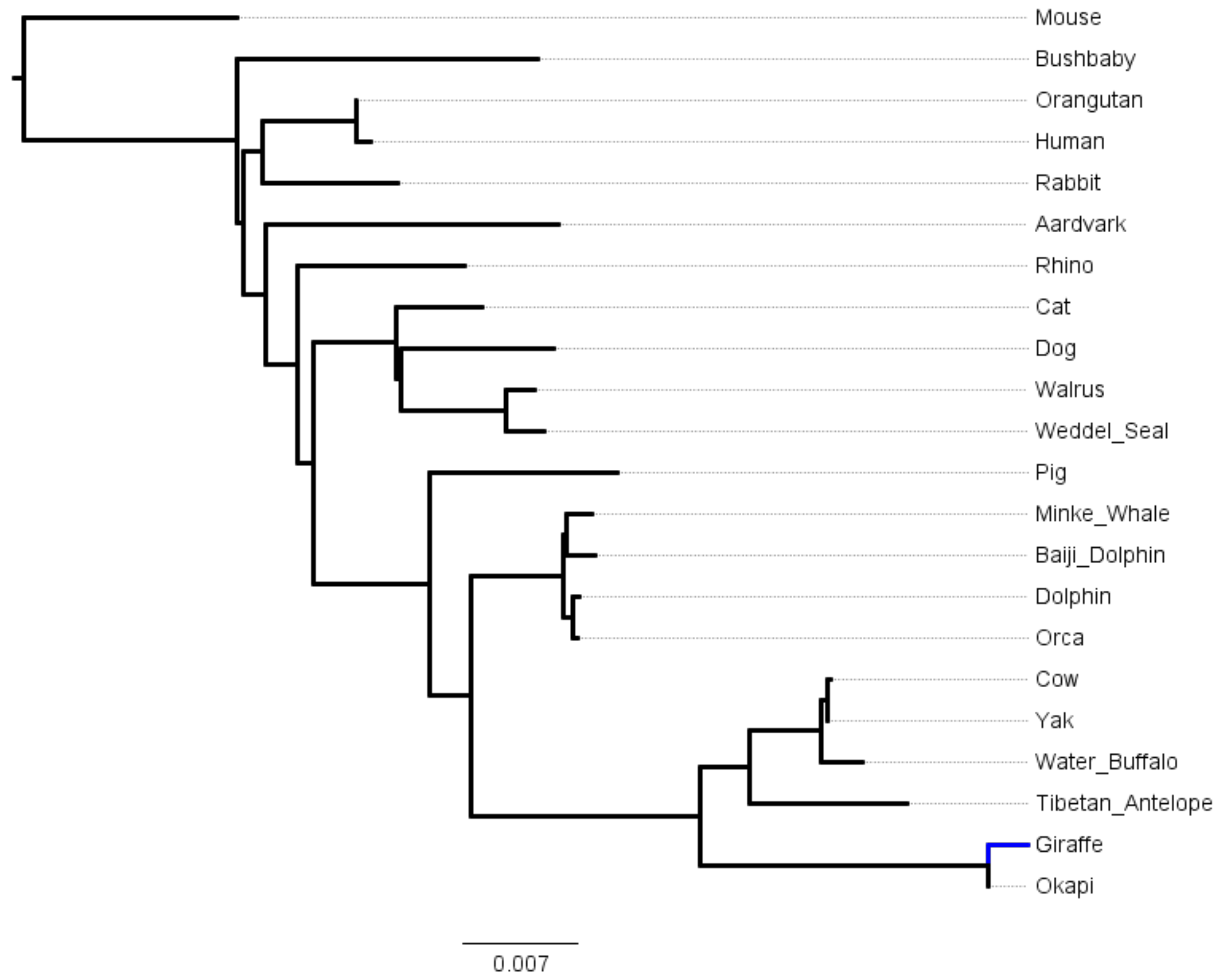
Protein sequence Alignment of Cow, Giraffe and Okapi JAG1

```
Cow       1    MRSPRTRGRPGRPLSLLLALLCALRAKVCGASGQFELEILSMENVNGELQNGNCCGGSRN  60
Giraffe   1    ............................................P...............  60
Okapi     1    ............................................P...............  60

Cow       61   PGDRKCSRDECDTYFKVCLKEYQSRVTAGGPCSFGSGSTPVIGGNTFDLKASRGNERNRI  120
Giraffe   61   ...........N............................L.............DG....  120
Okapi     61   ...........N............................L.............DG....  120

Cow       121  VLPFSFAWPRSYTLLVEAWDSSNDTVQPDSIIEKASYSGMINPGRQWQTLKQNTGVAHFE  180
Giraffe   121  ..............F...............L..R...................A......  180
Okapi     121  ..............F...............L..R...................A......  180

Cow       181  YQIRVTCDDYYYGFGCNKFCRPRDDFFGHYACDQNGNKTCMEGWMGPECNKAICRQGCSP  240
Giraffe   181  ............................................................  240
Okapi     181  ............................................................  240

Cow       241  KHGSCKLPGDCRCQYGWQGLYCDKCIPHPGCVHGTCNEPWQCLCETNWGGQLCDKDLNYC  300
Giraffe   241  ............................................................  300
Okapi     241  ............................................................  300

Cow       301  GTHQPCLNGGTCSNTGPDKYQCSCPEGYSGPNCEIAEHACLSDPCHNRGSCKETSLGFEC  360
Giraffe   301  ............................................................  360
Okapi     301  ............................................................  360

Cow       361  ECSPGWTGPTCSTNIDDCSPNNCAHGGTCQDLVNGFQCVCPPQWTGKTCQLDANECEAKP  420
Giraffe   361  .......................S............K.......................  420
Okapi     361  .......................S............K.......................  420

Cow       421  CVNARSCKNLIASYYCNCLPGWMGQNCDININDCVGQCQNDASCRDLVNGYRCICPPGYA  480
Giraffe   421  ...........G....D...........................Q...............  480
Okapi     421  ...........G....D...........................Q...............  480

Cow       481  GDHCETDIDECASNPCLNGGHCQNEINRFQCLCPTGFSGNLCQLDIDYCEPNPCQNGAQC  540
Giraffe   481  ............................................................  540
Okapi     481  ............................................................  540

Cow       541  YNRASDYFCKCPEDYEGKNCSHLKDHCRTTPCEVIDSCTVAMASNDTPEGVRYISSNVCG  600
Giraffe   541  ............................................................  600
Okapi     541  ............................................................  600

Cow       601  PHGKCKSQSGGKFTCDCNKGFTGTYCHENINDCESNPCRNGGTCIDGVNSYACICSGGWE  660
Giraffe   601  ...............................................I............  660
Okapi     601  ............................................................  660

Cow       661  GAHCETNINDCSQNPCHNGGSCRDLVNDFYCDCKNGWKGKTCHSRDSQCDEATCNNGGTC  720
Giraffe   661  .....A......................................................  720
Okapi     661  .....A......................................................  720

Cow       721  YDEGDAFKCMCPGGWEGTTCNIARNSSCLPSPCHNGGTCVVNGESFTCVCKEGWEGPICT  780
Giraffe   721  ............................................................  780
Okapi     721  ............................................................  780

Cow       781  QNTNDCSPHPCYNSGTCVDGENWYRCECAPGFAGPDCRININECQSSPCAFGATCVDEIN  840
Giraffe   781  ............................................................  840
Okapi     781  ............................................................  840
```

```
Cow          841    GYRCICPPGHSGAKCQEVSGRSCVTMGSVIPDGAKWDADCNACQCLDGRVACSKVWCGPR  900
Giraffe      841    .............T...........I..M........D......................  900
Okapi        841    .............T...........I..M........D......................  900

Cow          901    PCSLHRGHSECPSGQSCVPILDTQCFVRPCTGVGECRSSSLQPVKTKCASDPYYQDNCAN  960
Giraffe      901    .....K..NQ.....T......................P.....R...V...........  960
Okapi        901    .....K..NQ..................................R...V...........  960

Cow          961    ITFTFNKEMMSPGLTTEHICSELRNLNILKNVSAEYSIYIACEPSPSANNEIHVAISAED  1020
Giraffe      961    ..................................K...................T.....  1020
Okapi        961    ..................................K...................T.....  1020

Cow          1021   IRDDGNPIKEITDKIINLVSKRDGNSSLIAAVAEVRVQRRPLKSRTDFLVPLLSSVLTVA  1080
Giraffe      1021   .............R..D..........................N................  1080
Okapi        1021   .............R..D..........................N................  1080

Cow          1081   WVCCLVTAFYWCVRKRRKPGSHARAASEDNTTNNVREQLNQIKNPIEKHGANTVPVKDYE  1140
Giraffe      1081   .......................................................I....  1140
Okapi        1081   .......................................................I....  1140

Cow          1141   SKNSKMSKIRTHNSEVEEDDMDKHQQKARFAKQATYTLVDREEKPAHGTPAKHPNWTNKQ  1200
Giraffe      1141   .............................................P..............  1200
Okapi        1141   .............................................P..............  1200

Cow          1201   DNRDLESAQSLNRMEYIV                                            1219
Giraffe      1201   ..................                                            1219
Okapi        1201   ..................                                            1219
```

Newick Tree of Mammalian JAG1

(mouse:0.0130438, (bushbaby:0.0184162, (((orangutan:0, human:0.000829258):0.00576013, rabbit:0.00830182):0.00113569, (aardvark:0.0179997, (rhino:0.0102121, ((cat:0.00525205, (dog:0.00933142, (walrus:0.001755, weddel_seal:0.00235855):0.00642237):0.00031529):0.00507031, (pig:0.0115497, (((minke_whale:0.00153792, baiji_dolphin:0.00175157):0.000250757, (dolphin:0.000460762, orca:0.000360593):0.000571613):0.00560691, ((((cow:0.000187183, yak:0):0.000337076, water_buffalo:0.0025458):0.00437421, tibetan_antelope:0.00964462):0.00306327, (giraffe:0.00240867, okapi:5.54004e-05):0.0176221):0.0139723):0.00256881):0.00711842):0.000895776):0.00203781):0.00127203):0.000451414):0.0130438);



Locus Name: Jagged 1 homolog to Drosophila Serrate (JAG1)

Locus Name: delta-like three (DLL3)

ENSBTAT00000013852 DLL3-201 Notch ligand embryonic somitogenesis
mouse: disruption of somite boundaries, shortened trunk, vertebrae malformed

PP2: (Giraffe/Okapi) L103M, R261G, P342L; (Okapi) G132D, G148C

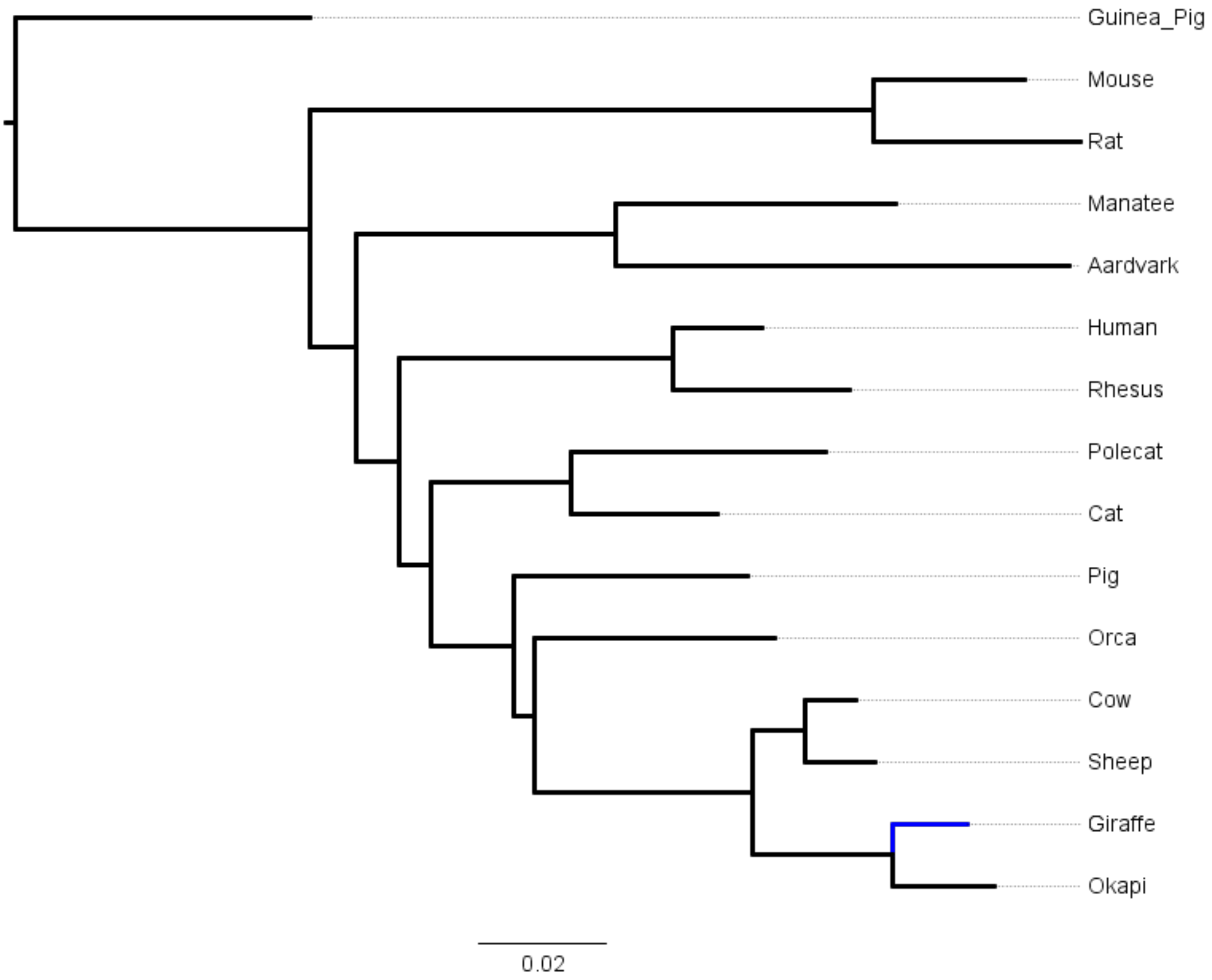
Giraffe: L10F UPS, G195A UPS, P197S UPS, L258F UIS, A475T UPS
Giraffe/Okapi: P7L UPS, E71D UIS, V89A UPS, L103M UIS, S254R UPS, R261G UIS, P526R UPS, R585P
Okapi: S69P UIS, G132D UPS, L143V UIS, G148C UIS

Protein sequence Alignment of Cow, Giraffe and Okapi DLL3

```
Cow     1    MVAPQMPQLLSSTVILALFFLPQAQPAGVFELQIHSFGPGPGPGTPRSPCKAGGSCRLFF  60
Giraffe 1    ......L..F..................................A........S......  60
Okapi   1    ......L............L........................A........S......  60

Cow     61   RVCLKPGLSEETAEAPCTLGAALSARGPVYTAQPGALAPELRLPDGLLRVPFRDAWPGTF  120
Giraffe 61   ..........D.................A.......P.....M...........T.....  120
Okapi   61   ........P.D.................A......VP.....M.................  120

Cow     121  SLIIETWREELGGQIGGAAWSLLARVAGRRLLAAGGPWTRDVQRAGAWELRFSYRARCEP  180 DSL domain
Giraffe 121  .................P............R.............................  180
Okapi   121  ...........D.....P....V..M.C..R.............T...............  180

Cow     181  PAVGAACARLCRSRGAPLRCDPELRPCAPVEEECEAPPVCRAGCSPEHGFCEQPDECRCL  240
Giraffe 181  ..............A.S..........T...D....L.......................  240
Okapi   181  ...........................T...D....L.......................  240

Cow     241  EGWTGPLCTIPVSSSSCLSSRGPSSATTGCLVPGPGPCDGNPCANGGSCSETLGSFECTC  300 6 EGF repeats
Giraffe 241  .............R...F..G.......................................  300 between DSL & TM
Okapi   241  .............R......G.......................................  300

Cow     301  PRGFYGLRCEVSGVTCADGPCFNGGLCVGGADPDSAYICHCPPGFQGSNCEKRVDRCSLQ  360
Giraffe 301  ..............................T..........L..................  360
Okapi   301  ..............................T..........L.................K  360

Cow     361  PCRNGGLCLDLGHALRCRCRAGFAGPRCEHDLEDCTGHTCANGGTCLEGGGARRCSCALG  420
Giraffe 361  ............................................................  420
Okapi   361  ............................................................  420

Cow     421  FGGRDCRERADPCAARPCAHGGRCYAHFSGLVCACAPGYMGARCEFPVHPDGAGALPAAQ  480
Giraffe 421  ......................................................T.....  480
Okapi   421  ............................................................  480

Cow     481  PGLREGDPQRFLLPPALGLLVAAGLAGAALLLVHVRRRGPSRDTGPRLLAGTPEPSVHAL  540 TM domain
Giraffe 481  ....Q......................................S.R..............  540
Okapi   481  ....Q......................................S.R..............  540

Cow     541  PDALNNMRTQEGPGDGPSPSSDWNHPEDGDARSIYVISAPSVYAREA  587
Giraffe 541  .........R........L......................I..P..  587
Okapi   541  .........R...............................I..P..  587
```

Newick Tree of Mammalian DLL3

(guinea_pig:0.0460113, ((mouse:0.0238228, rat:0.0323618):0.0883706, ((manatee:0.0439186, aardvark:0.070948):0.0408664, ((human:0.0140158, rhesus:0.0278144):0.0428855, ((polecat:0.0399908, cat:0.0230087):0.0219097, (pig:0.0366227, (orca:0.0377216, ((cow:0.00797501, sheep:0.0109108):0.00810372, (giraffe:0.0116582, okapi:0.0159333):0.0219494):0.0343832):0.00320336):0.012967):0.00504953):0.0067664):0.00721435):0.0460113);



Locus Name: delta-like three (DLL3)

Locus Name: Neurogenic Locus Notch Homolog Protein 4 (Notch4)

ENSBTAT00000050083 NOTCH4-201 notch pathway mesoderm development, angiogenesis, neurogenesis mouse: Homozygotes for null alleles exhibit no obvious phenotypic defects. However, in conjunction with Notch1 deficiency, embryonic, vascular, and nervous system defects are observed.

PP2 (Giraffe) D650N, Q750H, V1714I; (Giraffe/Okapi) G1893E; (Okapi) Q638M, A846T

Protein sequence Alignment of Cow, Giraffe and Okapi

```
Cow     1     MQPPSLLLPLLLLLCQPVVRTRGLQCGSFPEPCANGGTCLSLSQGQGTCQCAPGFLGETC  60
Giraffe 1     .....P.........R.................................H..........  60
Okapi   1     .....P.........R.................................H..........  60

Cow     61    QFPDPCQDAQPCQNGGSCHTFLPTLPGSPGTPSPMAPSFFCTCPSGFTGDRCQAQIRDPC  120
Giraffe 61    ..........................S..SA.........................K...  120
Okapi   61    ..........................S..S..........................K...  120

Cow     121   SSFCSKMGRCHLQDSGRPRCSCMPGWTGEHCQLRDFCSANPCVNGGVCLATYPQIQCRCP  180
Giraffe 121   .............A...............Q..............................  180
Okapi   121   .............A...............Q..............................  180

Cow     181   PGFEGHACEHDVNECYLDPGPCPKGTTCHNTLGSCQCLCPAGREGPRCGLRPGPCTPRGC  240
Giraffe 181   ..................................F.....S..........L.....M..  240
Okapi   181   ..................................F........D................  240

Cow     241   LNGGTCQLVPGRDSTFHLCLCPPGFTGPSCEVNPDDCAGHQCQNGGTCQDGLGTYTCLCP  300
Giraffe 241   .....................................V......................  300
Okapi   241   .....................................V......................  300

Cow     301   EAWTGWDCSEDVDECEVQGPPRCRNGGTCQNSAGDFYCVCVSGWGGAGCEENLDDCVAAT  360
Giraffe 301   ....................................H.......................  360
Okapi   301   ....................................H.......................  360

Cow     361   CAPGSTCIDRVGSFSCLCPPGRTGLLCHMEDMCLSQPCHEEAQCSTNPLSGSTLCVCQPG  420
Giraffe 361   ............................................................  420
Okapi   361   ............................................................  420

Cow     421   YTGPTCHQDLDECQMAQQGPSPCEHGGSCLNTPGSFECLCPPGYTGSRCEADHNECLSQP  480
Giraffe 421   ............................................................  480
Okapi   421   ............................................................  480

Cow     481   CHRGGTCLDLLATFQCLCPPGLEGQLCEVEIDECASAPCLNQADCHDLLNGFQCICQPGF  540
Giraffe 481   .Q......................R....................N...S..R.V.R...  540
Okapi   481   .Q...........................................N......R.V.R...  540

Cow     541   TGPRCEEDINECQSSPCANGGECQDQPGSFHCKCPPGFEGPRCQEEVDECLSGPCPTGAS  600
Giraffe 541   .....................Q......................................  600
Okapi   541   ..S..Q...............Q......................................  600

Cow     601   CLDLPGAFLCVCPSGFTGHLCEIPLCAPNLCQPKQKCQDQEDNAHCLCPDGNPGCVPTED  660
Giraffe 601   ..................Q..................P....R.....SN..........  660
Okapi   601   ..........I...D...Q..................M....R.................  660

Cow     661   NCTCHHGHCQRSSCVCDGGWTGPECDTDLGGCVSTPCAHGGTCHPQPFGYNCTCPTGYTG  720
Giraffe 661   .................E..........................................  720
Okapi   661   ............................................................  720

Cow     721   PTCSEEVTACHSGPCLNGGSCSPSPGGYTCTCPLSHTGLRCQTSIDHCASALCLNGGTCV  780
Giraffe 721   ............................S.A....................P........  780
Okapi   721   ............................S.A....................P........  780

Cow     781   NKPGTFSCLCTPGFQGPRCEGRTRPSCADSPCRNMATCQDSPQGPRCLCPPGYTGGSCQT  840
Giraffe 781   .R...S....A...H...................K.........................  840
Okapi   781   .R...S....A.......................K.........................  840
```

```
Cow     841   LMDLCAQKPCPQNSHCLQTGPSFQCLCLQGWTGPLCNLPLSSCQKVALSQGTEVSSLCQN  900
Giraffe 841   ............................................................  900
Okapi   841   .V...T......................................................  900

Cow     901   GGVCIDSGPSHFCHCPPGFQGSICQDQVNPCESRPCQHGATCVAQPNGYLCQCAPGYSGQ  960
Giraffe 901   ......................T.....................................  960
Okapi   901   ......................T......................R..............  960

Cow     961   NCSEEPDACQSQPCHNQGTCISKPGGFHCACPPGFVGLRCEGDVDECLDRPCHPTGTAAC  1020
Giraffe 961   .....L..............TP.....Y....A...........................  1020
Okapi   961   .....L..............TP..........A...........................  1020

Cow     1021  HSLANAFYCQCLPGHTGQWCEVELDPCQSQPCAHSGSCEATAGPPPGFTCHCPQGFEGPT  1080
Giraffe 1021  ..................................G.........................  1080
Okapi   1021  ..................................G.........................  1080

Cow     1081  CSHRAPSCGLHHCHHGGLCLPSPKPGLPPRCACLNGYGGPDCLTPPAPSGCGPPSPCLHN  1140
Giraffe 1081  ......P.....................................................  1140
Okapi   1081  ............................................................  1140

Cow     1141  GSCSETPGLGGPGFRCSCPASSPGPRCQRPGVKGCEGRSGDGACDAGCSGPGGNWDGGDC  1200
Giraffe 1141  .....I....D.................................................  1200
Okapi   1141  ............................................................  1200

Cow     1201  SLGVPDPWKGCPSHSRCWLLFRDGQCHPQCDSEECLFDGYDCETPPACIPAYDQYCRDHF  1260
Giraffe 1201  ...............Q................................T.......H...  1260
Okapi   1201  ................................................T...........  1260

Cow     1261  HNGHCEKGCNTAECGWDGGDCRPEDGNSEWGPSLALLVVLSPSTLDQQLLALARVLSLTL  1320
Giraffe 1261  ...........................................I.....F....A.....  1320
Okapi   1261  ............................................................  1320

Cow     1321  RVGLWVRKDSEGKDMVYPYPGAQAEEELGGTPDPSQQERAAPQTEPTGKETDSLSTGFVV  1380
Giraffe 1321  ............R...............................Q...............  1380
Okapi   1321  ............R...............................Q......N........  1380

Cow     1381  VMGVDLSHCGPERPASRCPWDPGLLLRFLAAMAAVGALEPLLPGPLLAAHPRAGTKPSAN  1440
Giraffe 1381  .......R....H..........................................E....  1440
Okapi   1381  .......R....H..........................................E....  1440

Cow     1441  QLPWPVLCSPVVGVLLLALGALLVLQLIRRKRREHGALWLPPGFTRRPRTQPVSRRRRPP  1500
Giraffe 1441  ............................................................  1500
Okapi   1441  ............................................................  1500

Cow     1501  LGEDSIGLKALKAEADMDEDGVVMCSVPKEGEEVGQAEEMASPPKCQLWSLSSDCQELPQ  1560
Giraffe 1501  ...............E...............Q........V...................  1560
Okapi   1501  ...............E...........................H................  1560

Cow     1561  AAMLTPPQDSEMDVPDVDTQGPDGVTPLMSAVCCGGVESRTYQETWLGSPEPWEPLLEGG  1620
Giraffe 1561  .........................................................D..  1620
Okapi   1561  .........................................................D..  1620

Cow     1621  ACPQVHTVGTGETPLHLAARFSRPTAARRLLEAGANPNQPDRAGRTPLHTAVAADAREVC  1680
Giraffe 1621  ............................................................  1680
Okapi   1621  ............................................................  1680

Cow     1681  QLLLRSRQTAVDARTEDGTTALMLAARLAVEDLVEELIAAQADVGARDKWGKTALHWAAA  1740
Giraffe 1681  .................................I..........................  1740
Okapi   1681  ............................................................  1740

Cow     1741  VNNARAARSLLQAGADKDAQDGREQTPLFLAAREGAMEVAQLLLGLGAAQGLRDQAGLTP  1800
Giraffe 1741  .................................................R..........  1800
Okapi   1741  .................................................R..........  1800

Cow     1801  GDVARQRNHWDLLTLLEGAGPPEARHKPTPGRGAGTFQRARTASGSVPPRGGGAVPRCRT  1860
Giraffe 1801  ...................................P........................  1860
Okapi   1801  .............................T.....A........................  1860
```

```
Cow     1861  LSAGARPQARTLSVDLAAHGGGAYSHCRSLSKGTGEGPPLRGRRFSAGMRGPRPNPAMVR  1920
Giraffe 1861  ..........................S.....E.....A..................V..  1920
Okapi   1861  ..........................S.....E........................V..  1920

Cow     1921  GRPGVSAGSGGVAATVDWPCDWVPLGACGPASNTPIPPPCLTPSPERGSPQVAWGPPAHQ  1980
Giraffe 1921  ..S..A........A........A....................................  1980
Okapi   1921  ..S..A........A........A....................................  1980

Cow     1981  VIPLNAGGEGQK  1992
Giraffe 1981  ............  1992
Okapi   1981  ............  1992
```

Newick Tree of Mammalian NOTCH4

```
(manatee:0.0382014, ((((human:0.00838792, orangutan:0.00875044):0.00688613,
baboon:0.0288976):0.040128, bushbaby:0.0643707):0.00864676, ((panda:0.0217116,
walrus:0.023918):0.0351746, ((rhino:0.0295228, horse:0.03205):0.00969203, (pig:0.0403091,
(((spermwhale:0.00902558, (dolphinfw:0.00705352, orca:0.012218):0.00243441):0.00220093,
minkewhale:0.0105096):0.0180912, (((tibetantlp:0.00485875, sheep:0.00630344):0.0064468,
(cow:0.00781667, waterbuffalo:0.00837873):0.00808722):0.00212078, (giraffe:0.012021,
okapi:0.00621759):0.00658709):0.0291063):0.00746966):0.0116224):0.00173587):0.0127588):0.0382014;
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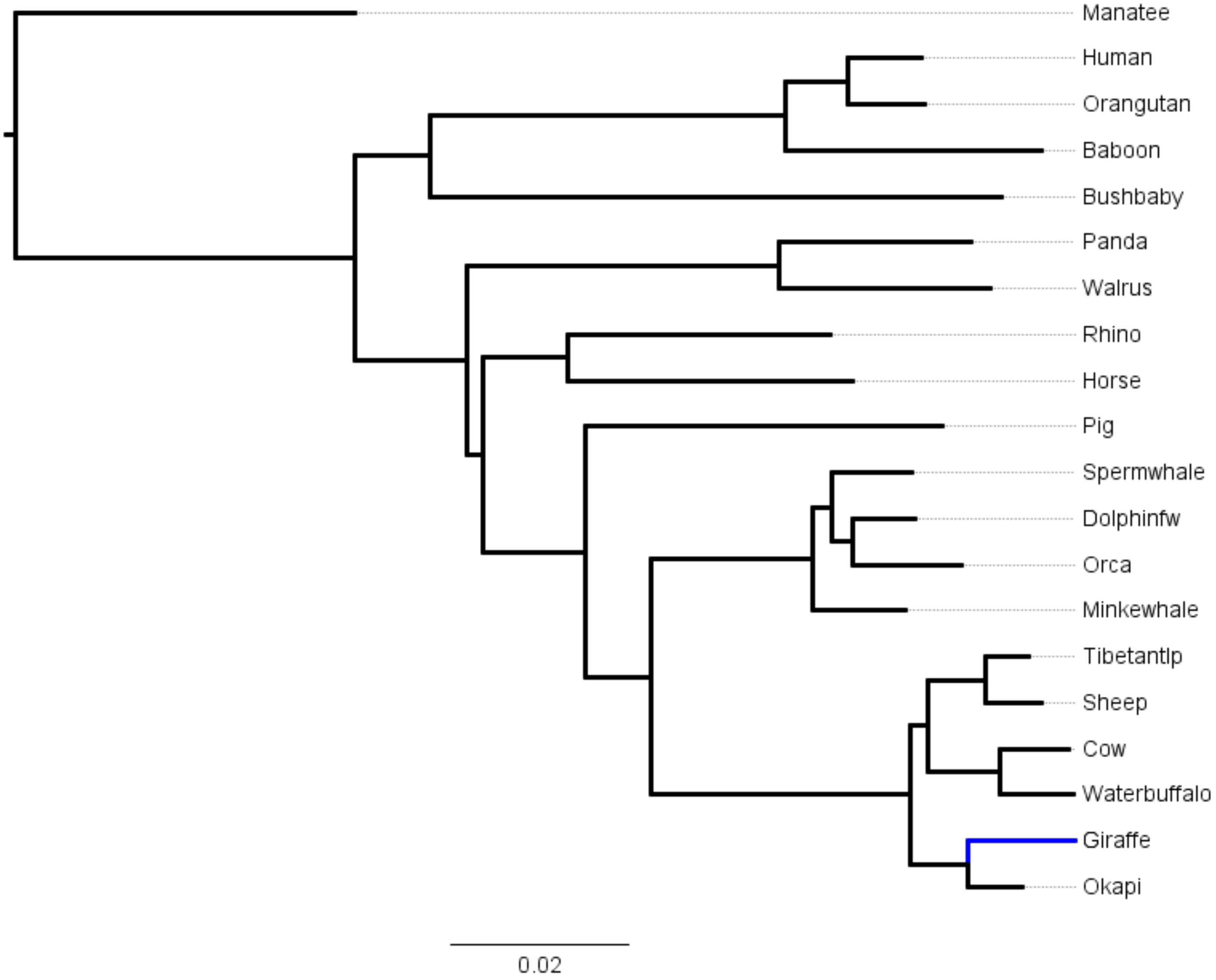

Locus Name: Neurogenic Locus Notch Homolog Protein 4 (Notch4)

Locus Name: Fibroblast growth factor receptor-like 1 (FGFRL1)

ENSBTAT00000039444 FGFRL1-201 decoy FGF receptor cranofacial, axial & appendicular skeleton, heart, kidney mouse: multiple skeletal defects, delayed mineralization in cervical vertebrae, heart defects human: Wolf-Hirschhorn syndrome

PSG: T250A 0.908, D259G 0.905, F260S 0.910, F266L 0.909, K269R 0.918, K275R 0.908, E285D 0.906
PP2: (Giraffe) D259G, F260S, K269R, K275R, E285D

Giraffe: T250A UIS, D259G UIS, F260S UIS, F266L UIS, K269R UIS, K275R UIS, E285D UIS
Giraffe/Okapi: G254S UIS

Protein sequence Alignment of Cow, Giraffe and Okapi FGFRL1

```
Cow     1    MTPSPALVLPLLLLLGALPPAAAARGPPRMADKVVPRQVARLGRTVRLQCPVEGDPPPLT  60
Giraffe 1    ............................................................  60
Okapi   1    ............................................................  60

Cow     61   MWTKDGRTIHGGWSRFRVLPQGLKVKEVEPEDAGAYVCKATNGFGSLSVNYTLIVMDDTS  120
Giraffe 61   ............................................................  120
Okapi   61   ............................................................  120

Cow     121  PGRESPGHDSSSGGQEDPASKQWARPRFTQPSKMRRRVIARPVGSSVRLKCVASGHPRPD  180
Giraffe 121  .........G.........G........................................  180
Okapi   121  ...................G........................................  180

Cow     181  IMWMKDDQALTRPEAGEHRKKKWTLSLKNLRPEDSGKYTCRVSNRAGAINATYKVDVIQR  240
Giraffe 181  ............................................................  240
Okapi   181  ............................................................  240

Cow     241  TRSKPVLTGTHPVNTTVDFGGTTSFQCKVRSDVKPVIQWLKRVEYGAEGRYNSTIDVGGQ  300
Giraffe 241  .........A.......GS.....L..R.....R.........D................  300
Okapi   241  ............................................................  300

Cow     301  KFVVLPTGDVWSRPDGSYLNKLLITRARQDDAGMYICLGANTMGYSFRSAFLTVLPDPKP  360
Giraffe 301  ............................................................  360
Okapi   301  ............................................................  360

Cow     361  PGPPVAPSSSTTSLPWPVVIGIPAGAVFIVGTVVLWLCQAKKKPCAPAPPAPAHRPPATA  420
Giraffe 361  ............................................................  422
Okapi   361  .................................................S..........  422

Cow     421  RDRGGDKDLPAPATVGSGPGVGLCEELGPPAAPQHLLGPGSATGPKLYPKLYTDTHTHTH  480
Giraffe 423  .E.S......T..PL.................A......S....................  482
Okapi   423  .E........T..PL.................T......S....................  482

Cow     481  SHTHSHVEGKVHQHQHTHYHC  501
Giraffe 483  ................I..Q.  503
Okapi   483  ................I..Q.  503
```

Newick Tree of Mammalian FGFRL1

```
(rat:0.0365636, (guineapig:0.0405323, (((human:0.00871237, (baboon:0,
rhesus:0.00218068):0.00832846):0.025617, bushbaby:0.042395):0.00227335, ((elephant:0.024841,
aardvark:0.0239686):0.0233709, ((camel:0.00607814, alpaca:0.00241458):0.0272582,
((rhino:0.0386203, (((polecat:0.0248259, (walrus:0.00855245,
weddel_seal:0.0147311):0.0119796):0.00264384, cat:0.0275929):0.00302873,
dog:0.035323):0.0135985):0.00230938, ((orca:0.00669743, baiji_dolphin:0.00821288):0.00352718,
(cow:0.00721142, (giraffe:0.0192411,
okapi:0.00419128):0.0111612):0.0139591):0.00336271):0.00286468):0.0106337):0.00882947):0.0104164)
:0.0365636);
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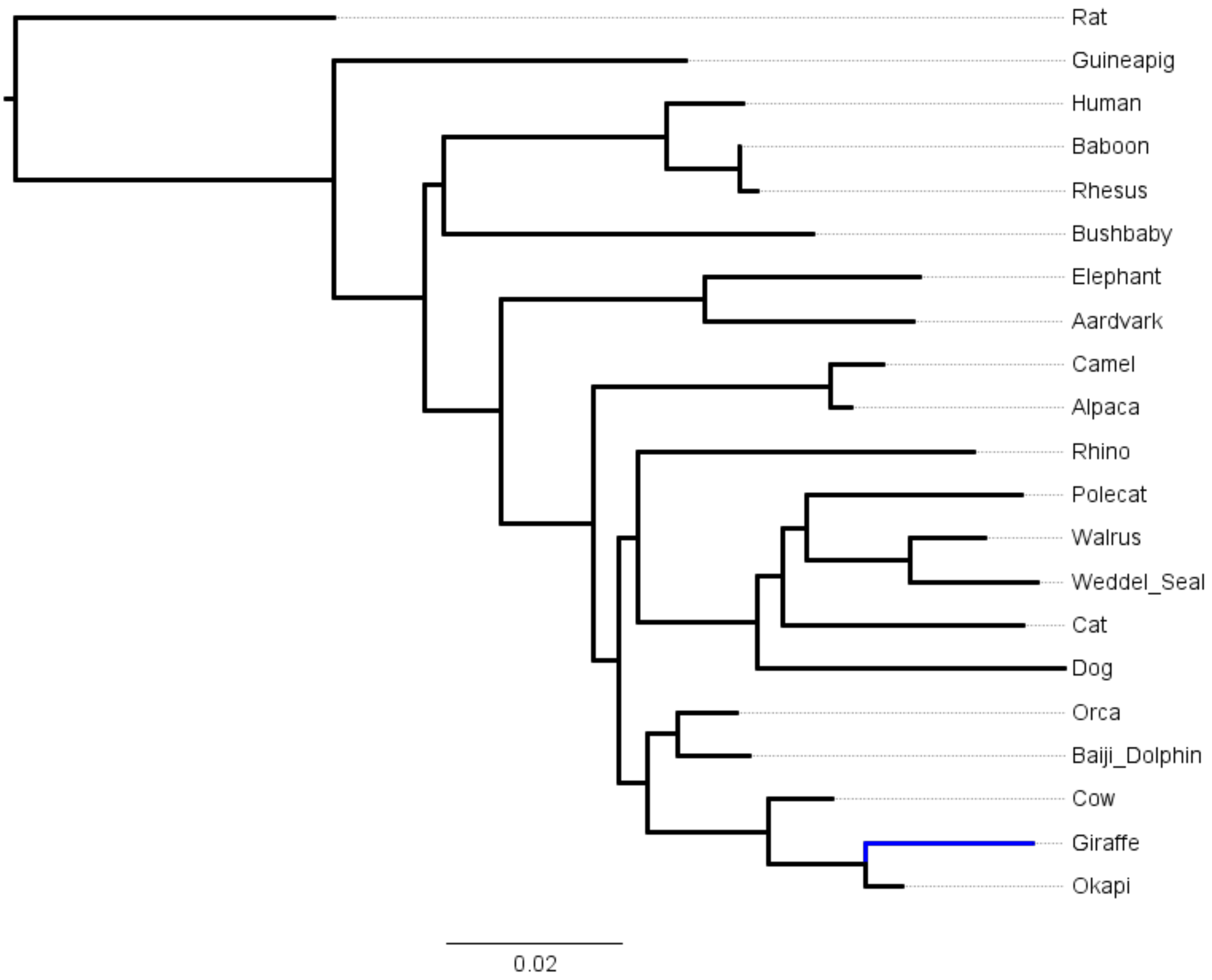


Locus Name: Fibroblast growth factor receptor-like 1 (FGFRL1)

Locus Name: programmed cell death 2-like (PDCD2L)

ENSBTAT00000003327 PDC2L-201   transcriptional repressor programmed cell death
no mutants described for mouse or human

PP2: (Giraffe) D128G

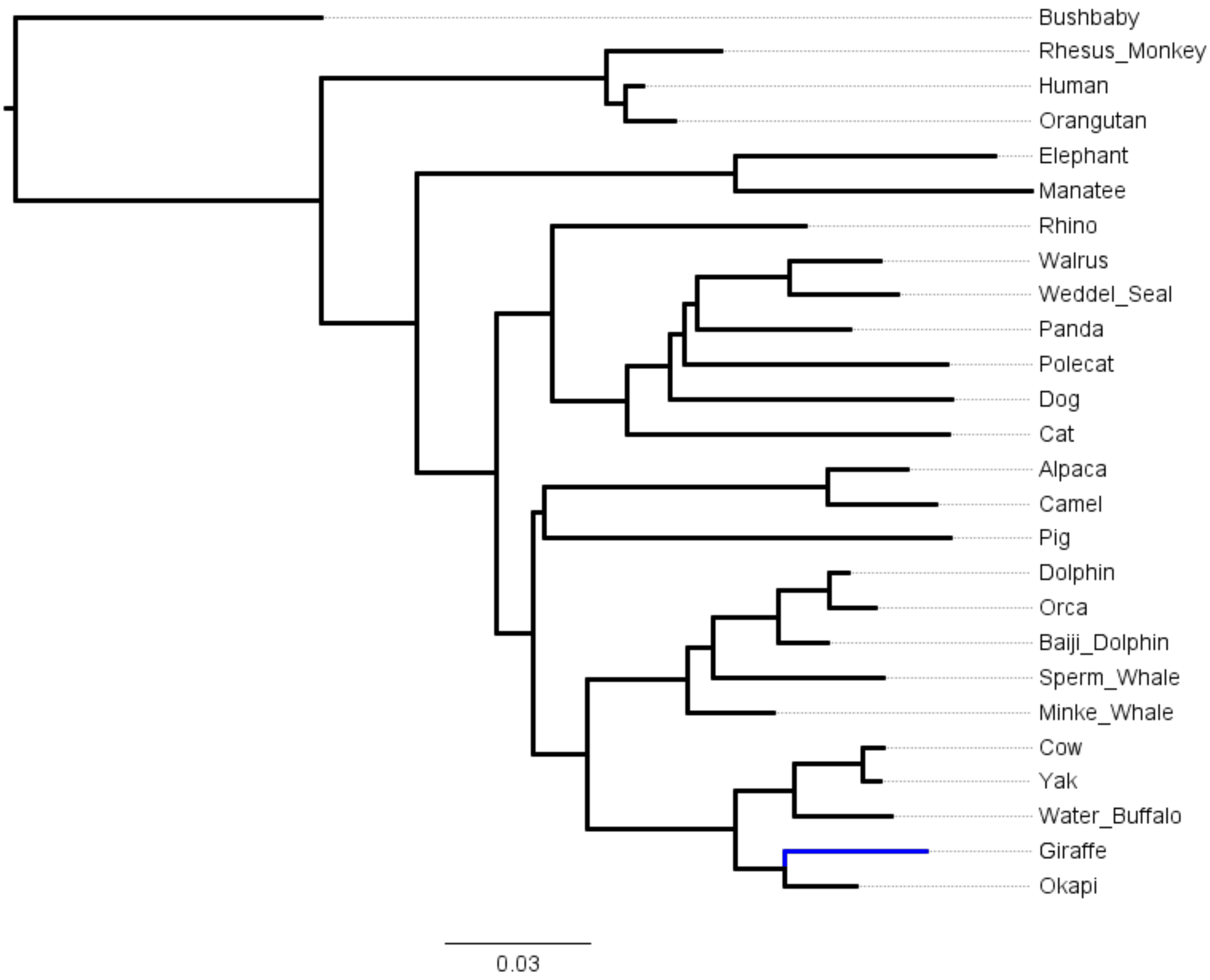
Giraffe: K6E UPS, V35D UPS, D128G UIS, A137S UPS, G181R UPS, K248R UIS
Okapi: T207M UPS, T285I UPS

Protein sequence Alignment of Cow, Giraffe and Okapi PDCD2L

```
Cow     1    MAAVRKPVLLGLRDAAVHGRPTGPSAWTASKLGGVPDALPAVAAPRPVCELCRQPLALVV  60
Giraffe 1    ...A.E......................S.....D.........................  60
Okapi   1    ...A........................................................  60

Cow     61   QVYCPLEGSPFHRLLHVFACPRPECGSGGARSWKVFRSQCLQMREKETQDAQKQENGLTA  120
Giraffe 61   ............................................................  120
Okapi   61   ..........................................................A.  120

Cow     121  EDWCEGADDWGSDSEEASPLQPVSEFGNDLSNAKDRDWTSQLQDLRLQDTVPGVAPPAPP  180
Giraffe 121  .......G........S..P..I.D....S.......................A......  180
Okapi   121  ...................P..I.D....S.S.............H.......A......  180

Cow     181  GGGPALPPSVPQFLPYYICVVDEDDYTDFISLDHAQSLLREYQQREGVDMEQLLSQSLSS  240
Giraffe 181  RE.L....A.........S..N.......V.........K....................  240
Okapi   181  .E.L....V.........G.......M..V.........K....................  240

Cow     241  DGDEKYEKTVIKSGDKMFYKFMKRIAACQEQILRYSWSGEPLFLTCPTSEVTELPACSYC  300
Giraffe 241  .......R.I................................................H.  300
Okapi   241  .........I..................................I.............H.  300

Cow     301  GARRIFEFQLMPALVSMLRSANLDLSVEFGTILIYTCEKSCWPQNDQAPMEEFCIIQEDP  360
Giraffe 301  ....V............................V...............I..........  360
Okapi   301  .................................V...............I..........  360

Cow     361  DELLFK  366
Giraffe 361  ......  366
Okapi   361  ......  366
```

Newick Tree of Mammalian PDCD2L

(bushbaby:0.0637978, ((rhesus_monkey:0.0240491, (human:0.00359046,
orangutan:0.0104749):0.0040552):0.0596258, ((elephant:0.0545039, manatee:0.0618291):0.0665387,
((rhino:0.0528277, (((((walrus:0.0191956, weddel_seal:0.0226637):0.0193703,
panda:0.0319915):0.0026076, polecat:0.0551402):0.00288622, dog:0.058893):0.00901244,
cat:0.0672426):0.0157226):0.0117629, (((alpaca:0.0165552, camel:0.0225659):0.0593276,
pig:0.08493):0.00229234, (((((dolphin:0.00399435, orca:0.00976145):0.0106728,
baiji_dolphin:0.0101595):0.0138221, sperm_whale:0.035824):0.00514097,
minke_whale:0.0178994):0.0211134, (((cow:0.00437979, yak:0.0038508):0.0143783,
water_buffalo:0.0205185):0.0122919, (giraffe:0.0295816,
okapi:0.0150087):0.010454):0.0309843):0.0112464):0.00779422):0.0165112):0.0201117):0.0637978);



Locus Name: programmed cell death 2-like (PDCD2L)

Locus Name: cMyc

ENSBTAT00000011066 MYC-201   transcription factor   cell proliferation, growth control, oncogene
mouse: Mutations affect growth and development of heart, pericardium, neural tube, vasculogenesis and erythropoeisis. Homozygous null mutants die by embryonic day 10.5. Heterozygotes have reduced body size and multiorgan hypoplasia;

PP2: (Giraffe) L3Y; (Giraffe/Okapi) G108S, P207S, A209D

Giraffe: L3Y UPS, V5A UPS, S79A UPS, A215S UPS
Giraffe/Okapi: R83K UPS, G108S UIS, A209D UPS, L224F UIS
Okapi: L3H UPS, V5S UPS, N9H UPS, C25Y UIS, S347C UIS

Protein sequence Alignment of Cow, Giraffe and Okapi

```
Cow          1    MPLNVSFANKNYDLDYDSVQPYFYCDEEENFYHQQQQSELQPPAPSEDIWKKFELLPTPP  60
Giraffe      1    ..Y.A...SR..................................................  60
Okapi        1    ..H.S...HR..........H...Y...................................  60

Cow          61   LSPSRRSGLCSPSYVAVASFSPRGDDDGGGGSFSSADQLEMVTELLGGDMVNQSFICDPD  120
Giraffe      61   ..............F...A...K...G..........R.........S............  120
Okapi        61   ..............F..T....K...G..........R.........S............  120

Cow          121  DETLIKNIIIQDCMWSGFSAAAKLVSEKLASYQAARKDGGSPSPARGHGGCSTSSLYLQD  180
Giraffe      121  ...F........................................................  180
Okapi        121  ...F........................................................  180

Cow          181  LSAAASECIDPSVVFPYPLNDSSSPKPCASPDSTAFSPSSDSLLSSAESSPRASPEPLAL  240
Giraffe      181  ..........................S.D.....S........F................  240
Okapi        181  ..........................S.D..............F................  240

Cow          241  HEETPPTTSSDSEEEQEDEEEIDVVSVEKRQPPAKRSESGSPSAGSHSKPPHSPLVLKRC  300
Giraffe      241  ............................................................  300
Okapi        241  ............................................................  300

Cow          301  HVSTHQHNYAAPPSTRKDYPAAKRAKLDSGRVLKQISNNRKCASPRSSDTEENDKRRTHN  360
Giraffe      301  ............................................................  360
Okapi        301  .....................T........................C.............  360

Cow          361  VLERQRRNELKRSFFALRDQIPELENNEKAPKVVILKKATAYILSVQAEQQKLKSEIDVL  420
Giraffe      361  .................................................E...I..K...  420
Okapi        361  ...............................................T.E...I..K...  420

Cow          421  QKRREQLKLKLEQIRNSCA  439
Giraffe      421  R..................  439
Okapi        421  R..................  439
```

Newick Tree of Mammalian

```
(mouse:0.0233071, ((((baboon:0.00407647, human:0.00278075):0.00844617,
rhesus_monkey:0.00304353):0.00302863, orangutan:0.0149023):0.023451, (bushbaby:0.0344622,
((manatee:0.01719, elephant:0.0106576):0.0248904, (rabbit:0.020061, ((((polecat:0.000163893,
panda:0.00440234):0.00702407, dog:0.00677006):0.00247914, (rhino:0.0148197,
horse:0.0224893):0.00844672):0.00170805, ((alpaca:0.00484276, pig:0.0112688):0.00379907,
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cow:0.00983787):0.00286794):0.00254809, (giraffe:0.00773998,
okapi:0.0175805):0.0197851):0.011432):0.00142065):0.00297063):0.00105204):0.00109731):0.00607101)
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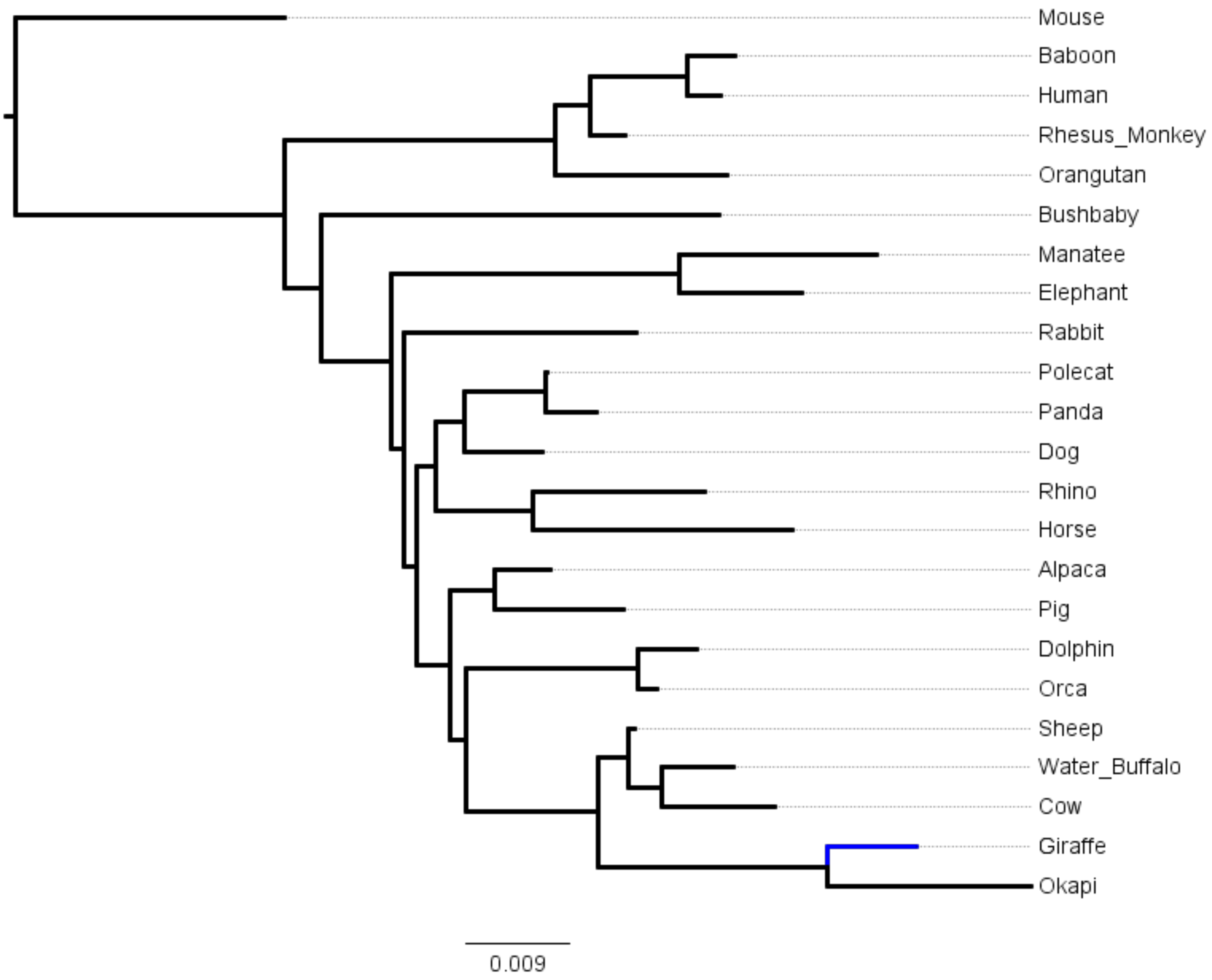


Locus Name: cMyc

Locus Name: E2F transcription factor 4 (E2F4)

ENSBTAT00000015999 E2F4-201 transcription factor cell proliferation, growth control, cranofacial, erythroid
mouse: mice die postnatally of an increased susceptibility to bacterial infection and exhibit craniofacial defects, erythroid abnormalities, and growth retardation.

PP2: P252H

Giraffe: P252H UPS, P254L UPS, V255I UIS, S284N UPS, E286D UIS
Giraffe/Okapi/Gerenuk: V402A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi E2F4

```
Cow      1    MAEAGPQAPPPPGTPSRHEKSLGLLTTKFVSLLQEAKDGVLDLKLAADTLAVRQKRRIYD  60
Giraffe  1    ............................................................  60
Okapi    1    ............................................................  60

Cow      61   ITNVLEGIGLIEKKSKNSIQWKGVGPGCNTREIADKLIELKAEIEELQQREQELDQHKVW  120
Giraffe  61   ............................................................  120
Okapi    61   ............................................................  120

Cow      121  VQQSIRNVTEDVHNSPHTLAYVTHEDICRCFAGDTLLAIRAPSGTSLEVPIPEGLNGQKK  180
Giraffe  121  ............Q...............................................  180
Okapi    121  ............Q...............................................  180

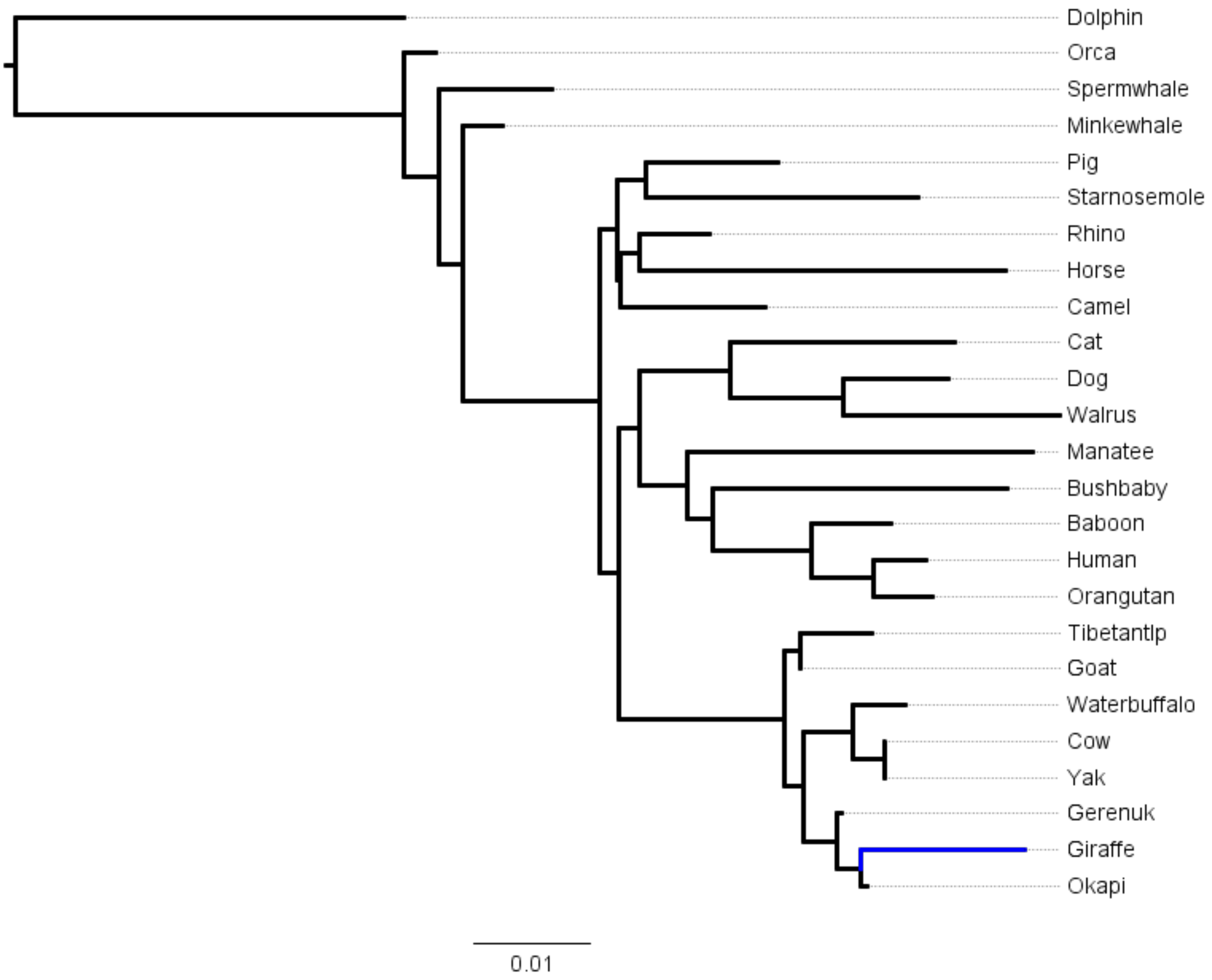
Cow      181  YQIHLKSVSGPIEVLLVNKEAWSSPPVAVPVPPPEDLLQNPPAVSTPPLLPKPSLAQPQD  240
Giraffe  181  .......................................S.............A...S..  240
Okapi    181  .......................................S.............A......  240

Cow      241  ASRPSSPQATTPNPVPSSTEAQGVAGPAAEIPVSGGHGTESKDSGELSSLPLGLAALDTR  300
Giraffe  241  ...........H.LI.........................N..N.D..............  300
Okapi    241  ........................................N...................  300

Cow      301  PLQSSALLDSSSSSSNSSSSGPNPSTSFEPIKADPTGVLELPKELSEIFDPTRECMSSEL  360
Giraffe  301  ............................................................  360
Okapi    301  ............................................................  360

Cow      361  LEELMSSEVFAPLLRLSPPPGDHDYIYNLDESEGVCDLFDVPVLNL  406
Giraffe  361  ........................................A.....  406
Okapi    361  ........................................A.....  406
```

Newick Tree of Mammalian E2F4
(dolphin:0.0338304, (orca:0.0028308, (spermwhale:0.0098671, (minkewhale:0.0033991, (((((waterbuffalo:0.00462629, (cow:0, yak:3.66971e-06):0.00282723):0.00429898, (gerenuk:0.000435762, (giraffe:0.0143575, okapi:0.000568709):0.0020552):0.0029183):0.00160793, (tibetantlp:0.00622668, goat:0):0.0013208):0.0144871, ((cat:0.0195981, (dog:0.00918394, walrus:0.0187758):0.00984373):0.00798754, (manatee:0.0301534, (bushbaby:0.0256082, (baboon:0.00694266, (human:0.00464845, orangutan:0.00513173):0.00531368):0.00860929):0.00230165):0.00415335):0.00175748):0.00161818, ((pig:0.0114845, starnosemole:0.0237023):0.00255027, ((rhino:0.00607722, horse:0.0319593):0.00163675, camel:0.0126628):0.0003507):0.00142501):0.011978):0.00212959):0.00304652):0.0338304);



Locus Name: E2F transcription factor 4 (E2F4)

Locus Name: E2F transcription factor 5 (E2F5)

ENSBTAT00000012342 E2F5-201   transcription factor   cell proliferation, growth control, brain
mouse: Homozygous null mice develop non-obstructive hydrocephalus, ruffled coats, ataxic gait, and dehydration after weaning and die prematurely at an average age of 6 weeks. They exhibit dilated ventricles and cerebral cortex atrophy.

PP2: (Giraffe) S8C, T59A, V240M, P262T

Giraffe: H150R UIS, K162E UIS, T183V UPS, E199Q UIS, V202G UPS, I223V UIS
Giraffe/Okapi: V196M UIS

Protein sequence Alignment of Cow, Giraffe and Okapi E2F5

```
Cow          1      KQAADTLAVRQKRRIYDITNVLEGIDLIEKKSKNSIQWKGVGAGCNTKEVIDRLKYLKAE  60
Giraffe      45     .A....................................................R.....  104
Okapi        1      ......................................................R.....  60

Cow          61     IEDLELKERELDQQKLWLQQSIKNVMDDSINNSTFSYVTHEDICNCFNGDTLLAIQAPSG  120
Giraffe      105    ............................................................  164
Okapi        61     ............................................................  120

Cow          121    TQLEVPIPEMGQNGQKKYQINLKSHSGPIHVLLINKESSSSKPVVFPVPPPDDLAQPPSQ  180
Giraffe      165    .............................R...........E.M..........T.....  224
Okapi        121    ...........................................M..........T.....  180

Cow          181    PPTPVPPHKPSSAVQSLPEPPVSERSQPLQHTPATDLSSAGSISGDIIDELMSSDVFPLL  240
Giraffe      225    .SV........T.A....Q..G.....D...........V..V.................  284
Okapi        181    .S.........T...............S................................  240

Cow          241    RLSPTPADDYNFNLDDNEGVCDLFDVQILNY                              272
Giraffe      285    ...............................                              316
Okapi        241    ...............................                              272
```

Newick Tree of Mammalian E2F5
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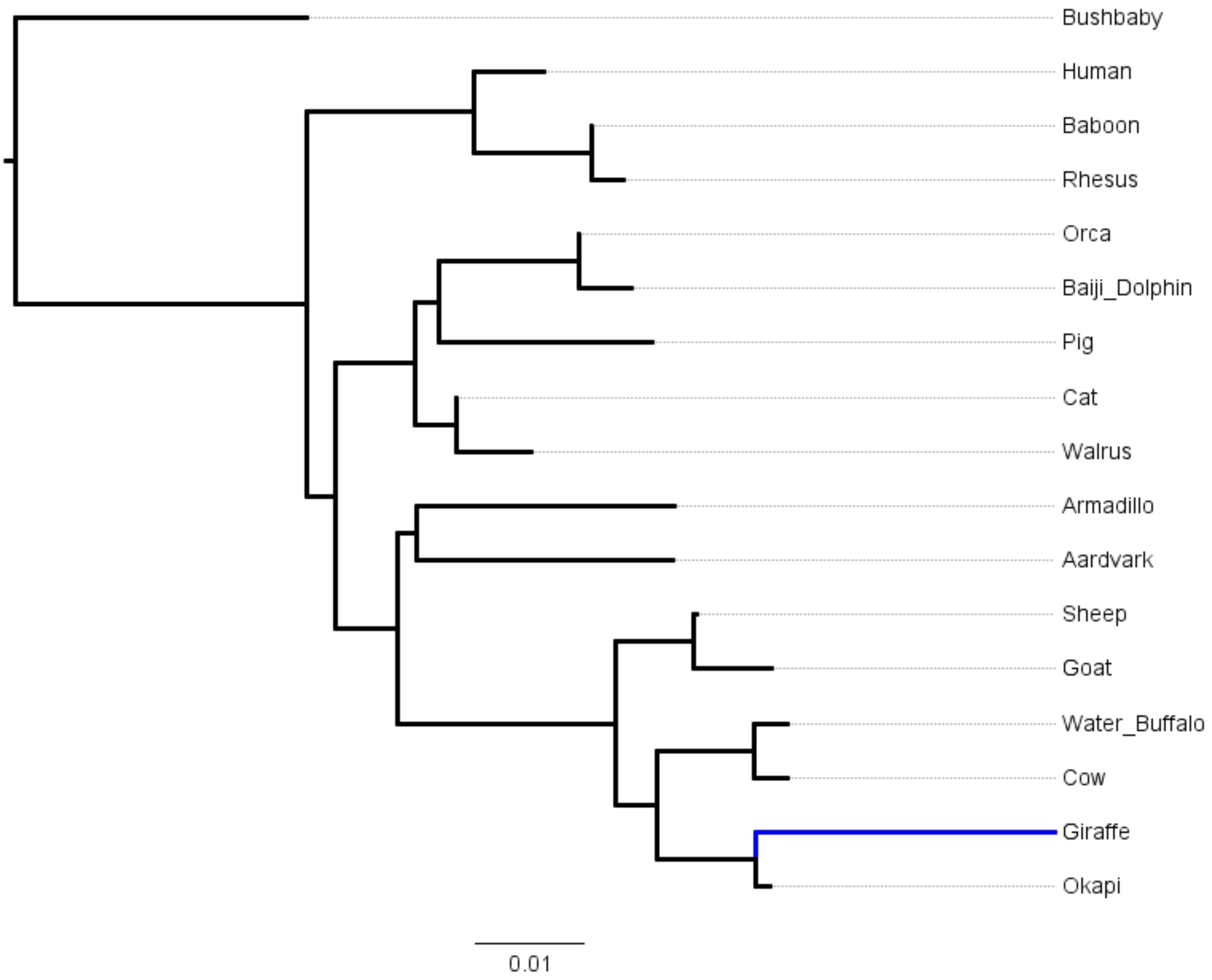


Locus Name: E2F transcription factor 5 (E2F5)

Locus Name: E26 avian leukemia oncogene homolog (**ETS2)**

ENSBTAT00000012144 ETS2-201   ETS transcription factor   somitogenesis, heart development
mouse: expressed in posterior compartment of somites, short neck phenotype when overexpressed in mice
PP2: NO DAMAGING HITS

Giraffe/Okapi: S42A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ETS2

```
Cow          1      MNDFGIKNMDQVAPVASSYRGTLKRQAAFDTFDGSLLAVFPSLNEEQTLQEVPTGLDSIS  60
Giraffe      1      ......................................I..A.S................  60
Okapi        1      .........................................A..................  60

Cow          61     HDSANCELPLLTPCSKAVMSQALKATFSGFKKEQRRLGIPKNPWLWTEQQVCQWLLWATN  120
Giraffe      61     ............................................................  120
Okapi        61     ............................................................  120

Cow          121    EFSLVDVNLQRFGMTGQVLCNLGKERFLELAPDFVGDILWEHLEQMIKENQEKNEDQYEE  180
Giraffe      121    ....................D................................T......  180
Okapi        121    ....................D................................T......  180

Cow          181    NSHLNSVPHWINSNSLGFGVEQAPYGMQTQSYPKGGLLDGLCPASSAPSTLGPEQDFQMF  240
Giraffe      181    ..........................I.....................G...........  240
Okapi        181    ..........................I.....................G...........  240

Cow          241    PKARLNTVSVNYCSVGQDFPAGSLNLLSSASGKPRDHDSAETGGDSFESSESLLQSWNSQ  300
Giraffe      241    .....S...............S......................................  300
Okapi        241    .....S......................................................  300

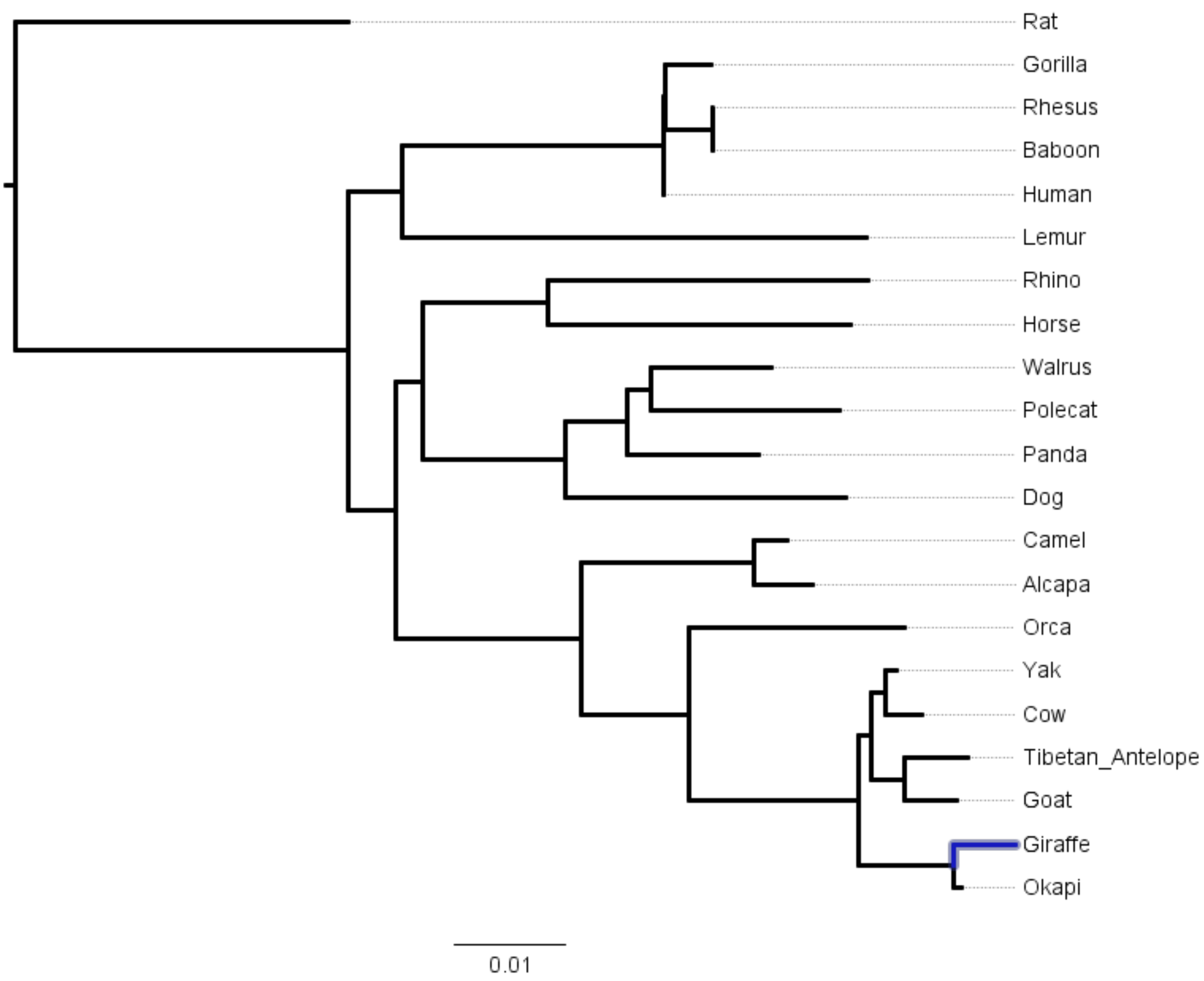
Cow          301    SSLLDVQRVPSFESFEDDCSQSLGLSKPTMSFKDYIQDRSDPVEQGKPVIPAAVLAGFTG  360
Giraffe      301    ............................................................  360
Okapi        301    ............................................................  360

Cow          361    SGPIQLWQFLLELLSDKSCQSFISWTGDGWEFKLADPDEVARRWGKRKNKPKMNYEKLSR  420
Giraffe      361    ............................................................  420
Okapi        361    ............................................................  420

Cow          421    GLRYYYDKNIIHKTSGKRYVYRFVCDLQNLLGFTPEELHAILGVQPDTED            470
Giraffe      421    ..................................................            470
Okapi        421    ..................................................            470
```

Newick Tree of Mammalian ETS2

(rat:0.0303961, ((((gorilla:0.00422325, (rhesus:0, baboon:0):0.00434222):0.000103139, human:0):0.0238534, lemur:0.0424498):0.0049381, (((rhino:0.0292759, horse:0.0276629):0.0114245, (((walrus:0.0109447, polecat:0.017169):0.00216096, panda:0.0119058):0.00563472, dog:0.0255789):0.0130936):0.00238709, ((camel:0.00313301, alcapa:0.00537778):0.0157604, (orca:0.0196581, (((yak:0.000992099, cow:0.00327231):0.00131552, (tibetan_antelope:0.00585099, goat:0.0048445):0.00297886):0.00113061, (giraffe:0.00560933, okapi:0.000780512):0.00859034):0.0155565):0.00986514):0.0168361):0.00439006):0.0303961);



Locus Name: E2F transcription factor 5 (E2F5)

Locus Name: Transforming Growth Factor, Beta 1 (TGFB1)

ENSBTAT00000027261 TGFB1-201   secreted growth factor   growth control, bone growth, heart
mouse: wasting syndrome accompanied by a multifocal, mixed inflammatory cell response and tissue necrosis, leading to organ failure and death; Camurati-Engelmann disease (CE) [MIMOUSE:131300]: Autosomal dominant disorder characterized by hyperostosis and sclerosis of the diaphyses of long bones.

PSG (Giraffe) N230D 0.965*, G242T 0.977*, H276N 0.972*, N283D 0.966*, A360V 0.963*
PP2: None

Giraffe: E215G UPS, N230D UIS, S241F UPS, G242T UPS, H275D UPS

Protein sequence Alignment of Cow, Giraffe and Okapi TGFB1

```
Cow         1     MPPSGLRLLPLLLPLLWLLMLTPGRPVAGLSTCKTIDMELVKRKRIEAIRGQILSKLRLA  60
Giraffe     1     ............................................................  60
Okapi       1     .............L..L...........................................  60

Cow         61    SPPSQGDVPPGPLPEAILALYNSTRDRVAGESAETEPEPEADYYAKEVTRVLMVEYGNKI  120
Giraffe     61    ............................................................  120
Okapi       61    ............................................................  120

Cow         121   YDKMKSSSHSIYMFFNTSELREAVPEPVLLSRADVRLLRLKLKVEQHVELYQKYSNNSWR  180
Giraffe     121   .E...............................EL.........................  180
Okapi       121   .E...............................EL.........................  180

Cow         181   YLSNRLLAPSDSPEWLSFDVTGVVRQWLTRREEIEGFRLSAHCSCDSKDNTLQVDINGFS  240
Giraffe     181   ..............................T...G..............D..........  240
Okapi       181   ..............................T.............................  240

Cow         241   SGRRGDLATIHGMNRPFLLLMATPLERAQHLHSSRHRRALDTNYCFSSTEKNCCVRQLYI  300
Giraffe     241   FT.................................N......D.................  300
Okapi       241   ............................................................  300

Cow         301   DFRKDLGWKWIHEPKGYHANFCLGPCPYIWSLDTQYSKVLALYNQHNPGASAAPCCVPQA  360
Giraffe     301   ...........................................................V  360
Okapi       301   ............................................................  360

Cow         361   LEPLPIVYYVGRKPKVEQLSNMIVRSCKCS       390
Giraffe     361   ..............................       390
Okapi       361   ..............................       390
```

Newick Tree of Mammalian TGFB1

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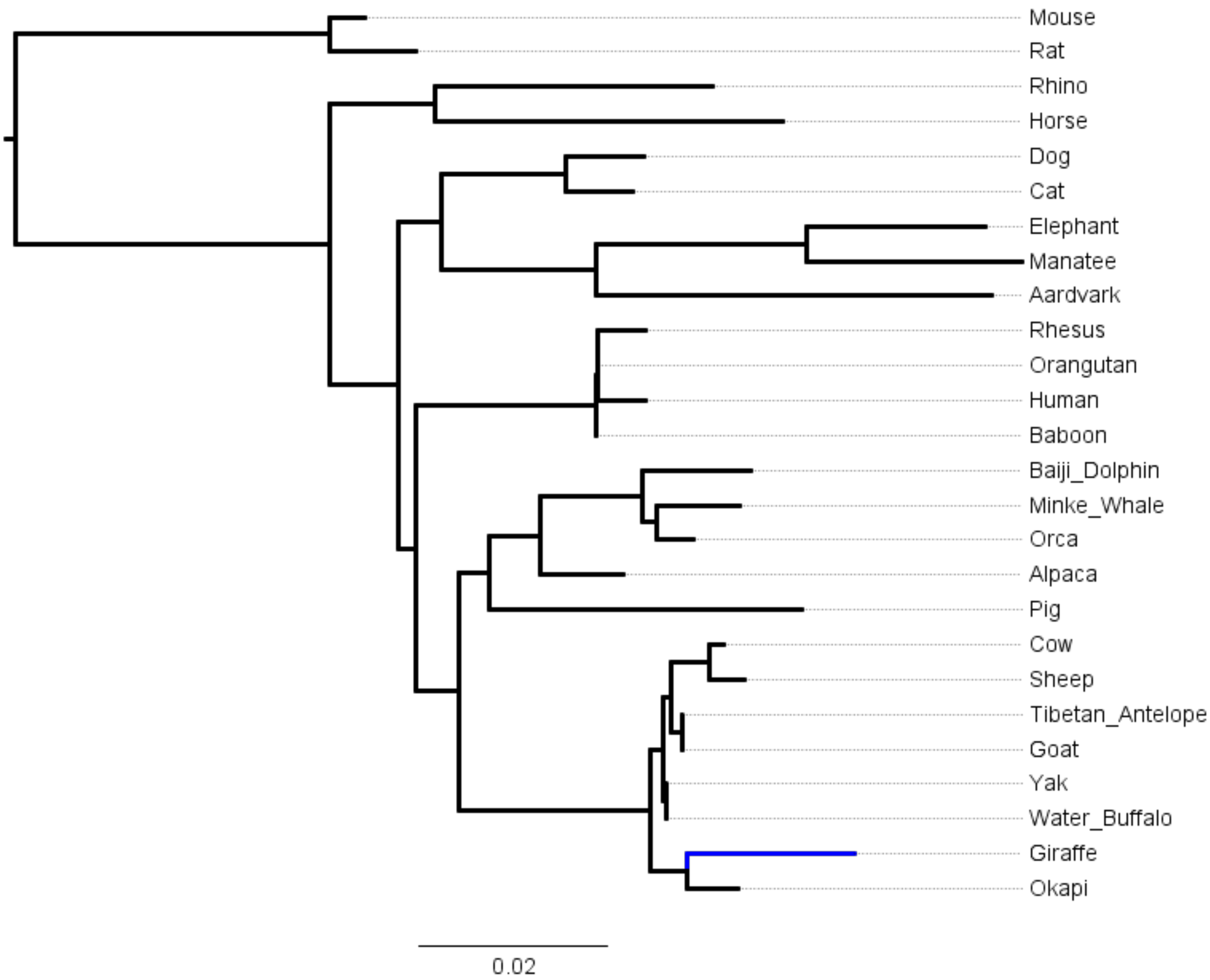

Locus Name: Transforming Growth Factor, Beta 1 (TGFB1)

Locus Name: Aldehyde dehydrogenase family 16 member A1 (**ALDH16A1)**

ENSBTAT00000043139 ALDH16A1-201 aldehyde dehydrogenase eye development
mouse: abnormal retinal development in mouse

PP2: (Giraffe) W120R, E600H, H728Y; (Giraffe/Okapi) L262M; (Okapi) R129Q, R132Q, L704M

Giraffe: A7P UPS, A505T UPS, A561P UIS, Q598H UPS, N603S UPS, E669Q UPS, H726Y UIS, L740V UPS
Giraffe/Okapi: S174P UPS, L497V UPS

Protein sequence Alignment of Cow, Giraffe and Okapi ALDH16A1

```
Cow         1     MAATRTASRACEIFTTLEYGPAPESHACALAWLDTQDRHLGHYVNGQWLKPEHRSSVPCQ  60
Giraffe     1     ......P.....................................................  60
Okapi       1     ......................................................N.....  60

Cow         61    DPITGENLASCLQAQSEDVAAAVEAARASLENWSTQPGAIRAQHLTRLAKVIQKHQRLLW  120
Giraffe     61    .......................................F...................R  120
Okapi       61    .......................................F..........A..-..Q...  119

Cow         121   TLESLVTGRAVREVRDRDVPLAQQLLQYHAVQAHTQEEALAGWEPMGVIGLILSPTFPFL  180
Giraffe     121   .....................................................P......  180
Okapi       120   ........Q..Q....--.S........N.........T............M.P......  177

Cow         181   DMMWRICPALAVGCTVVVLVPPASPTPLLLAQLAGELGPFPGILNVISGPASLGPVLAAQ  240
Giraffe     181   N.....................................................S.....  240
Okapi       178   N.....................................Q...............S.....  237

Cow         241   PGVQKVAFCGAIEEGRALRRTLAGWVPELGLALGAESLLLLTEVADVDSAVEGIVDAAWS  300
Giraffe     241   .....................M...G...S..............................  300
Okapi       238   .....................M...G...S.S............................  297

Cow         301   DRSPGGLRLLIQEAVWDETMRRLQERMGRLRCGHGLDGAVDMGARGAAARDLAQRYVSEA  360
Giraffe     301   ..G..............................R............T..........R..  360
Okapi       298   ..G..............................R............T..........R..  357

Cow         361   QSQGAQVFQAGSEPSDSPFFPPTLVSDLPPASPCTQAEVPWPLVVASPFRTAKEALAVAN  420
Giraffe     361   ............V...............................................  420
Okapi       358   ............V...............................................  417

Cow         421   GTPRGGSASVWSERLGQALELAYGLQVGTVWINAHGLRDPAVPTGGCKESGSSWHGGQDG  480
Giraffe     421   ...........................................M................  480
Okapi       418   .........................H..................................  477

Cow         481   LYEYLRPSGTPAWIPYLSKTLNYDAFGLALPSTL--PAGPET--GPAP--PYGLFVGGRF  534
Giraffe     481   ................V..S....T.......-ILP......GE..ET............  537
Okapi       478   ................V..S.............LL-......GE..V.--..........  534

Cow         535   QAPGARSSRPIQDSQGSLQGYVAEGGAKDIRGAVEAAHQAAPGWMSQSPAARAALLWALA  594
Giraffe     538   ................N.H.......P..................G..............  597
Okapi       535   ..................H..........................G..............  594

Cow         595   AALQRREPNLVSRLERHGVELKVAKAEVELSVKRLRAWGARVQAQGCALQVAELRGPVLR  654
Giraffe     598   ...H....S...................................................  657
Okapi       595   ............................................................  654

Cow         655   LREPLGVLAIVCPDEWPLLAFVSLLAPALAHGNTVVLVPSGACPIPALEVCQEMATLLPA  714
Giraffe     658   ..............Q.........................R...................  717
Okapi       655   ...............................................M............  714

Cow         715   GLVNVVTGDRDHLTRCLALHQDIQALWYFGSAQGSQFVEWASAGNLKPVWVNRGCPRAWD  774
Giraffe     718   ...........Y.............V..................................  777
Okapi       715   ............................................................  774

Cow         775   QEAEGAGPELGRRAARTKALWLPMGD                                    800
Giraffe     778   ...........L..............                                    803
Okapi       775   ...........L..............                                    800
```

Newick Tree of Mammalian ALDH16A1

```
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polecat:0.0453532):0.00243257, dog:0.0463734):0.0271743, ((rhino:0.025468,
horse:0.0349596):0.012711, ((alpaca:0.00868336, camel:0.00892807):0.033421, ((dophin:0.00199813,
orca:0.00425584):0.0396676, (((gerenuk:0.013941, (goat:0.0107265,
tibantlp:0.0109459):0.00452875):0.0031143, (cow:0.00310885,
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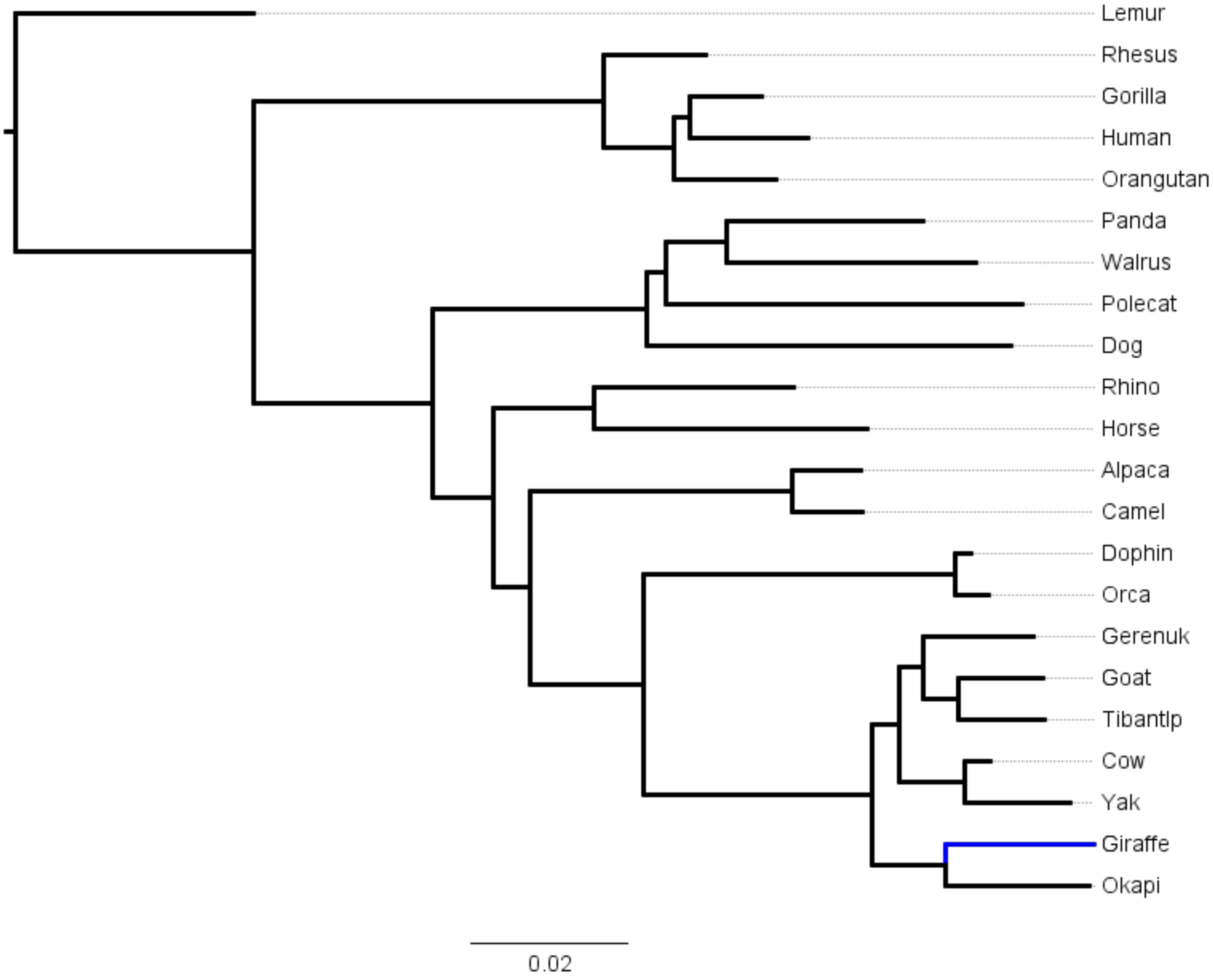


Locus Name: Aldehyde dehydrogenase family 16 member A1 (**ALDH16A1)**

Locus Name: Four And A Half LIM Domains 5 (FHL5)

ENSBTAT00000002359 FHL5-201 Four-half lim domains testis, heart, brain human: GWAS for migraine headache, mouse: Male mice homozygous for disruptions of this gene have reduced sperm counts and abnormal sperm

PSG: (Giraffe) D242G, N251T
PP2: (Giraffe): R35C

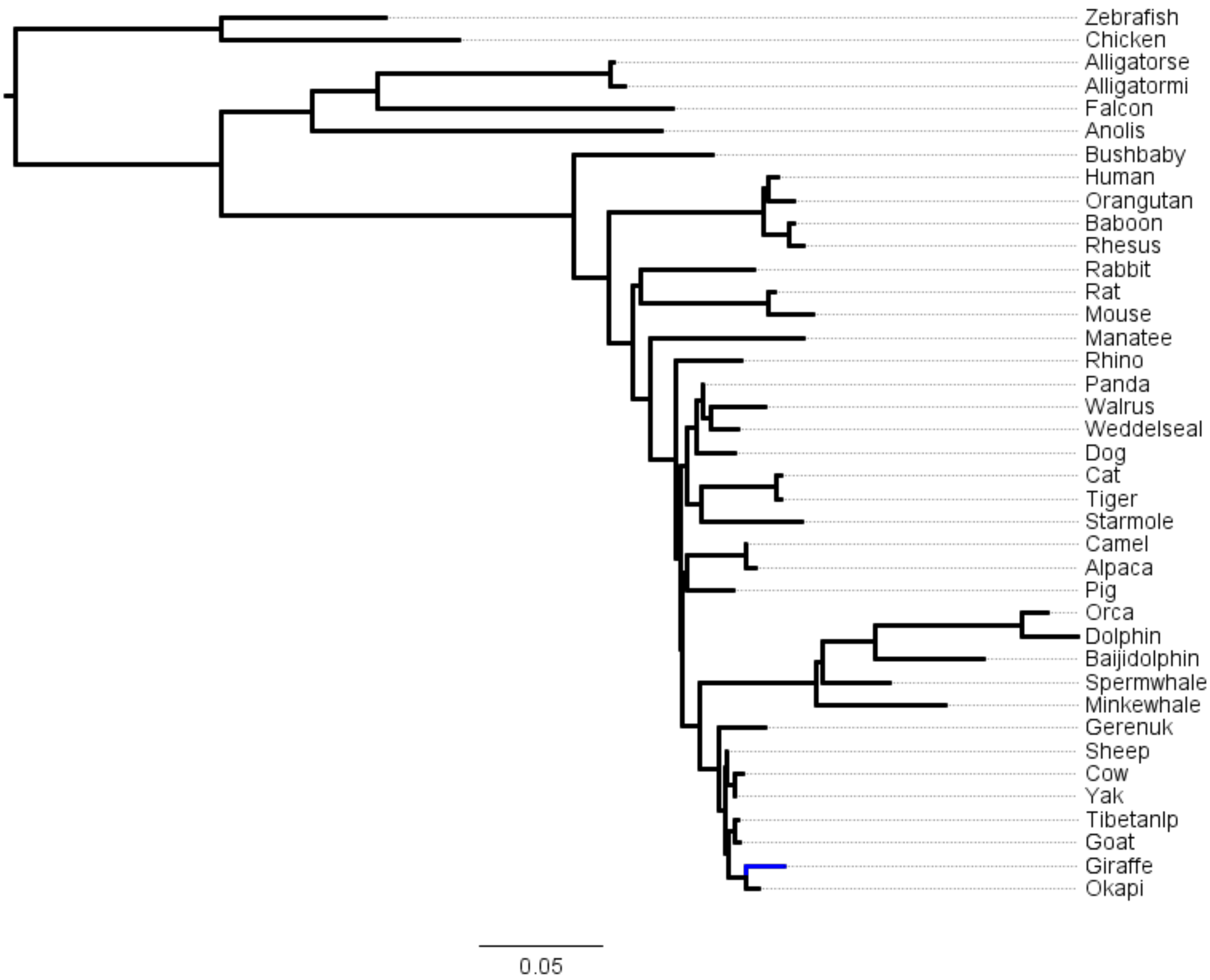
Giraffe: R35C UPS, E49A UPS, D242G UIS, N251T UIS, I284S UPS
Giraffe/Okapi: D25N UIS

Protein sequence Alignment of Cow, Giraffe and Okapi FHL5

```
Cow          1     MTTPQFYCQYCMASLLGKKYVLKDDNPYCVSCYDRIFSNYCEECKEPIESGSKDLCYKGH  60
Giraffe      1     ...A....................N.........C.............A..........R  60
okapi        1     ...A....................N.......................V..........R  60

Cow          61    HWHEGCFNCTKCNHSLVEKPFAAKDERLLCSECYSNECSSKCFHCKKTIMPGSRKMEFKG  120
Giraffe      61    ............................................................  120
Okapi        61    ............................................................  120

Cow          121   NYWHETCFVCEHCRQPIGTKPLISKESGNYCVPCFEKEFAHYCSFCKKVITSGGITFRDQ  180
Giraffe      121   .........................................................H..  180
Okapi        121   .........................................................H..  180

Cow          181   PWHKECFLCSGCRKELCEEEFMSRDDYPFCLDCYNHLYAKKCAACTKPITGLRGAKFICF  240
Giraffe      181   ............................................................  240
Okapi        181   ............................................................  240

Cow          241   QDRQWHSECFNCGKCSVSLVGEGFLTHNKEIFCRKCGSGVDTDI   284
Giraffe      241   .G........T................................S   284
Okapi        241   ..........................................N.   284
```

Newick Tree of Mammalian FHL5

((zebrafishuman:0.0668376, chicken:0.0970388):0.0833155, ((((alligatorse:0.00130397, alligatormi:0.00586458):0.0948263, falcon:0.119757):0.0262781, anolis:0.14137):0.0374446, (bushbaby:0.0559843, (((human:0.00409343, orangutan:0.0100917):0.00187668, (baboon:0.00174038, rhesus:0.00532684):0.0106608):0.0630953, ((rabbit:0.0456561, (rat:0.00305221, mouse:0.0183025):0.0516199):0.00325014, (manatee:0.0622959, (rhino:0.026086, ((((panda:0, (walrus:0.0215425, weddelseal:0.0106662):0.00351075):0.00246469, dog:0.0154795):0.00385592, ((cat:0.00176367, tiger:0.00176367):0.030445, starmole:0.0408813):0.00568553):0.00277947, (((camel:0, alpaca:0.00361645):0.0241293, pig:0.0191361):0.00176541, (((((orca:0.0102221, dolphin:0.0221023):0.0599355, baijidolphin:0.0442202):0.0211295, spermwhale:0.0271777):0.00250532, minkewhale:0.052086):0.0474888, (gerenuk:0.0186301, ((sheep:0.000223805, (cow:0.00328827, yak:0.000239075):0.00330981):0.000484349, ((tibetanlp:0.00154523, goat:0.00198212):0.0021112, (giraffe:0.0159476, okapi:0.00533138):0.0068569):0.00128658):0.00283108):0.00758024):0.00718322):0.000834176):0.00163687):0.0104579):0.00716852):0.00999347):0.01381):0.143717):0.0833155);



Locus Name: Four And A Half LIM Domains 5 (FHL5)

Locus Name: Integrin alpha 10 (ITGA10)

ENSBTAT00000011023 ITGA10-201   integrin alpha 10   heart, muscle articular cartilage
mouse: Homozygous null mice display slightly shortened long bones and mild abnormalities in ephysiseal plate morphology.

PP2: Giraffe, N839D; Okapi, R821Q

Giraffe: A679T UIS, L755V UPS, N839D UIS, L942I UPS
Giraffe/Okapi: D116G UPS, G1053R UIS, K1078R UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ITGA10

```
Cow          1     MEFPLIPHLFLPLMFLTGLCSSFNLDVHRPRLFLGPPEAEFGYSVLQHVGGGRQWMLVGA  60
Giraffe      1     .....................P...............................R......  60
Okapi        1     .....................P...............................R......  60

Cow          61    PWDGPSGDRRGDVYRCLVGGSHSAPCAKGHLGDHPLGNSSRPAVNMHLGMSLLETDGNGG  120
Giraffe      61    .......................................................G....  120
Okapi        61    .................................Y.....................G....  120

Cow          121   FMACAPLWSRACGSSVFSSGICARVDASFRPQGSLAPTAQRCPTYMDVVIVLDGSNSIYP  180
Giraffe      121   ............................................................  180
Okapi        121   .......................H....................................  180

Cow          181   WSEVQTFLRRLVGRLFIDPEQIQVGLVQYGESSVHEWSLGDFRTKEEVVRAARNLSRREG  240
Giraffe      181   ............................................................  240
Okapi        181   ............................................................  240

Cow          241   RETKTAQAIMMACTEGFSQSRGGRPEAARLLVVVTDGESHDGEELPTALQACEAGRVTRY  300
Giraffe      241   ............................................................  300
Okapi        241   ..................R.........................................  300

Cow          301   GIAVLGHYLRRQRDPSSFLREIRAIASDPDEKFFFNVTDEAALTDIVDALGDRIFGLEGS  360
Giraffe      301   ............................................................  360
Okapi        301   .......................T....................................  360

Cow          361   HGENESSFGLEMSQIGFSTHQLKDGILFGMVGAYDWGGSVLWLEEGRRLFPPRTALEDEF  420
Giraffe      361   ............................................................  420
Okapi        361   ............................................................  420

Cow          421   PPALQNHAAYLGYSVSSMFLRGGRRLFLSGAPRFSHRGKVIAFQLKKDGAVRVAQSLQGE  480
Giraffe      421   ..................................R.........................  480
Okapi        421   ..................................R.........................  480

Cow          481   QIGSYFGSELCPLDIDGDGTTDVLLVAAPMFLGPQNKETGRVYVYLVGQPSLLTLQRTLQ  540
Giraffe      481   ............................................................  540
Okapi        481   ............................................................  540

Cow          541   PESPQDARFGFAMGALPDLNQDGFADVAVGAPLEDGHRGALYLYHGAQRGVRPRPAQRIA  600
Giraffe      541   .....................................................H......  600
Okapi        541   .....................................................H......  600

Cow          601   AVAMPQALSYFGRSVDGRLDLDGDDLVDVAVGAQGAAILLSSRPIVRLAPSLDVTPPAIS  660
Giraffe      601   ..S..................................V........H.............  660
Okapi        601   ..S.........................................................  660

Cow          661   VVQRDCKRRGQEATCLSAALCFQVTSRTPGHWDRRFHVRFTASLDEWTTAARAAFDGSGQ  720
Giraffe      661   ..................T...........R..H...LQ...........T..V......  720
Okapi        661   ..............................R.......Q.....................  720

Cow          721   RLSPRRLRLSVGNITCEQLHFHVLDTSDYLRPVSLSVTFALDNTTKPGPVLDEGSPTSIR  780
Giraffe      721   .........N...V....................VT........................  780
Okapi        721   .............V.....................T........................  780

Cow          781   KLVPFSKDCGPDNECVTDLVLQANMDIRGSRKDPFVVRGGRRKVLVSATLENKKENAYNT  840
Giraffe      781   ..........................................................D.  840
Okapi        781   ........................................Q...................  840
```

```
Cow          841    SLSLNFSRNLHLSSFTPQSNSPVKVECAAPTPHTRLCSVGHPVFQTGAKVTFLLEFEFSC  900
Giraffe      841    ....S.........................S..A...........M..............  900
Okapi        841    ....S.........................S..A...........M..............  900

Cow          901    SFLLSQVLVRLTATSSSLERNGTLRDNTAQTSAYIQYEPHLLFSSESTLHRYEVHPYGTL  960
Giraffe      901    .........................................I..................  960
Okapi        901    ............................................................  960

Cow          961    PVGPGPEFKTTLRVQNLGCYVVSGLIVSALLPAVAYGGNYFLSLSQVITNNASCTVQNLT  1020
Giraffe      961    ..........................I.................................  1020
Okapi        961    ..........................I.................................  1020

Cow          1021   EPPGPPVHPEELQHTSRLNESNTRCQVVRCHLGRLAKGTEISVGLLRLVHNEFFRRAKFK  1080
Giraffe      1021   .......................H........R........................R..  1080
Okapi        1021   .......................H........R........................R..  1080

Cow          1081   SLTVVSTFELSTEEGSVLLLTEASRWSESLLEVIQSRPVLISLWILIGSVLGGLLLLALL  1140
Giraffe      1081   ..........G.........................H.......................  1140
Okapi        1081   ..........G.................................................  1140

Cow          1141   VFCLWKLGFFARKKIPEEEKREDKLEQ          1167
Giraffe      1141   ...................E..E....          1167
Okapi        1141   ..........S...M....E..E....          1167
```

Newick Tree of Mammalian ITGA10

```
(Elephant:0.022716, (((Human:0.00371817, Orangutan:0.00402388):0.00461126,
Rhesus:0.0127369):0.0271021, ((((Cat:0.000463002, Tiger:0.00297639):0.0253433,
Dog:0.0290155):0.000248483, Walrus:0.0262011):0.0137373, ((Rhino:0.0189875,
Horse:0.0194546):0.0122169, ((Alpaca:0.00621601, Camel:0.0110714):0.0320862, ((Orca:0.00845164,
Minkewhale:0.0114551):0.0151917, ((((Goat:0.00177715, Sheep:0.00423924):0.00173142,
Tibetantlp:0.00863256):0.00356924, ((Cow:0.000848975, Yak:0.00344473):0.00214421,
Waterbuffalo:0.00302013):0.00556089):0.00324758, (Giraffe:0.0104911,
Okapi:0.00591051):0.00552424):0.0243155):0.00642702):0.00245339):0.00053918):0.00435728):0.022716
);
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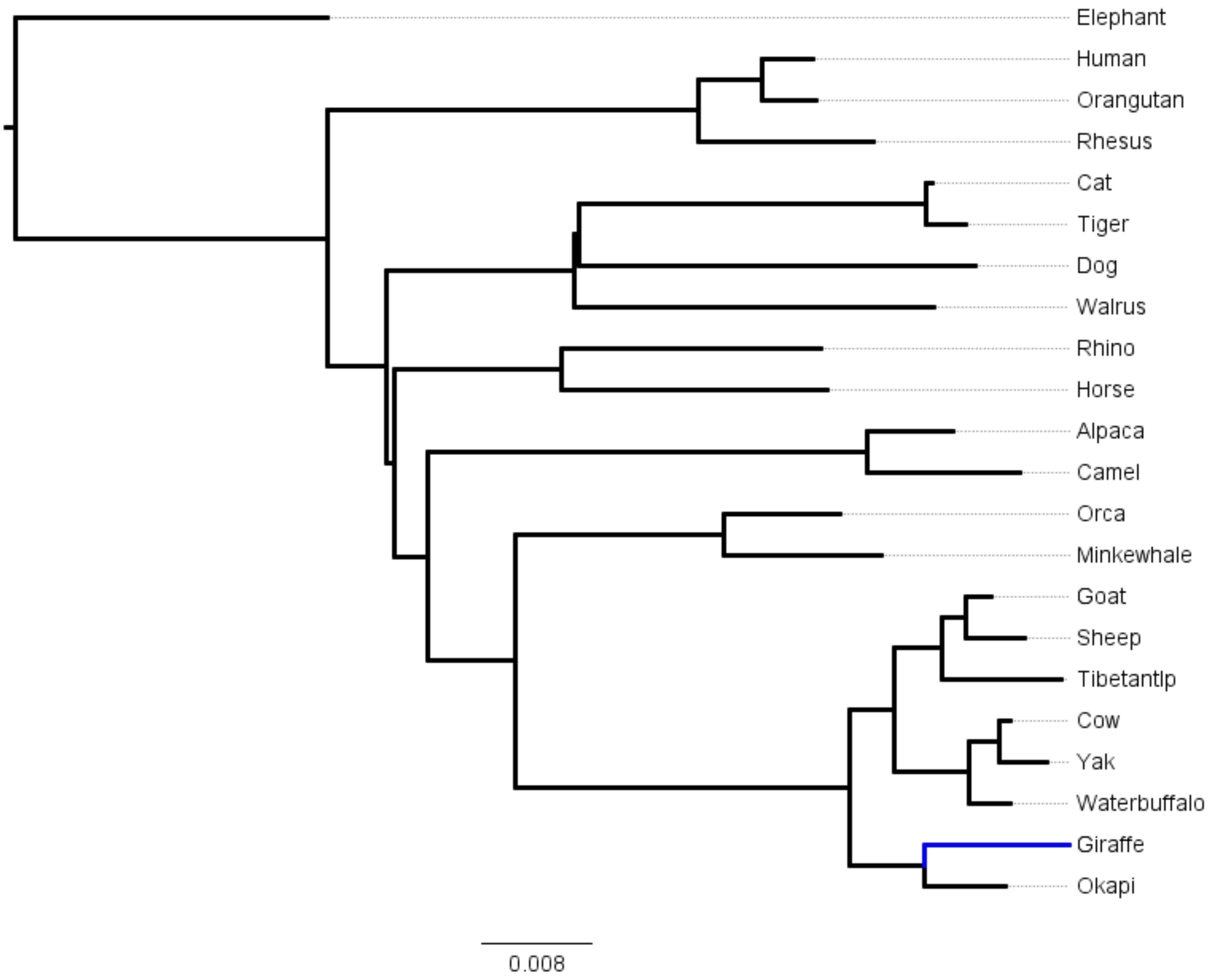


Locus Name: Integrin alpha 10 (ITGA10)

Locus name: Extracellular matrix protein 1 (**ECM1)**

ENSBTAT00000004959 ECM1-201 extracellular matrix protein endochondral bone formation and angiogenesis human: Lipoid proteinosis (LiP) [MIMOUSE:247100]: Rare autosomal recessive disorder characterized by generalized thickening of skin, mucosae and certain viscera. human height SNP

PP2: (Giraffe) V41M, S63F, T227M; (Giraffe/Okapitty) A15I, G161V

Giraffe: A7V UIS, V45M UPS, S67F UPS, S141N UPS, A230M UPS, T417A UPS
Giraffe/Okapi: T15I UPS, E78K UIS, I88V UPS, K104N UPS, G164V UIS, T245A UPS, Q339K UPS

**Water buffalo used instead of Cow because cow sequence incomplete.

Protein sequence Alignment of Water Buffalo, Giraffe and Okapi ECM1

```
Water Buffalo 1     MGTMSGAALVLACLTVASVASDRGFKAPGQRELGPQPLTHPLQEVGYAAPPSPPLSRALP  60
Giraffe       1     ......V.......I.......G....S.......E...Y....M..........A....  60
Okapi         1     ..............I.......G....S.......E...Y...............A....  60

Water Buffalo 61    QGHPRTSQHSLHFEGQSEVQASPSQDAIPLQEELPAPQLPVEKKGGPPLPQEAIPLQEEL  120
Giraffe       61    ....D.F.........RK.......E.V......LP.......N................  120
Okapi         61    ....D...........RK.......E.V......LP.......N................  120

Water Buffalo 121   PPPQVPIEQKEEKPAPSMDHSPPEPESWNPAQHCQQGRPRRGWGHRLDGFPPGRPSLDNL  180
Giraffe       121   ..................N.N...................GS.V................  180
Okapi         121   ..................N.....................GS.V................  180

Water Buffalo 181   DQICLPSRQHVVYGPWNLPQTGFSHLSRQGETLNLLETGYSRCCRCRNRANRLDCAELVW  240
Giraffe       181   ..............................................H.PM..........  240
Okapi         181   ..............................................H.PT..........  240

Water Buffalo 241   EDAVTRFCEAEFSVKTQPHGCCKKQGEARLSCFQEEAPRPHYQLRACPSHQPGISLGPEL  300
Giraffe       241   ....A.......................................................  300
Okapi         241   ....A.......................................................  300

Water Buffalo 301   PFPPGLPTVDNIKNICHLKRFRSVPRNLPATDSIQRQLQALTRLEAEFQRCCRQGNNHTC  360
Giraffe       301   ......................................K.....................  360
Okapi         301   ......................................K.....................  360

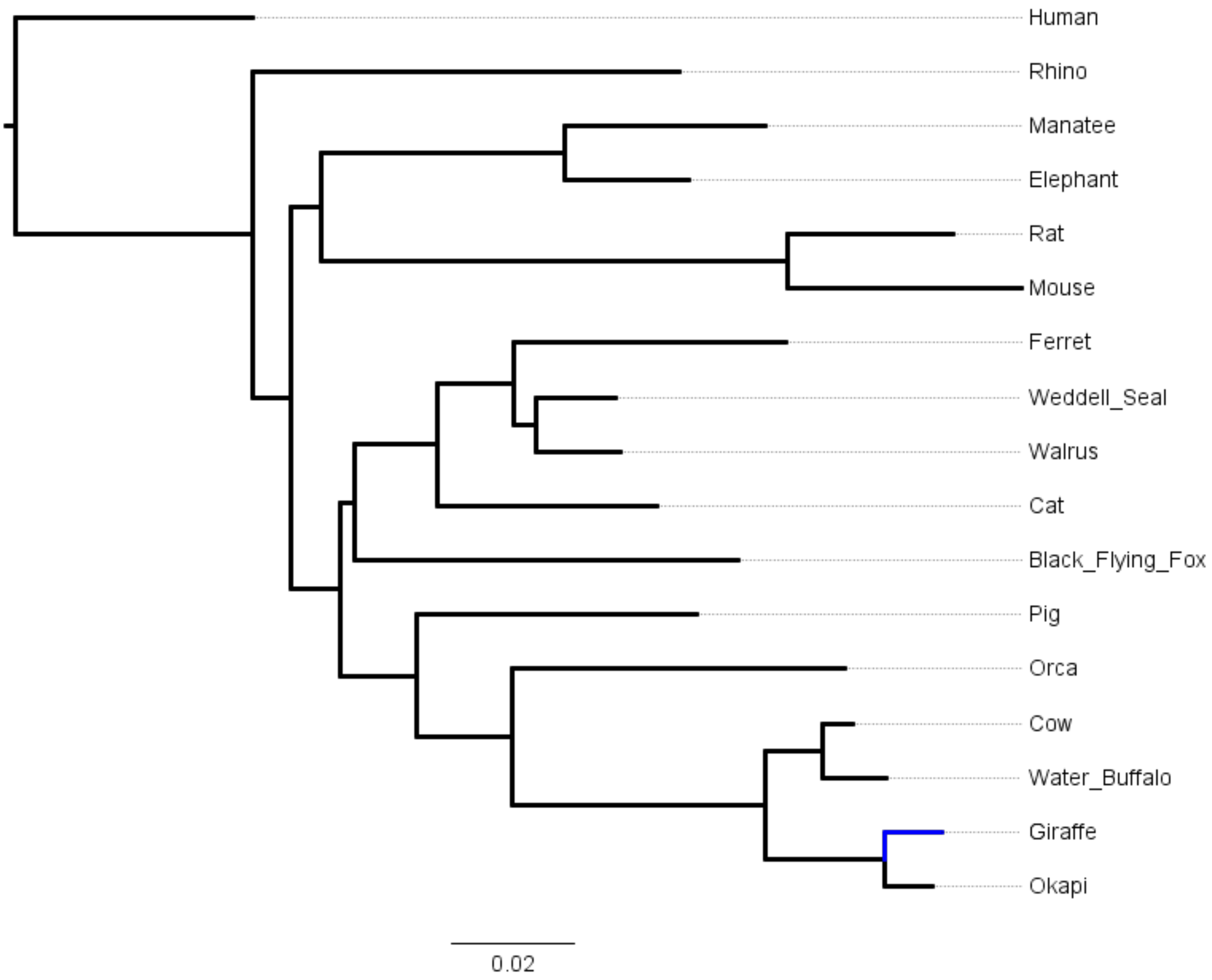
Water Buffalo 361   TWKAWEDTLDGYCDWEQAIKTHHHSCCNYPPSPLRDECFARRAPYPNYDRDILTLDLSRI  420
Giraffe       361   ..............R............H................................  420
Okapi         361   ..............R............H................................  420

Water Buffalo 421   TPNLMNHLCGNRRVLSKHKQIPGLIQKVTARCCDLPFPEQACCAEEEKSAFIDELCGSRR  480
Giraffe       421   .....S...............................................D......  480
Okapi         421   ...........Q.........................................D......  480

Water Buffalo 481   NFWRDSALCCKLSPGDEQINCFNTKYLRNVALVTGDTRDAKGPREQGPTQGTNSSPTSEP  540
Giraffe       481   ........................N...........A......G................  540
Okapi         481   ........................N..................G................  540

Water Buffalo 541   KEE    543
Giraffe       541   ...    543
Okapi         541   ...    543
```

Newick Tree of Mammalian ECM1
(elephant:0.0750334, ((((human:0.0167993, orangutan:0.0113753):0.00957764, (macaque:0.0096667, baboon:0.0092029):0.027333):0.091352, lemur:0.107534):0.0199236, (((((_Ailuropoda_melanoleuca_:0.00571839, polar_bear:0.0148253):0.0290693, (walrus:0.0392861, Weddell_seal:0.0414904):0.0078879):0.00731417, dog:0.0831403):0.0098806, (cat:0.00947357, tiger:0.00486409):0.0835722):0.0220459, ((camel:0.00519368, alpaca:0.00591778):0.0387242, ((sperm_whale:0.0414087, (minke_whale:0.0337845, (Chinese_dolphin:0.0201641, (orca:0.00563662, bottle_nose_dolphin:0.0092065):0.00995856):0.0111664):0.00183346):0.0469186, (((tibetan_antelope:0.00979868, goat:0.0111361):0.0101703, (yak:0.0136206, water_buffalo:0.0125033):0.00962957):0.00562099, (giraffe:0.0135262, okapi:0.0013169):0.0247143):0.066024):0.00660271):0.0157028):0.0183566):0.0750334);



Locus name: Extracellular matrix protein 1 (**ECM1**)

Locus Name: Tweety family member 2 (**TTYH2**)

ENSBTAT00000014618 TTYH2-201   chloride channel   growth control, development
no mutants described for mouse or human; Drosophila mutants are flightless

PP2: (Giraffe) D38N; (Giraffe/Okapi) G384S
PSG: (Giraffe) K414R
Giraffe: D38N UIS, K414R UIS
Giraffe/Okapi: V105A UPS, G384S UIS, H521R UPS

Protein sequence Alignment of Cow, Giraffe and Okapi TTYH2

```
Cow         1     MPAARVEYIAPWWVVWLHSVPHLGLRLQPVDSTFRPRDESYQESLLFLGLVAAVGLGLLV  60
Giraffe     1     .....................................N......................  60
Okapi       1     ............................................................  60

Cow         61    LLAAYLVCVCCCRQDDAVQTKRPRSCCVTWTAVVAALICCAAVGVGFYGNSEANDGVYQL  120
Giraffe     61    ..V....................G....................A...............  120
Okapi       61    ..T....................G....................A...............  120

Cow         121   LYALDNANHTFSGIDVLVSGTTQKMKVDLEQHLARLGEIFATRGDYLQTLKFLQQTAGSI  180
Giraffe     121   ...............E.........................A..................  180
Okapi       121   ............R..E.........................A......M...........  180

Cow         181   IAQIAGVPVWTEVTEELTELANQTSSVEYYRWLSYLLLFVLDLVLCLLACLGLAKRSRCL  240
Giraffe     181   .V.M....T................F..................................  240
Okapi       181   .V.M....T............Y...F..................................  240

Cow         241   LASMLCCGVLALLFSWTSLAADAAAAVGTSDFCAAPDTFILNITEGQVRPEVTQYYLYCS  300
Giraffe     241   ........A....L.......................................R......  300
Okapi       241   ........A....L.......................................R......  300

Cow         301   QSASSPFQQALTVFQRSLTAMQIQVAGLLQFAVPRFPTAEKDLLGIQLLLNSSESGLHQL  360
Giraffe     301   ......................T.....................................  360
Okapi       301   ............I.........T.....................................  360

Cow         361   TALLDCRGLHKDYLDALAGICYDGLEGLLYLGLFSLLAALAFSIMICLGPGAWKHCATRD  420
Giraffe     361   .................S.....S.............................R...S..  420
Okapi       361   .......................S....................................  420

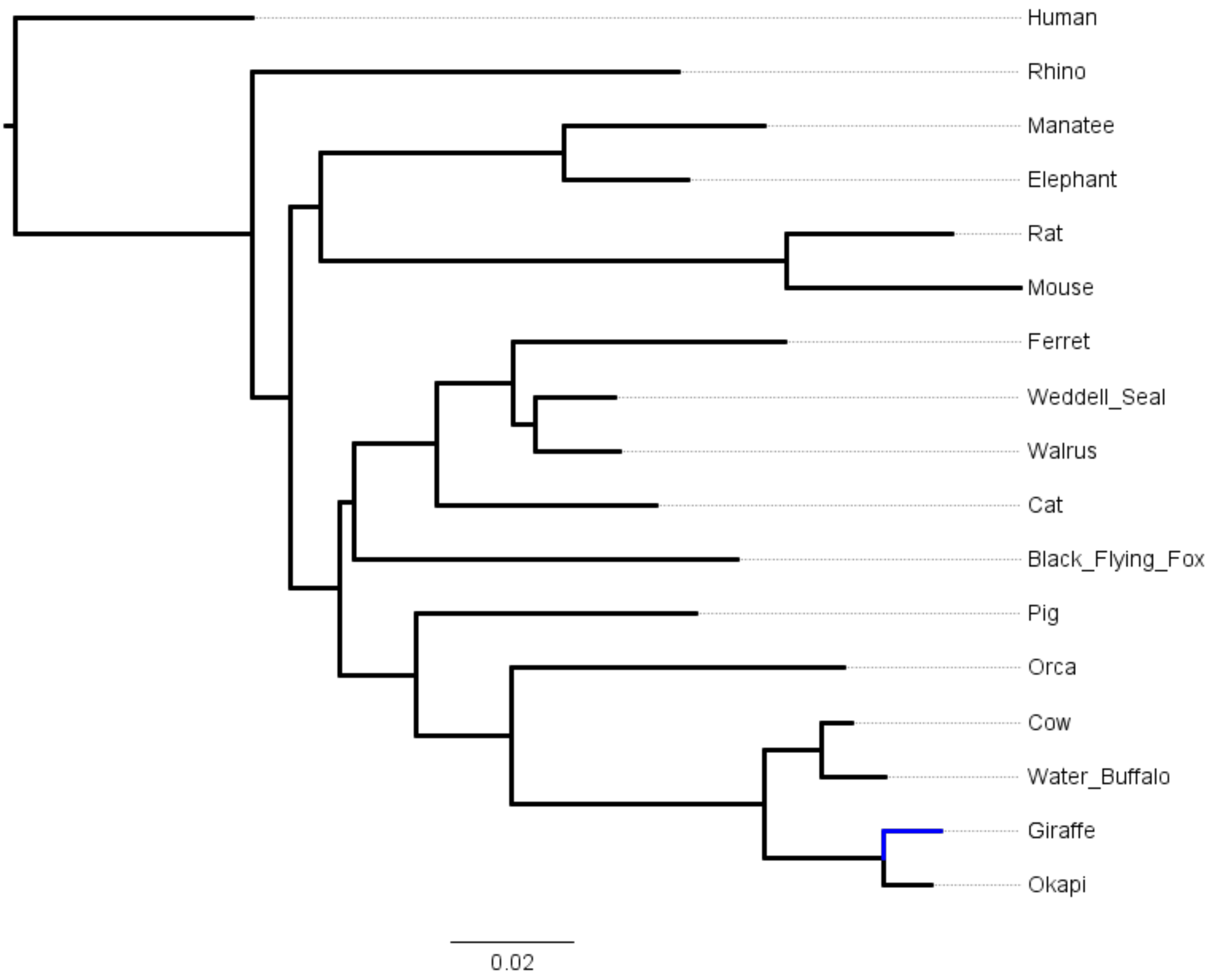
Cow         421   RDYDDIDDDDPFNPQARRIATHNPPRGQLRSFCSYSSGLGSQGSLHPAQTISNAPVSEYM  480
Giraffe     421   ....................A..........................T............  480
Okapi       421   ....................A..........................T............  480

Cow         481   NQAALFGGNPRYENVPLIGRGSPPPTYSPSMRATYLSVADEHLRHYGNEFPG          533
Giraffe     481   .........................................R..........          533
Okapi       481   .........................................R..........          533
```

Newick Tree of Mammalian TTYH2

```
(Human:0.0382285, (Rhino:0.0688808, (((Manatee:0.0323078, Elephant:0.0200028):0.0393509,
(Rat:0.026561, Mouse:0.0375202):0.075332):0.00474799, ((((Ferret:0.043937,
(Weddell_Seal:0.0128347, Walrus:0.0137355):0.00361613):0.0122243, Cat:0.0354042):0.0132597,
Black_Flying_Fox:0.0616557):0.00252206, (Pig:0.0451661, (Orca:0.0538598, ((Giraffe:0.00924067,
Okapi:0.00778989):0.0190247, (Cow:0.00494582,
Water_Buffalo:0.0102066):0.0090632):0.0410263):0.0153503):0.0123817):0.00775085):0.0063642):0.038
2285);
```

Locus Name: Tweety family member 2 (**TTYH2**)



Locus Name: Tweety family member 2 (**TTYH2)**

Locus Name: CREB Binding Protein (CREBBP)

ENSBTAT00000005092 CREBBP-201 CBP histone acetylase angiogenesis, skeletal growth, regulates Hox protein activity human: Rubinstein-Taybi syndrome 1 (RSTS1) [MIMOUSE:180849]: A disorder characterized by craniofacial abnormalities, postnatal growth deficiency, broad thumbs, broad big toes, mental retardation and a propensity for development of malignancies.

PP2: Giraffe, A130T, G2171S; Giraffe/Okapi, A2268G

Giraffe: A259T UIS, T859P UIS, A1022V UPS, G2165S UIS
Giraffe/Okapi: PG2073-2074AS UISs, A2258G UIS

Protein sequence Alignment of Cow, Giraffe and Okapi CREBBP

```
Cow          1     MAENLLDGPPNPKRAKLSSPGFSANDSTDFGSLFDLENDLPDELIPNGGELSLLNSGNLV  60
Giraffe      1     ............................................................  60
Okapi        1     ............................................................  60

Cow          61    PDAASKHKQLSELLRGGSSSSINPGIGNVSASSPAQQGLGSQAQGQPSSANMASLGAMGK  120
Giraffe      61    ........................................G...................  120
Okapi        61    ........................................G...................  120

Cow          121   SPLNQGDSSAPSLPKQAASTSGPTPPASQALNPQAQKQVGLVTSSPATSQTGPGICMNAN  180
Giraffe      121   .........T..................................................  180
Okapi        121   ............................................................  180

Cow          181   FNQTHPGLLNSNSGHGLMNQAQQGQAQVMNGSLGAAGRGRGAGMPYPTPAMQGATSSVLA  240
Giraffe      181   ...A...........S...............................A............  240
Okapi        181   ...............S....T.......................................  240

Cow          241   ETLTQVSPQMASHAGLNTAQAGGMSKMGMTGNTSPFGQPFSQTGGQQMGAPGVNPQLPSK  300
Giraffe      241   ..................S.........................................  300
Okapi        241   ............................................................  300

Cow          301   QSMVNSLPPFAADIKNASVTNVPNMPQMQTSVGIVPTQAIATGPTADPEKRKLIQQQLVL  360
Giraffe      301   ........A..T.............S..................................  360
Okapi        301   ........A..T.............S..................................  360

Cow          361   LLHAHKCQRREQANGEVRACALPHCRTMKNVLNHMTHCQAGKACQVAHCASSRQIISHWK  420
Giraffe      361   ....................S.......................................  420
Okapi        361   ....................S.......................................  420

Cow          421   NCTRHDCPVCLPLKNASDKRNQQTILGSPAGGIQNTIGSVGTGQQNATSLSNPNPIDPSS  480
Giraffe      421   ..............................S.............................  480
Okapi        421   ..............................S.............................  480

Cow          481   MQRAYAALGLPYLNQPQTQLQPQVPGQQPAQPQTHQQMRSLNPLGNNPMNIPAGGITTDQ  540
Giraffe      481   ............................................................  540
Okapi        481   ............................................................  540

Cow          541   QPSNLISESALPTSLGATNPLMNDGSNSGNIGTLSTIPAAAPPSSTGVRKSWHEHVTQDL  600
Giraffe      541   ..P.........................................................  600
Okapi        541   ..P.........................................................  600

Cow          601   RSHLVHKLVQAIFPTPDPAALKDRRMENLVAYAKKVEGDMYESANSRDEYYHLLAEKIYK  660
Giraffe      601   ............................................................  660
Okapi        601   ............................................................  660

Cow          661   IQKELEEKRRSRLHKQGILGNQPALSAPGTQPPGIPQAQPVRPPNGPMPLTVNRMQVSQG  720
Giraffe      661   .........................P.............S..........P.........  720
Okapi        661   .........................P.............S..........P.........  720

Cow          721   MNSFNPISLGNVQLPQAPMGPRAASPMNHSVPMNSMGSVPGMAISPSRMPQPPNMMGAHA  780
Giraffe      721   .......................................................L...T  780
Okapi        721   .......................................................L....  780

Cow          781   NSMMAQAPAQSQFLPQSQFPSSSGALSVSSVGMGQPAAQAGVPQGQVPGAALPNPLNMLG  840
Giraffe      781   ............................................................  840
```

```
Okapi         781    ..................................................T.........  840

Cow           841    PQASQLPCPPVTQPPLHQTPPPASTAAGMPSLQHPAAPGVTPPQPAAPTQPSTPASSSGQ  900
Giraffe       841    ..................P.........................................  900
Okapi         841    ............................................................  900

Cow           901    TPTPTPGSVPSASQTQSTPTVQAAAQAQVTPQPQTPVQPPSVATPQSSQQQPTPVHTQPP  960
Giraffe       901    ............................................................  960
Okapi         901    ............................................................  960

Cow           961    GTPLSQTAASIDNRVPTPSSVASAETNSQQPGPEVPLLEMKAEIKTEDTEPDAGEPKGEP  1020
Giraffe       961    .......................T....................................  1020
Okapi         961    ............................................................  1020

Cow           1021   GATMMEEDLQGSSQVKEETDPTEQKSEPMEVDEKKTEVKVEAKEEEEGSTNGTASQSTSP  1080
Giraffe       1021   .VA.........................................................  1080
Okapi         1021   .VA.........................................................  1080

Cow           1081   SQPRKKIFKPEELRQALMSTLEALYRQDPESLPFRQPVDPQLLGIPDYFDIVKNPMDLST  1140
Giraffe       1081   ..................P.........................................  1140
Okapi         1081   ..................P.........................................  1140

Cow           1141   IKRKLDTGQYQEPWQYVDDVWLMFNNAWLYNRKTSRVYKFCSKLAEVFEQEIDPVMQSLG  1200
Giraffe       1141   ............................................................  1200
Okapi         1141   ............................................................  1200

Cow           1201   YCCGRKYEFSPQTLCCYGKQLCTIPRDAAYYSYQNRYHFCEKCFTEIQGENVTLGDDPSQ  1260
Giraffe       1201   ............................................................  1260
Okapi         1201   ............................................................  1260

Cow           1261   PQTTISKDQFEKKKNDTLDPEPFVDCKECGRKMHQICVLHYDIIWPSGFVCDNCLKKTGR  1320
Giraffe       1261   ............................................................  1320
Okapi         1261   ............................................................  1320

Cow           1321   TRKENKFSAKRLQTTRLGNHLEDRVNKFLRRQNHPEAGEVFVRVVASSDKTVEVKPGMKS  1380
Giraffe       1321   ............................................................  1380
Okapi         1321   ............................................................  1380

Cow           1381   RFVDSGEMSESFPYRTKALFAFEEIDGVDVCFFGMHVQEYGSDCPPPNTRRVYISYLDSI  1440
Giraffe       1381   ............................................................  1440
Okapi         1381   ............................................................  1440

Cow           1441   HFFRPRCLRTAVYHEILIGYLEYVKKLGYVTGHIWACPPSEGDDYIFHCHPPDQKIPKPK  1500
Giraffe       1441   ............................................................  1500
Okapi         1441   ............................................................  1500

Cow           1501   RLQEWYKKMLDKAFAERIIHDYKDILKQANEDRLTSAKELPYFEGDFWPNVLEESIKELE  1560
Giraffe       1501   .............................T..............................  1560
Okapi         1501   .............................T..............................  1560

Cow           1561   QEEEERKKEESTAASETTEGSQGDSKNAKKKNNKKTNKNKSSISRTNKKKPSMPNVSNDL  1620
Giraffe       1561   .............................................A..............  1620
Okapi         1561   .............................................A..............  1620

Cow           1621   SQKLYATMEKHKEVFFVIHLHAGPVIHTLPPIVDPDPLLSCDLMDGRDAFLTLARDKHWE  1680
Giraffe       1621   ..........................N.................................  1680
Okapi         1621   ..........................N.................................  1680

Cow           1681   FSSLRRSKWSTLCMLVELHTQGQDRFVYTCNECKHHVETRWHCTVCEDYDLCINCYNTKS  1740
Giraffe       1681   ............................................................  1740
Okapi         1681   ............................................................  1740

Cow           1741   HTHKMVKWGLGLDDEGGSQGEPQSKSPQESRRLSIQRCIQSLVHACQCRNANCSLPSCQK  1800
Giraffe       1741   ............................................................  1800
Okapi         1741   ............................................................  1800

Cow           1801   MKRVVQHTKGCKRKTNGGCPVCKQLIALCCYHAKHCQENKCPVPFCLNIKHKLRQQQIQH  1860
Giraffe       1801   ............................................................  1860
Okapi         1801   ............................................................  1860
```

```
Cow          1861  RLQQAQLMRRRMATMNTRNVPQQSLPSPTSAPPGTPTQQPSTPQTPQPPAQPQPSPVSMS  1920
Giraffe      1861  ............................................................  1920
Okapi        1861  ............................................................  1920

Cow          1921  PAGFPSVARTQPPTTVSTGKPTNQVPAPPPPAQPPPAAVEAARQIEREAQQQQHLYRVNI  1980
Giraffe      1921  ............................................................  1980
Okapi        1921  ............................................................  1980

Cow          1981  NNGMPPGRTGMVTPVSQMAPVGLNVPRPGQVSGPVVPTLPAGQWQQAPIPQQQPMPGMPR  2040
Giraffe      1981  ............................................................  2040
Okapi        1981  ............................................................  2040

Cow          2041  PVMSMQAQPAVAGPRMSGVQPPRSISPGALQDLLRTLKSPSSPQQQQQVLNILKSNPQLM  2100
Giraffe      2041  ............................................................  2100
Okapi        2041  ............................................................  2100

Cow          2101  AAFIKQRTAKYVASQPGLQPQPGLQAQPGLHQQPGLQNLNAMQASGPRPGVPPQQQAMGG  2160
Giraffe      2101  ............................S...............G..............S  2160
Okapi        2101  ............................S...............G...............  2160

Cow          2161  LNPQGQALNIMNPGHNPSMASMNPQYREMLRRQLLQQQQQQQQQQQQQQQGSAGMAGGMA  2220
Giraffe      2161  ....S.......AS.....................-...............G........  2219
Okapi        2161  ............AS.....................----............G........  2216

Cow          2221  GHSQFQQPPGPAGYPPAMPQQRMQQHLPMQGSAMGPMAAQMGQLGQMGQPGLGADSTPNI  2280
Giraffe      2220  ..G..................................G......................  2279
Okapi        2217  ..G.............T....................G......................  2276

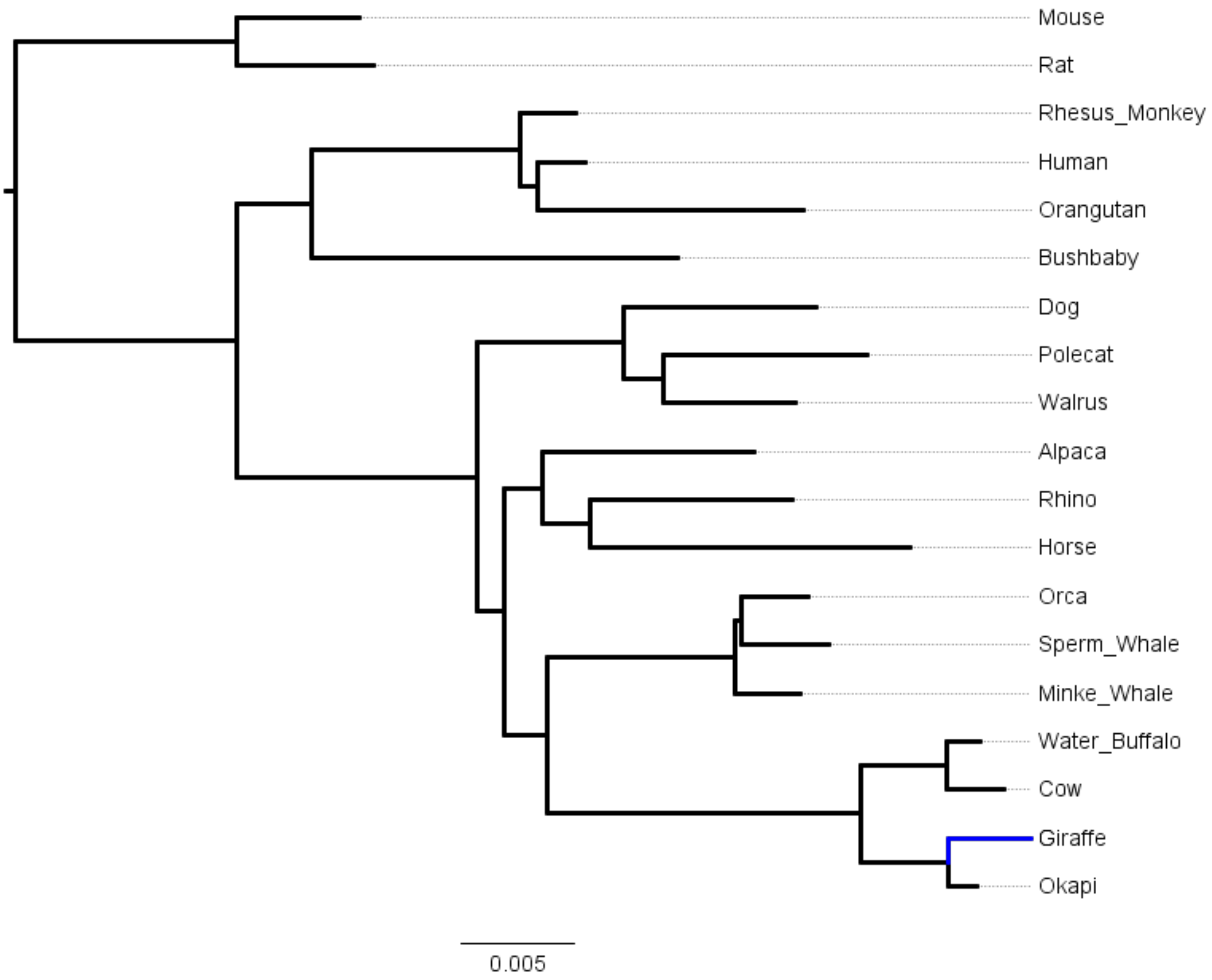
Cow          2281  QQALQQRILQQQQMKQQMGSPGQPNPMSPQQHMLSGQPQASHLPGQQMATSLSSQVRSPA  2340
Giraffe      2280  ............................................................  2339
Okapi        2277  ............................................................  2336

Cow          2341  PVQSPRPQSQPPHSSPSPRIQPQPSPHHVSPQTGSPHPGLAVTMASSIDQGHLGNPEQSA  2400
Giraffe      2340  ............................................................  2399
Okapi        2337  ............................................................  2396

Cow          2401  MLPQLNTPNRSALSSELSLVGDTTGDTLEKFVEGL                           2435
Giraffe      2400  ...................................                           2434
Okapi        2397  ...................................                           2431
```

Newick Tree of Mammalian CREBBP

((mouse:0.0054413, rat:0.00609596):0.00984197, (((rhesus_monkey:0.00251445, (human:0.00218422, orangutan:0.0118545):0.000778584):0.00922866, bushbaby:0.0162716):0.00335433, ((dog:0.00854825, (polecat:0.00905969, walrus:0.00584797):0.0017997):0.00653838, ((alpaca:0.0094531, (rhino:0.00897713, horse:0.0142625):0.00214399):0.00166158, (((orca:0.0029489, sperm_whale:0.0039329):0.000244742, minke_whale:0.00283622):0.00837558, ((water_buffalo:0.00153525, cow:0.00257999):0.00379528, (giraffe:0.00365283, okapi:0.00129566):0.00387512):0.0139488):0.00191949):0.00123868):0.0106762):0.00984197);



Locus Name: CREB Binding Protein (CREBBP)

Locus Name: Intraflagellar Transport 74 (**IFT74)**

ENSBTAT00000026073 IFT74-201 intraflagellar transport protein ciliogenesis kidney, heart, lung
mouse: heterotaxy syndrome (ambiguous lung lobation) with congenital heart disease, including a common atrium, double outlet right ventricle with atrioventricular septal defect, and dual inferior vena cavae.

PP2: (Giraffe/Okapi) Q7P, E386Q

Giraffe: I121M UIS, S469T UIS
Giraffe/Okapi: P7Q UPS, Q388E UIS

Protein sequence Alignment of Cow, Giraffe and Okapi IFT74

```
Cow          1     MASNHKPSAVRPVSRGGIGLTGRPPSGIRPPSGNIRVATGMPPGTARPGSRGGPIGTGGV  60
Giraffe      1     ......Q.....I...............................................  60
okapi        1     ......Q..L..................................................  60

Cow          61    LSSQIKVADRPVTQQGLSGMKTGMKGPQRQILDKSYYLGLLRSKISELTTEINKLQKEIE  120
Giraffe      61    .......................V....................................  120
Okapi        61    .......................V....................................  120

Cow          121   MYNQENSVYLSYEKRAETLAVEIKEFQGQLADYNMLADKLNTNTEMEEVMNDYNMLKAQN  180
Giraffe      121   I...........................................................  180
Okapi        121   ............................................................  180

Cow          181   DRETQSMDIIFTERQAKEKQIRSVEEEIEQEKQAAEGIIKNMSPEKQVKYIEMKTTNEKL  240
Giraffe      181   ....................................D.......................  240
Okapi        181   ............................................................  240

Cow          241   LQELDTLQQQLDSLNMKKESLESEIAHSQVKQEAVLLHEKLYELESHRDQMIAEDKNMGS  300
Giraffe      241   .......K....................................................  300
Okapi        241   .......K...........................................M........  300

Cow          301   PMEERERLLKQVKEDNQEIASMERQLTDIKEKINQFNEEIRQLDMDLEEHQGEMNQKYKE  360
Giraffe      301   ....................................S.......................  360
Okapi        301   .T..............................M...S.......................  360

Cow          361   LKKREENMDTFIETFEDTKNQELERKAQIEASIVSLLEHSSRNINRMKQISSITNQELKM  420
Giraffe      361   ................E..........E...N............................  420
Okapi        361   ................E..........E...N............................  420

Cow          421   MQDDLNFKSTEMQKSQSTARNLTSDSQRLQLDLQKMDLLESKMTEEQQSLKNKIKQMITD  480
Giraffe      421   ....................................E...........T...........  480
Okapi        421   ....................................E.......................  480

Cow          481   LETYNDLAALKSSGEEKKKKLHQEKTVLSTRRNAFKKIMEKLNTEWETLKTQLQENETHS  540
Giraffe      481   ........................R....................C..............  540
Okapi        481   ........................R....................C..............  540

Cow          541   QLTNLERKWQHHEQNNFVMKEFIATKSQESDYRPIMKNVSKQIAEYNKNIVDALHSMSRN  600
Giraffe      541   ................................QQ.........S....S.M.........  600
Okapi        541   ................................QQ..............S.M.........  600
```

Newick Tree of Mammalian IFT74

((rat:0.010688, mouse:0.00781656):0.0235145, (manatee:0.0190562, (((rhesus_macaque:0.0095176, (orangutan:0.0109874, human:0.0160446):0.0265336):0.0326271, bushbaby:0.0395034):0.000633869, (((dog:0.0149467, tiger:0.0189613):0.00506636, (horse:0.0195728, rhino:0.0229996):0.00537898):0.00157705, ((pig:0.034436, (camel:0.00120612, alpaca:0.00381483):0.0232989):0.00112892, (((baiji_dolphin:0.0129324, (orca:0.00392894, dolphin:0.026535):0.00235439):0.00115393, (sperm_whale:0.00512886, minke_whale:0.00829456):0.000526762):0.0181528, (((cow:0.00166106, yak:0.00502798):0.0045889, ((goat:0, sheep:0.00503199):0.00186817, tibetan_antelope:0.00315708):0.00214983):0.00469667, (giraffe:0.00869598,

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okapi:0.00641823):0.0123638):0.0110942):0.00206966):0.00321477):0.00225747):0.00522931):0.0235145
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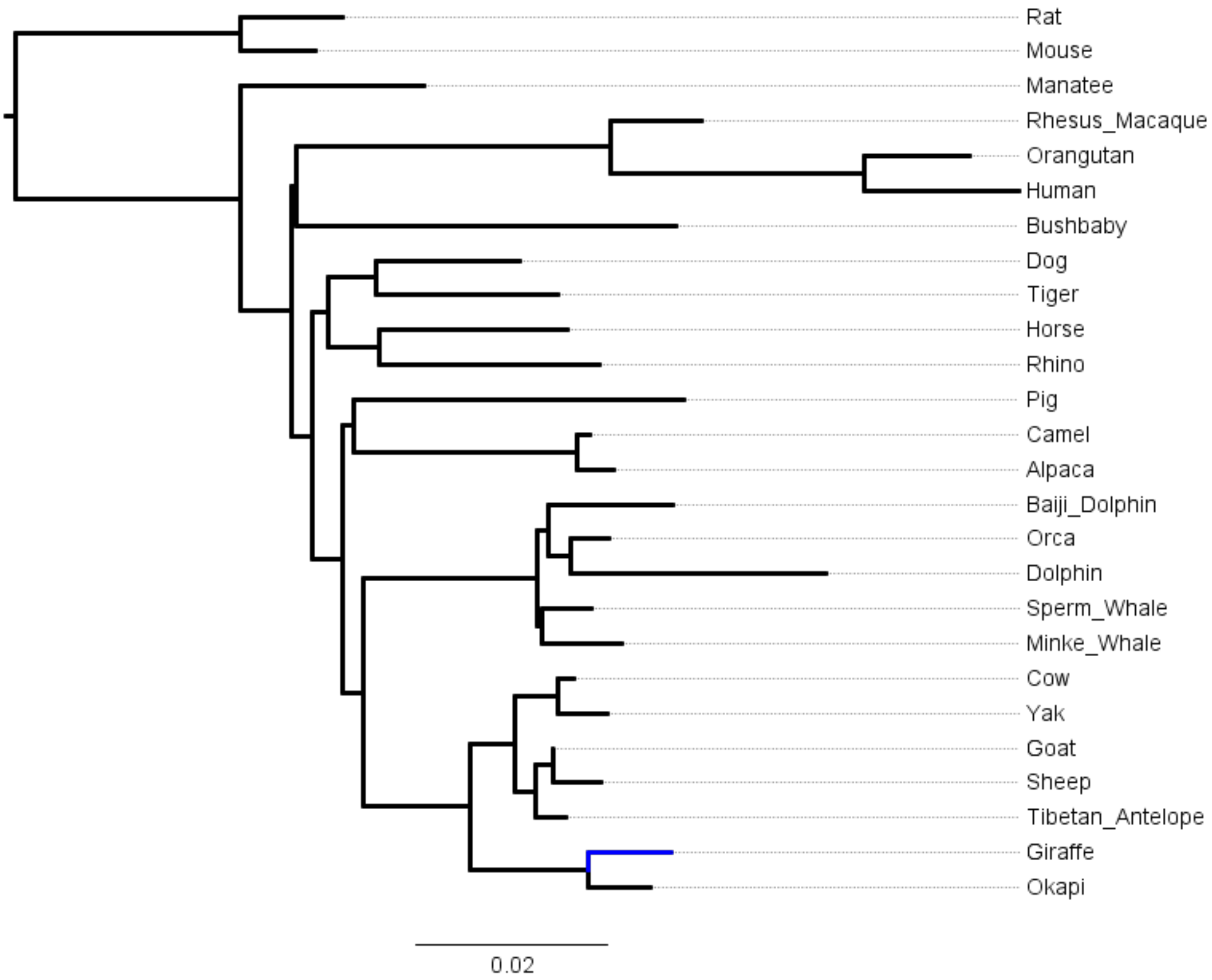

Locus Name: Intraflagellar Transport 74 (**IFT74)**

Locus name: Abhydrolase domain-containing protein 2 (ABHD2)

ENSBTAT00000026579 ABHD2-201   abhydroloase smooth muscle cell migration
mouse: Increase of smooth muscle cell migration and of intimal and femoral artery hyperplasia

PP2: (Giraffe) F14S, V25A

Giraffe: M5T UPS, T7A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ABHD2

```
Cow          1      MNAMMETSELPAVFDGVKLAAVAAVLYVIVRCLNLKSPTAPPDLYFQDSGLSRFLLKSCP  60
Giraffe      1      ....T.A......S..........A...................................  60
Okapi        1      ............................................................  60

Cow          61     LLTKEYIPPLIWGKSGHIQTALYGKMGRVRSPHPYGHRKFITMSDGATSTFDLFEPLAEH  120
Giraffe      61     ............................................................  120
Okapi        61     ............................................................  120

Cow          121    CVGDDITMVICPGIANHSEKQYIRTFVDYAQKNGYRCAVLNHLGALPNIELTSPRMFTYG  180
Giraffe      121    ...G........................................................  180
Okapi        121    ...G........................................................  180

Cow          181    CTWEFGAMVNYIKKTYPLTQLVVVGFSLGGNIVCKYLGETQANQEKVLCCVSVCQGYSAL  240
Giraffe      181    ............................................................  240
Okapi        181    ............................................................  240

Cow          241    RAQETFMQWDQCRRFYNFLMADNMKKIILSHRQALFGDHVKKPQSLEDTDLSRLYTATSL  300
Giraffe      241    ............................................................  300
Okapi        241    ............................................................  300

Cow          301    MQIDDNVMRKFHGYNSLKEYYEEESCMRYLHRIYVPLMLVNAADDPLVHESLLAIPKSLS  360
Giraffe      301    .....................................................T......  360
Okapi        301    .....................................................T......  360

Cow          361    EKRENVMFVLPLHGGHLGFFEGSVLFPEPLTWMDKLVVEYANAICQWERNKSQCSDTELV  420
Giraffe      361    ............................................................  420
Okapi        361    ............................................................  420

Cow          421    EADLE     425
Giraffe      421    .....     425
Okapi        421    .....     425
```

Newick Tree of Mammalian ABHD2

```
(Myotis_Brandtii_Bat:0.0126674, ((Human:0, (Alpaca:0, Camel:0.00237069):0.0023949):0.000939286,
(Bushbaby:0.0122577, ((((Orca:0.000272192, Baiji_Dolphin:0.00208352):0.00220453,
(Elephant:0.0115901, Aardvark:0.0122228):0.0145693):0.00222634, Horse:0.0121795):8.83777e-05,
(((Cat:0.00264401, ((Rat:0.000996293, Mosue:0.00372071):0.00164659, (Walrus:0.00206951,
(Panda:0.00235655, Bear:0):0.000288992):0.000721738):0.00267525):0.00210213,
Rhesus_Monkey:0.000552941):0.000377952, (Pig:0.00384487, (Rhino:0.0022047, ((Giraffe:0.0088849,
Okapi:0.000549268):0.00182319, (Cow:0, (Tibetan_Antelope:0.0023623, Water_Buffalo:0):1.21775e-
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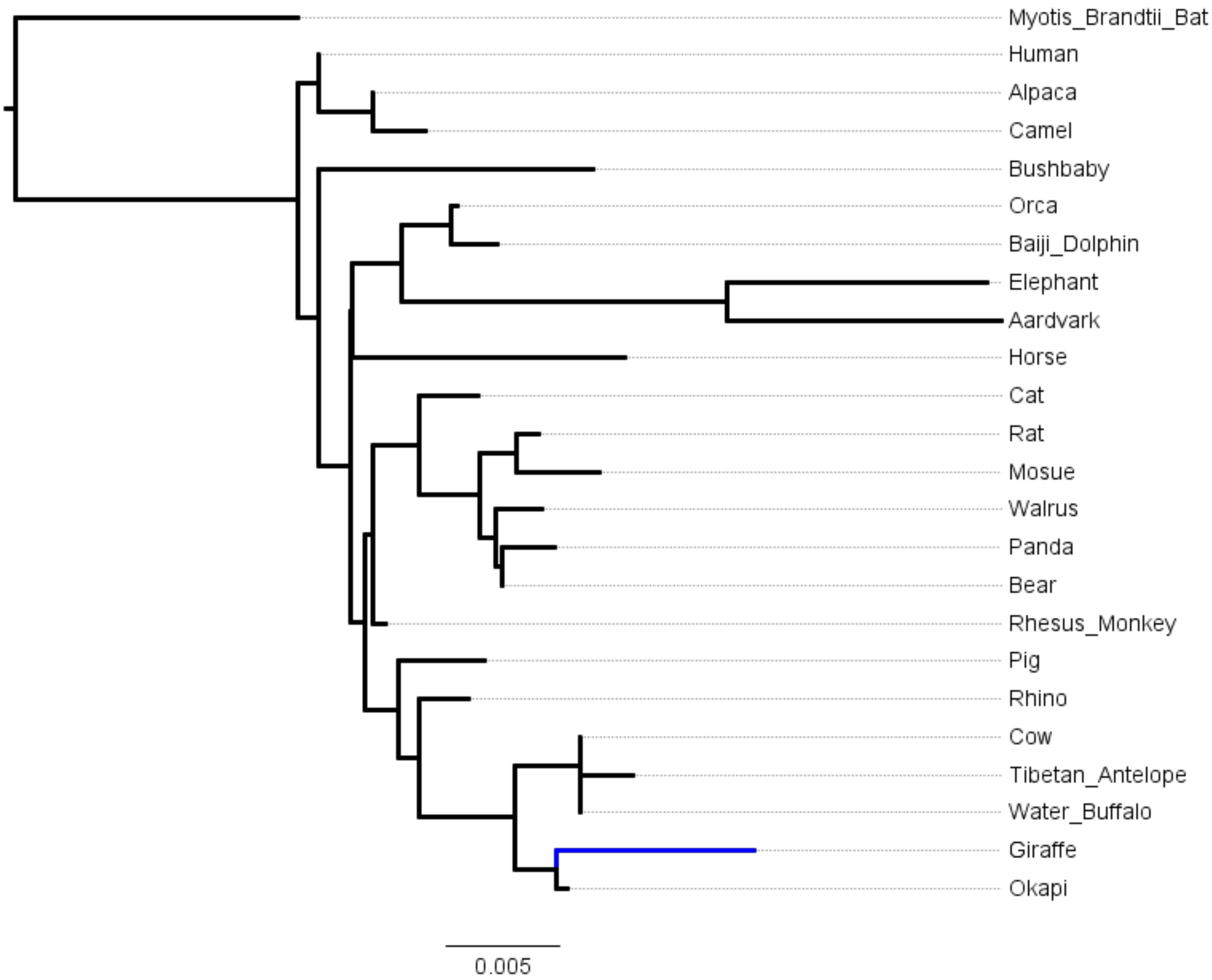

Locus name: Abhydrolase domain-containing protein 2 (ABHD2)

Locus Name: Endoglin (ENG)

ENSBTAT00000054745 ENG-201   endgolin   regulation of angiogenesis
mouse: defective vascular development, extra-arterial hematopoiesis, cardiac defects and die by embryonic day 11.0. Heterozygotes develop hemorrhagic telangiectasia causing strokes, fatal hemorrhage and heart failure

PP2: (Giraffe) S434, Q436S, R437Q; (Giraffe/Okapi) V426R, V427P, N428G, L430H, S431Q; (Okapi) T193M

Giraffe: C17F UIS
Giraffe/Okapi: D128H UPS, multi-UPS 419-427

Protein sequence Alignment of Cow, Giraffe and Okapi ENG
```
Cow          1     MDRGVLCQAMALLLVVCSLGPTSLAETVYCDLQPVDSEVTYVTSQVSEGCVAQIPDATLE  60
Giraffe      1     ....A....I......F..S.................K......................  60
Okapi        1     ....A....V.........S.................K......................  60

Cow          61    VHVLFLTFLGDVSRLELTLQTSKQGGIRPREVLLILSVNKSIFLKLQAPGIPLQLAYDSK  120
Giraffe      61    .............E.Q.....A.....W..............................P.  120
Okapi        61    .............E............................................P.  120

Cow          121   LVFHEALDANITQLPSFTTKDQLLNWANTQGSIASVAELSNPQSIFLRLDQASSSPFSCN  180
Giraffe      121   .......H..T..................K.P.T.A...N..K..L........A....S  180
Okapi        121   .......H..T..................K.P...A...N..K..L.H......A....S  180

Cow          181   LEPQKDMGHTLGWTPKAWGCRLEGVAGHKEAHILRILPGPEASPRTVTVKLELSCAWRDT  240
Giraffe      181   ...........E.S...Y........................W.................  244
Okapi        181   .........M.E.S...Y........................W.................  244

Cow          241   DAAVLILQGPPYVSWLIEANHNMQIWTTGEYSLKIFPDRINPGFQLPNTTQGLLGEARRL  300
Giraffe      245   E................D..........................................  304
Okapi        245   E................D..........................................  304

Cow          301   NASVVASFVELPVANDVSLRTHSCGSGLQPSPTPVEITTPNKGCNQELLLTLIQPKCSSD  360
Giraffe      305   ............L.S....K........................................  364
Okapi        305   ............L.S....K........................................  364

Cow          361   GMTLVLKKDLISTLLCTIKSLTFGDSSCQAKETEDEFVLSSGYSSCGMEVMENVVSNEVV  420
Giraffe      365   ..................T....W......E............................G  426
Okapi        365   ..................T....W......E............................G  426

Cow          421   IRLLSSSSPQRKKVQCINTDSLSLQLGLYLSPHFLQASDTIELGQQGFVQVSVSPSIPEL  480
Giraffe      427   THQA.LP....-......M...................N.....................  485
Okapi        427   THQA.LL....-......M...................N.....................  485

Cow          481   MIQLESCQLNLGPDMEIVELIQGQEAKSSCVSLLSPSPSGDIRFSFLLRGYMVPMPTTGI  540
Giraffe      486   ...............................N...................L........  545
Okapi        486   ............................................................  545

Cow          541   LSCSVTMHPRIRSLEVHKTVSTRLNIISTSLHDKGLVLPAVLGITFGAFLIGALLTAALW  600
Giraffe      546   ..........................V.A...............................  605
Okapi        546   ..........................V.A...............................  605

Cow          601   YIYSHTRHPGKREPVVAVAAPASSESSSTNHSIGSTQSTPCSTSSMA               647
Giraffe      606   ...............................................               652
Okapi        606   ...............................................               652
```

Newick Tree of Mammalian ENG
(elephant:0.072431, ((((human:0.010522, orangutan:0.0109859):0.0208525, macaque:0.0319625):0.0977316, (rat:0.0657712, mouse:0.128808):0.124244):0.00872041, ((((cat:0.00336395, tiger:0.0261992):0.0512544, (((panda:0.0049737, polar_bear:0.0490313):0.0321168, walrus:0.036087):0.00816102, dog:0.0540564):0.01956):0.0375917, (rhino:0.073731, Przewalskii_s_horse:0.138861):0.0213191):0.00223153, ((((sperm_whale:0.0141981, ((orca:0.00166369, bottle_nose_dolphin:0.00288523):0.00870219, baji_dolphin:0.00811665):0.00307396):0.00154817, minke_whale:0.00733948):0.0437027, (alpaca:0.00787746, camel:0.0104727):0.0799427):0.012384, (pig:0.136796, ((((goat:0.0194578, sheep:0.0019086):0.00324475, tibetian_antelope:0.00545567):0.0151977, (water_buffalo:0.00266271,

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(yak:0.00215987, cow:0.0055982):0.00590166):0.01563):0.0103541, (giraffe:0.0119799,
okapi:0.00503603):0.0213213):0.104162):0.00441165):0.0318778):0.0389065):0.072431);
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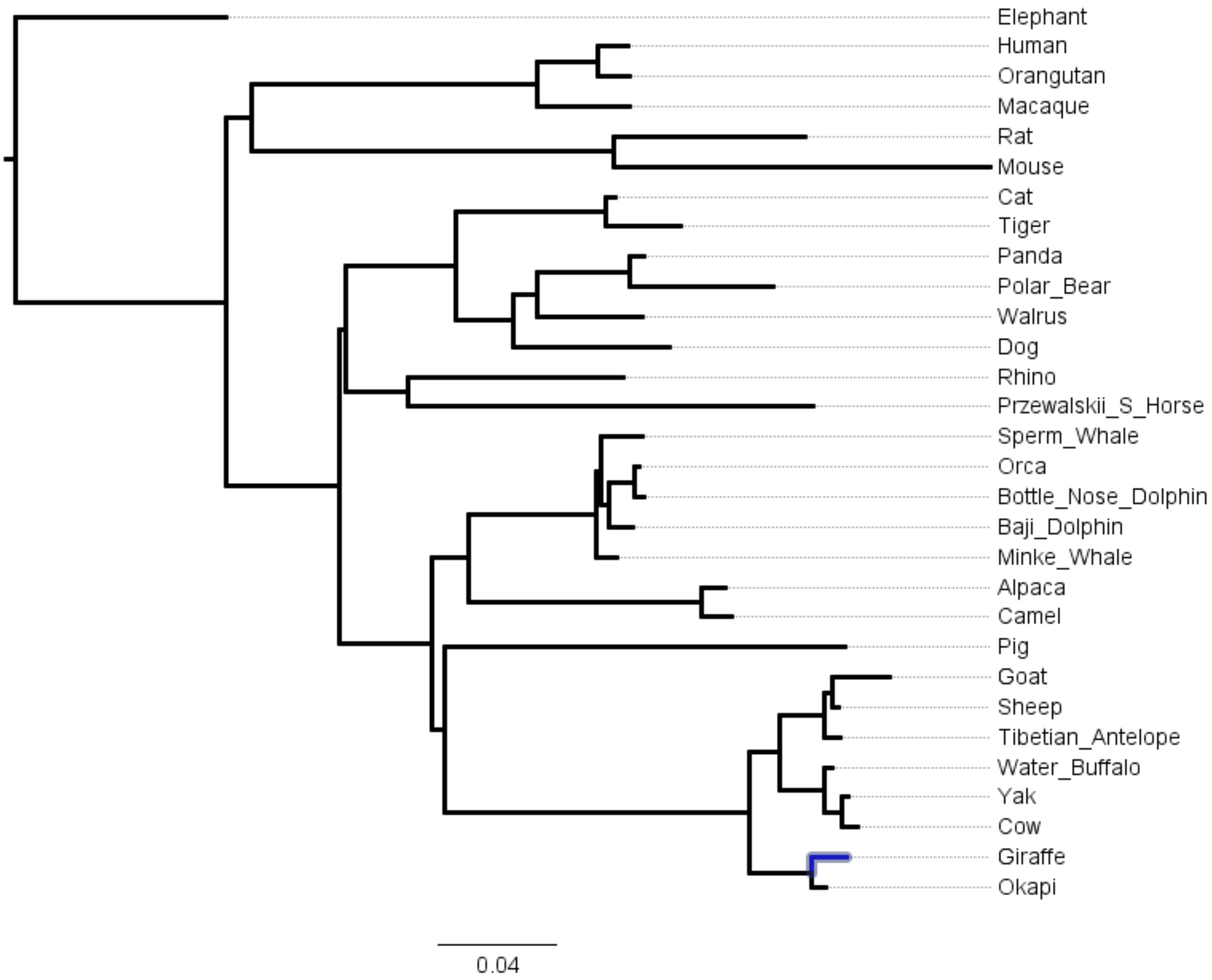

Locus Name: Endoglin (ENG)

Locus Name: Semaphorin 3E (SEMA3E)

ENSBTAT00000019866 SEMA3E-201 semaphorin 3E regulates angiogenesis and neuronal synaptogenesis in eye
mouse: abnormal intersomitic vascular development and loss of the normal segmented somite pattern

PP2: (Giraffe) F227L

Giraffe: A39E UIS, F227L UIS, P694Q UIS
Giraffe/Okapi: Y30S UIS, K313R UIS, V503I UIS
Okapi: I393L UIS, D570E

Protein sequence Alignment of Cow, Giraffe and Okapi SEMA3E

```
Cow         1     MLLDEYQERLFVGGKDLVYSLSLEHISSGYREIHWPSTALKTEECIMKGNDASECANYVR  60
Giraffe     1     .................I...........S........E.............N.......  60
Okapi       1     .............................S......................N.......  60

Cow         61    VLHHYNRTHLLTCGTGAFDPLCAFIRVGYHLEAPLFHLESHRSERGRGRCPFDPSSSFIS  120
Giraffe     61    ............................................................  120
Okapi       61    ............................................................  120

Cow         121   TLIGSELFAGLYSDYWGRDAAIFRSLGRLAQIRTEHDDERLLKEPKFVGSYMIPDNEDRD  180
Giraffe     121   ............................................................  180
Okapi       121   ............................................................  180

Cow         181   DNKVYFFFTEKALEAENSAHAIYTRVGRLCVNDMGGQRILVNKWSTFLKARLVCSVPGMN  240
Giraffe     181   ..............................................L.............  240
Okapi       181   ............................................................  240

Cow         241   GIDTYFDELEDVFLLHTRDHKNPVIFGLFNTTSNIFRGHAICVYHMSSIRAAFNGPYAHK  300
Giraffe     241   ............................................................  300
Okapi       241   ............................................................  300

Cow         301   EGPEYHWSLYEGKVPYPRPGSCASKVNGGRYETTKDYPDDAIRFARSHPLMYQPIKPAHK  360
Giraffe     301   ............R..............................................R  360
Okapi       301   ............R..............................................R  360

Cow         361   KPILVKTDGKYNLKQIAVDRVEAEDGQYDVLFIGTDNGIVLKVITIYNQETESMEEVILE  420
Giraffe     361   ............................................................  420
Okapi       361   ................................L...........................  420

Cow         421   ELQIFKDPVPIISMEISSKRQQLYIGSASAVAQVRFHQCDMYGSACADCCLARDPYCAWD  480
Giraffe     421   ............................................................  480
Okapi       421   ............................................................  480

Cow         481   GISCSRYYPTGTHAKRRFRRQDVRHGNAAQQCFGQQFVGDALDKTEERLAYGIENNSTLL  540
Giraffe     481   .............S........I.....................................  540
Okapi       481   .............S........I.....................................  540

Cow         541   ECTPRSLQAKVIWFVQKGRDARKEEVKTDDRVVKMDLGLLFLRVRRMDAGTYFCQTVEHS  600
Giraffe     541   ...........................................L................  600
Okapi       541   ...................E.........E.............L................  600

Cow         601   FVHTIRKITLEVVEEERVEEMFNKDFEEDRLHKMPCPAQSIIPRGTKPWYKEFLQLIGYS  660
Giraffe     601   ....V.......................................................  660
Okapi       601   ....V.......................................................  660

Cow         661   NFQRVEEYCEKVWCTDKKRKKLKMSPSKWKYANPQEKKLRPKTEHYRLPRHALDS       716
Giraffe     661   .................................Q.....................       716
Okapi       661   .......................................................       716
```

Newick Tree of Mammalian SEMA3E

(((mouse:0.00819491, rat:0.0130089):0.0312075, ((human:0.0017264, macaque:0.00388374):0.0235086, (lemur:0.0361279, ((elephant:0.0154507, (aardvark:0.0158782, manatee:0.0168242):0.000900524):0.0127502, (((rhino:0.0163994, horse:0.035285):0.00371721, (((Weddell_seal:0.00624211, walrus:0.0178236):0.00280579, panda:0.0413091):0.00617642, (cat:0.00132043, tiger:0.00288422):0.0110247):0.00386472):0.00176243, (big_brown_bat:0.0225403,

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orca:0.00853232):0.00601937):0.012962):0.000514436, ((yak:0.00253409,
cow:0.000267038):0.000442011, ((tibetan_antelope:0.0040512, (sheep:0.00140707,
goat:0.00279758):0.000160362):0.0071345, (water_buffalo:0.00416397, (giraffe:0.00565158,
okapi:0.00418703):0.00855504):0.00139084):0.000935351):0.0185334):0.00349495):0.000702794):0.0058
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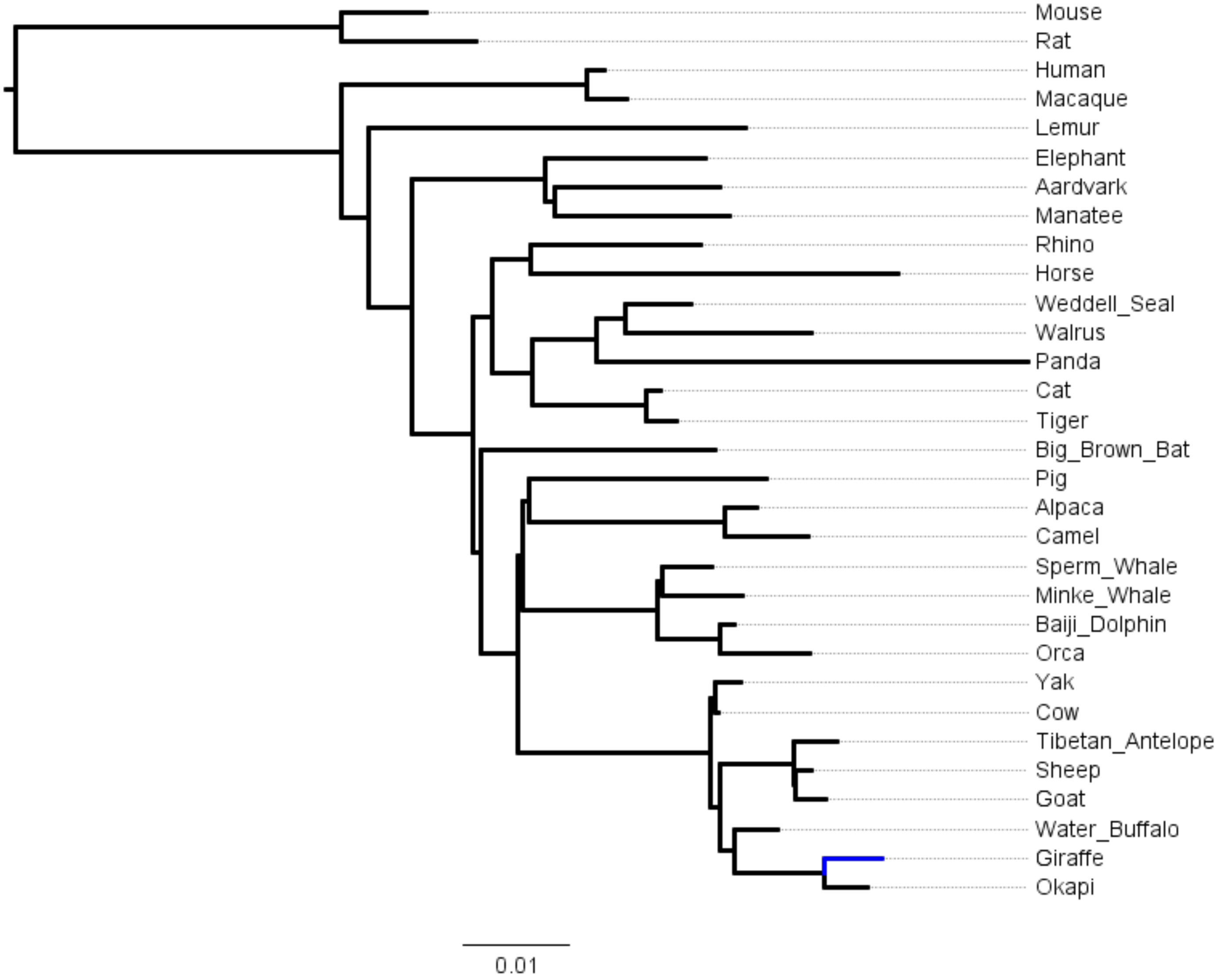


Locus Name: Semaphorin 3E (SEMA3E)

Locus Name: Jumonji, AT Rich Interactive Domain 2 (JARID2)

ENSBTAT00000017189 JARID2-201 modulates histone methyltransferase heart and nervous system development
mouse: defective neural tube closure, impaired hematopoiesis and hypoplasia of liver, thymus and spleen. Homozygotes for another mutation die at birth with cardiac defects. In cardiac cells, it is required to repress expression of cyclin-D1 (CCND1) by activating methylation of 'Lys-9' of histone H3

PP2: (Giraffe/Okapi) S313P, E802D, K1124R

Giraffe: A256L UPS, A272G UPS
Giraffe/Okapi: N200T UIS, A291T UPS, N307S UPS, T310A UIS, S314P UIS, M325L UPS, P442S UPS, K1125R UIS

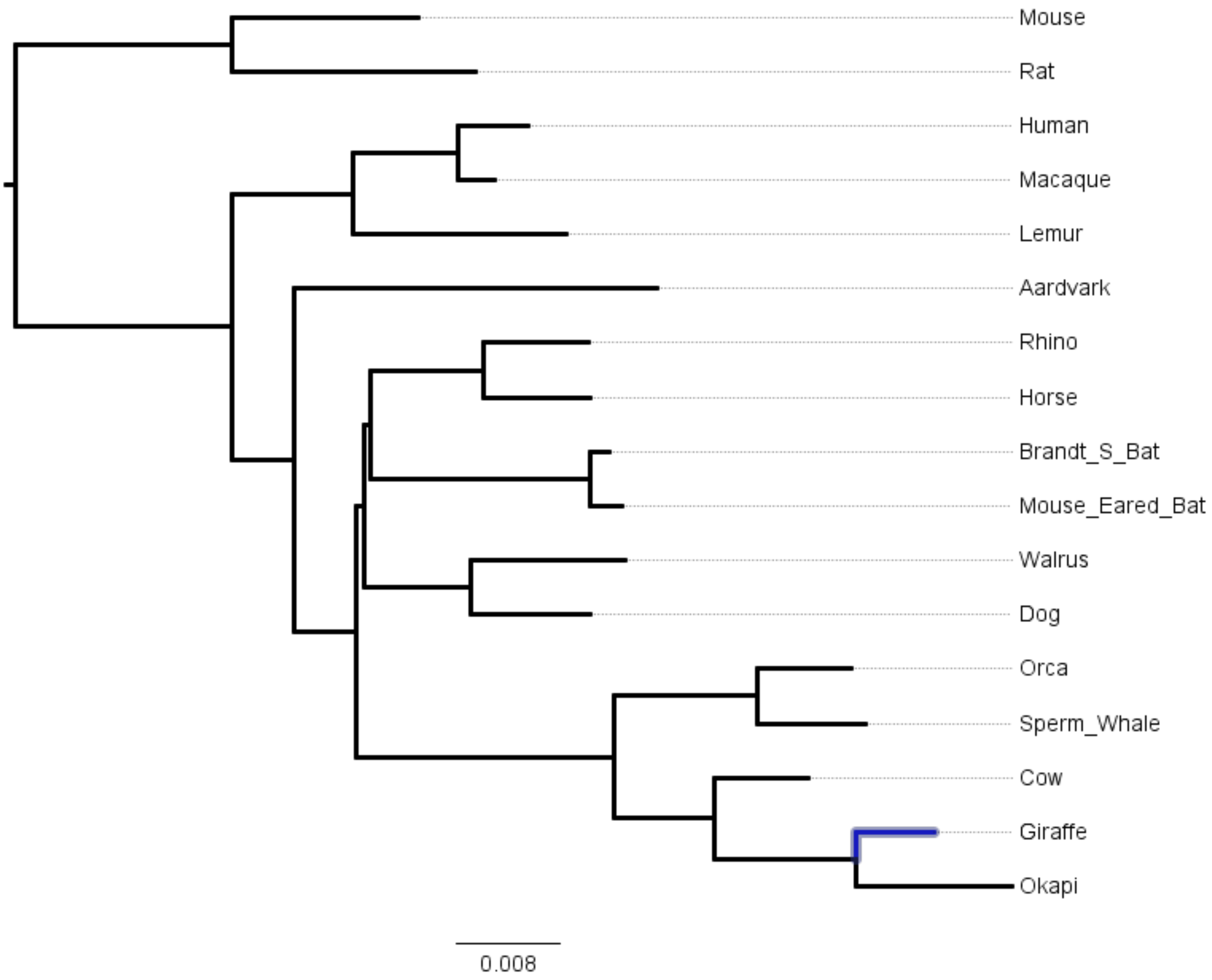
Protein sequence Alignment of Cow, Giraffe and Okapi JARID2

```
Cow          1      MSKERPKRNIIQKKYDDSDGIPWSEERVVRKVLYLSLKEFKNAQKRQHGEGIPGSLKAVN  60
Giraffe      1      ............................................................  60
Okapi        1      ............................................................  60

Cow          61     GLLGNGQSKGLGPASEQSENEKDDASQVSSTSNDVSSSDFEEGPSRKRPRLQAQRKFAQS  120
Giraffe      61     ............................................................  120
Okapi        61     ............................................................  120

Cow          121    QPNSPSTTPVKIVEPLLPPPATQISDLSKRKPKTEDFLTFLCLRGSPALPNSMVYFGSSQ  180
Giraffe      121    ............................................................  180
Okapi        121    ............................................................  180

Cow          181    DEEDVEEEDDETEDVKAATNNASSSCQSTPRKGKAHKHVHNGHVFNGSSRSSREKDPVQK  240
Giraffe      181    ...................T..............T.........................  240
Okapi        181    ...................T..............T.........................  240

Cow          241    HKSKEATPAKEKHSDARADARREQVSASHPPAAPAAGSSAKGLAAHHHHPALHRSAQDLR  300
Giraffe      241    .R............EL........A...Q..G........R.......L.T.........  300
Okapi        241    ..............E.........A.V....V...V............L.T.........  300

Cow          301    KQVSKVNGVTRMSSLGTSATSAKKMREVRPSPSKTVKYTATVTKGTVTYTKAKRELVKET  360
Giraffe      301    ......S..A...P...G......L..................................A  360
Okapi        301    ......S.AA...P...G......L................................R.A  360

Cow          361    KPHHHKPSSAVNHTISGKTESSNAKTRKQVLSLGGASKSTGPAVNGLKVSGRLNPKSCTK  420
Giraffe      361    .....................................R......................  420
Okapi        361    .............A.......................R......H.......P.......  420

Cow          421    EVGGRQLREGLRNSKRRLEEVPPADKPQSPPKKMKGAAGSAAEGPGRKAAPGPAEKAPLG  480
Giraffe      421    ....................AS.................M....................  480
Okapi        421    .G..................AS...Q.............V.......R..L.......P.  480

Cow          481    APGKKEAPERSLERNRPKRAAAGKGPPGRQAHGKPDGGAPCENRSTSQSEPLPRPHEGAA  540
Giraffe      481    G.....V..............................S......................  540
Okapi        481    G.....V..............................S.....H................  540

Cow          541    KAEKGAGRAGWAAMDEIPVLRPSAKEFHDPLVYIESVRPQVEKYGMCRVIPPPDWRPECK  600
Giraffe      541    ............................................................  600
Okapi        541    ............................................................  600

Cow          601    LNDEMRFVTQIQHIHKLGRRWGPNVQRLACIKKHLRSQGITMDELPLIGGCELDLACFFR  660
Giraffe      601    ............................................................  660
Okapi        601    ............................................................  660

Cow          661    LINEMGGMQQVTDLKKWNKLADMLRIPRTAQDRLAKLQEAYCQYLLSYDSLSPEEHRRLE  720
Giraffe      661    ............................................................  720
Okapi        661    ............................................................  720

Cow          721    KEVLMEKESLERRKGPLEGHTEQDYHRFHPLPRFEPKNGLINGVAHRNGFRSKLKEVGPA  780
Giraffe      721    ............................................................  780
Okapi        721    ...........................................................T  780
```

```
Cow       781   QLKTGRRRLFAQEKEVVKEEEEDKGILSDFHKCIYKGRSVSLTTFYRTARNIMNMCFSKE  840
Giraffe   781   ......................E.....................................  840
Okapi     781   ......................E.....................................  840

Cow       841   PAPAEIEQEYWRLVEEKDCHVAVHCGKVDTNTHGSGFPVGKSEPFSRHGWNLTVLPNNTG  900
Giraffe   841   ............................................................  900
Okapi     841   ............................................................  900

Cow       901   SILRHLGAVPGVTIPWLNIGMVFSTSCWSRDQNHLPYIDYLHTGADCIWYCIPAEEEHKL  960
Giraffe   901   .........................................................N..  960
Okapi     901   .........................................................N..  960

Cow       961   EDVVHTLLQANGTPGLQMLESNVMISPEVLCREGIKVHRTVQQSGQFVVCFPGSFVSKVC  1020
Giraffe   961   ..................................V.........................  1020
Okapi     961   ............................................................  1020

Cow       1021  CGYSVSETVHFATTQWTSMGFETAKEMKRRHIAKPFSMEKLLYQIAQAEAKKENGPTLST  1080
Giraffe   1021  ............................................................  1080
Okapi     1021  ............................................................  1080

Cow       1081  ISALLDELRDTELRQRRQLFEAGLHSSARYGSHDGSSAAPDGKKKPRKWLQLETSERRCQ  1140
Giraffe   1081  ............................................R...............  1140
Okapi     1081  ............................................R...............  1140

Cow       1141  VCQHLCYLSMVVQENENVVFCLECALRHVEKQKSCRGLKLMYRYDEEQIISLVNQICGKV  1200
Giraffe   1141  ............................................................  1200
Okapi     1141  ............................................................  1200

Cow       1201  SGKNGSIENCLSKPTPKRGPRKRATVDVPPSRLASS                          1236
Giraffe   1201  ....................................                          1236
Okapi     1201  ....................................                          1236
```

Newick Tree of Mammalian JARID2

((mouse:0.0143285, rat:0.0186293):0.0166807, (((human:0.00534, macaque:0.00271815):0.00815442,
lemur:0.0164536):0.00922036, (aardvark:0.027892, ((((rhino:0.00804583,
horse:0.00816269):0.00868825, (Brandt_s_bat:0.00152453,
mouse_eared_bat:0.00251263):0.0168041):0.000590236, (walrus:0.0118426,
dog:0.00919531):0.00819426):0.000571848, ((orca:0.00718431, sperm_whale:0.0083205):0.0110135,
(cow:0.00720798, (giraffe:0.00599024,
okapi:0.0119704):0.0108826):0.00763952):0.0198209):0.00477126):0.00472721):0.0166807);



Locus Name: Jumonji, AT Rich Interactive Domain 2 (JARID2)

Locus Name: 25-hydroxyvitamin D-1 alpha hydroxylase (CYP27B1)

ENSBTAT00000022485 CYP27B1-201 25-hydroxyvitamin D-1 alpha hydroxylase bone development and calicium metabolism
mouse: hypocalcemia, hyperparathyroidism, growth retardation, rickets; human: ricketts

PSG (Giraffe) N353G
PP2: (Giraffe) G354N; (Giraffe/Okapi) S280F, P423L

Giraffe: R10K UIS, P33S UPS, R103C UPS, G354N UPS, V456I UPS
Giraffe/Okapi: V244I UPS, P423L UIS

Protein sequence Alignment of Cow, Giraffe and Okapi CYP27B1

```
Cow          1      MTQTLKFASRVFHRVRCPELGASLGSRGSESAPRVLADIPGPSTPGFLAELFCKGGLSRL  60
Giraffe      1      ......L..K...................D..S...........................  60
Okapi        1      ......L..............T.......D..............................  60

Cow          61     HELQVQGAARFGPVWLASFGTVRTVYLAAPTLVEQLLRQEGPRPERCSFSPWTEHRRRRQ  120
Giraffe      61     ..........................................C.........A.......  120
Okapi        61     ....................................................V.......  120

Cow          121    RACGLLTAEGEEWQRLRSLLAPLLLRPQAAARYAGTLHGVVRDLVRRLRRQRGLGAGPPS  180
Giraffe      121    .................................................H.........A  180
Okapi        121    ...........................................................A  180

Cow          181    LVRDVAGEFYKFGLEGIAAVLLGSRLGCLEAEVPPDTETFIRAVGSVFVSTLLTMAMPSW  240
Giraffe      181    ..........................................................N.  240
Okapi        181    ......................................N...................N.  240

Cow          241    LHRVVPGPWDRLCRDWDQMFAFAQQHVEQREAEVAMRNQSEKSEEDMGPGAHLTYFLLQK  300
Giraffe      241    ...I.................................S.FG.................RE  300
Okapi        241    ...IL.....................I..........S.FG.................RE  300

Cow          301    ELPAASILGNVTELLLAGVDTVSNTLSWALYELSRHPEIQTALHAEITAALGPGSSTQPS  360
Giraffe      301    ............................................S........N......  360
Okapi        301    ............................................S...............  360

Cow          361    ATALSQLPLLKAVVKEVLRLYPVVPGNSRVPDRDICVGEYIIPKNTLVTLCHYATSRDPA  420
Giraffe      361    ................................K.....D.....................  420
Okapi        361    ................................K.....D.....................  420

Cow          421    QFPEPNSFRPARWLGEGPAPHPFASLPFGFGKRSCVGRRLAELELQMALAQILIHFEVQP  480
Giraffe      421    ..L................................I..................N.....  480
Okapi        421    ..L................................M..................N.....  480

Cow          481    EPGSAPVRPMTRTVLVPERSINLQFVDR                                  509
Giraffe      481    ............................                                  509
Okapi        481    ............................                                  509
```

Newick Tree of Mammalian CYP27B1

```
(aadrvark:0.0375242, (elephant:0.0622914, ((macaque:0.0148826, (human:0.00896279,
orangutan:0.00691122):0.0132665):0.0395558, (((((tiger:0.00238673, cat:0.00750471):0.0145471,
(((polar_bear:0.00899558, panda:0.016931):0.0163114, ferret:0.0316429):0.00178405,
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sperm_whale:0.0114343):0.0188347, (((tibetan_antelope:0.00404073, goat:0.00784087):0.00682575,
((yak:1.66149e-05, cow:0.00195383):0.0019791, water_buffalo:0.00593403):0.00921975):0.0114662,
(giraffe:0.0120963,
okapi:0.00975338):0.0076539):0.0190941):0.00254586):0.00162077):0.00916863):0.00447796):0.0071097
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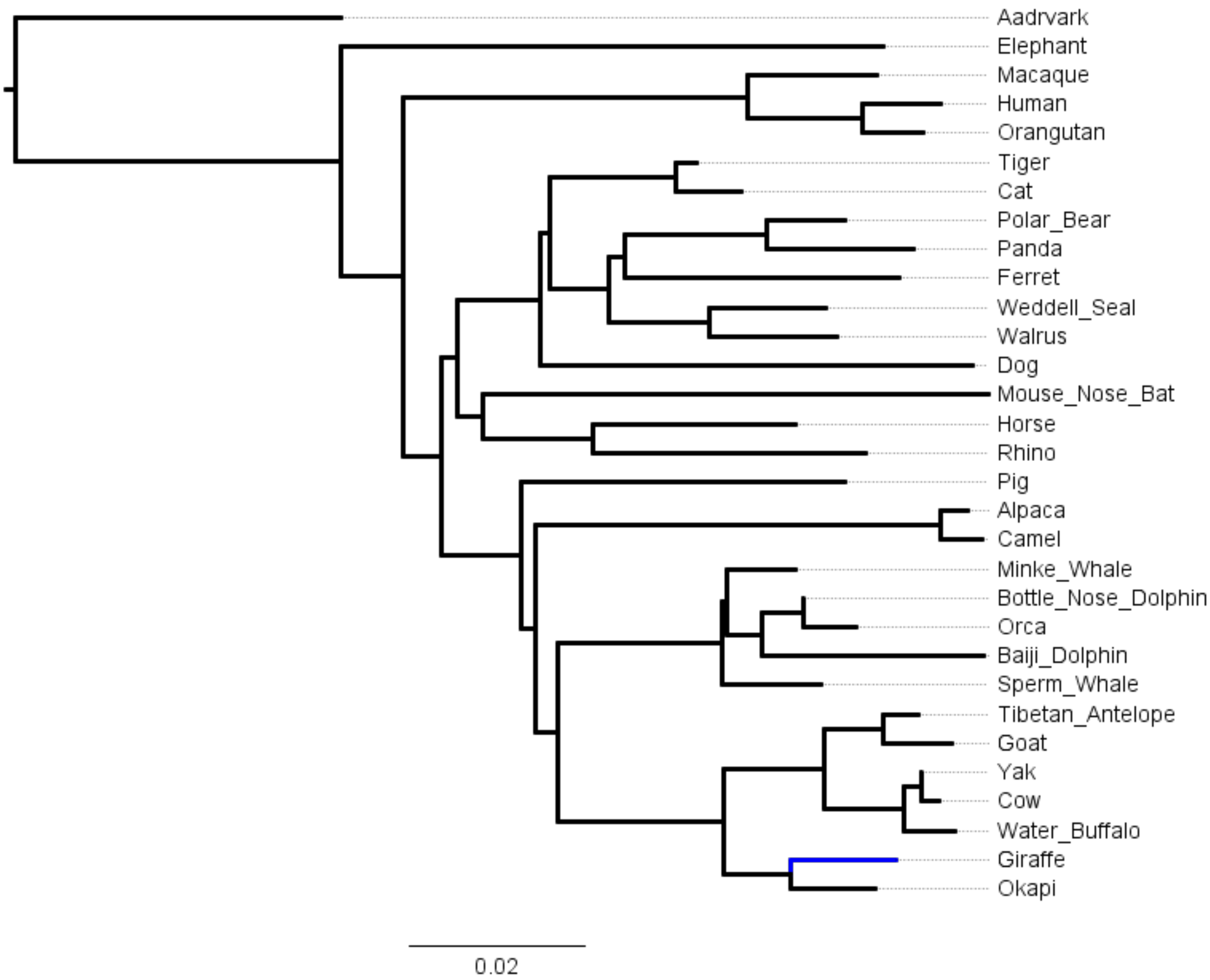


Locus Name: 25-hydroxyvitamin D-1 alpha hydroxylase (CYP27B1)

Locus name: Calcipressin-3 (RCAN3)

ENSBTAT00000023194 RCAN3-201 inhibits calcineurin A, binds troponin heart, brain, skeletal muscle, kidney, language SNP humans
no mutations in m/h; highest expression in heart, skeletal muscle kidney, liver and peripheral blood leukocytes. GWAS human linked to reading ability.

PP2: (Giraffe) S177R, S203G, E204G, T205A

Giraffe: K177R UIS, S203G UIS, E204G UIS, T205A UIS, E206D UIS, E209A UIS, I218V UIS

Protein sequence Alignment of Cow, Giraffe and Okapi RCAN3

```
Cow          1     MLRDTMNSWNDSQSDLCSTDHEEEEEMVFGENEDDLEEMMDLSDLPTSLFACRVHEAVFE  60
Giraffe      1     ....A.K...................I.........................S.......  60
Okapi        1     ....A.K...................I.........................S.......  60

Cow          61    VPEQKERFEALFTIYDDQVTFQLFKSFRRVRINFSKPEAAARARIELHETDFNGRKLKLY  120
Giraffe      61    ............................................................  120
Okapi        61    ............................................................  120

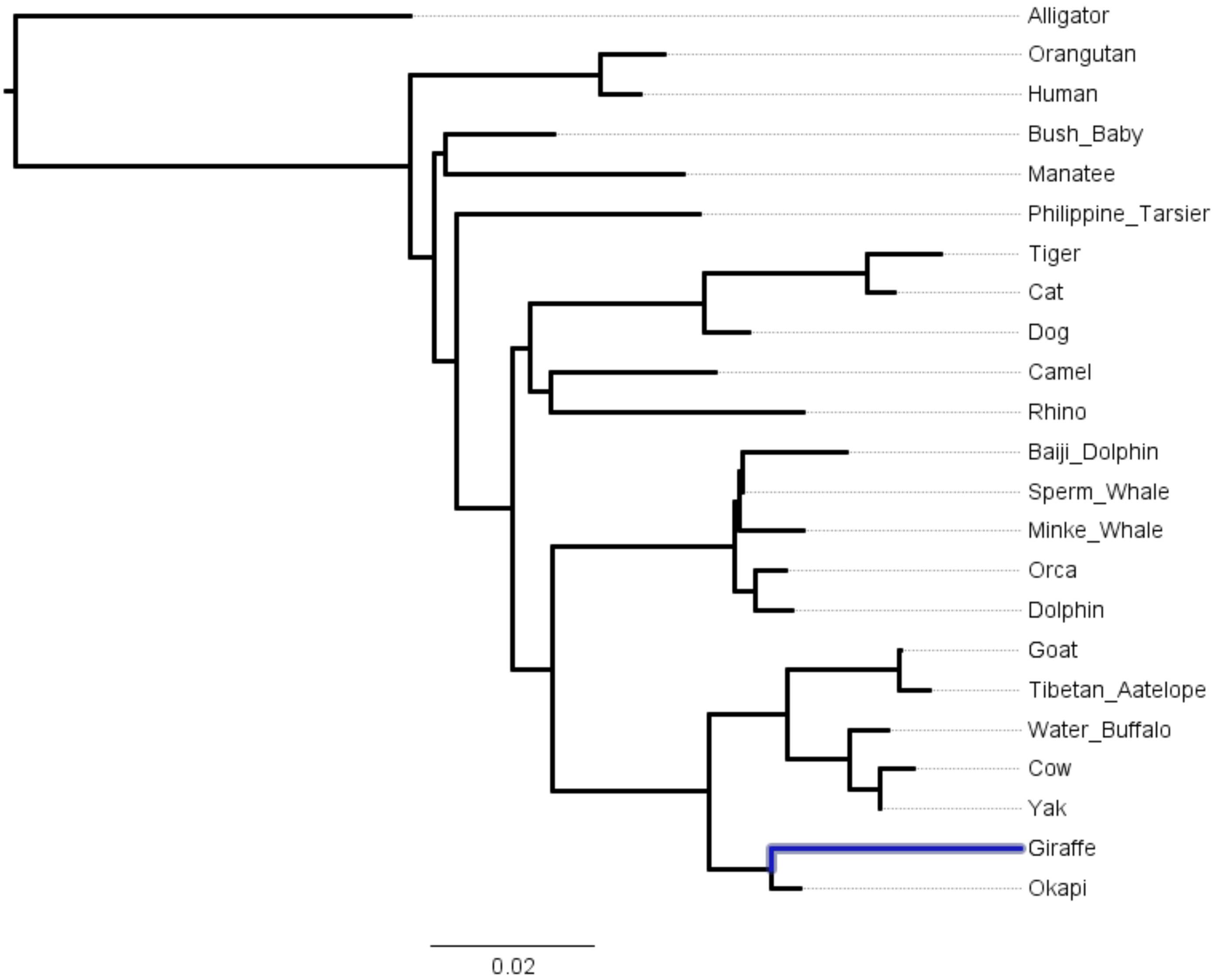
Cow          121   FAQVQMSGETRDKSYLQPPQPAKQFLISPPASPPVGWKQGGDATPVINYDLLCAVSKLGP  180
Giraffe      121   .......S................................E..M............R...  180
Okapi        121   .....I.S................................E..M................  180

Cow          181   GEKYELHAGTESTPSVVVHVCESETEEEEETKNPKQKITQTRRPEPPTAALSEPRAFDCA  240
Giraffe      181   ......................GGAD..A........V.........A............  240
Okapi        181   ...............................................A............  240

Cow          241   L
Giraffe      241   .
Okapi        241   .
```

Newick Tree of Mammalian RCAN3

(alligator:0.0483704, ((orangutan:0.00770631, human:0.00482028):0.0231866, ((bush_baby:0.0132982, manatee:0.0290937):0.00139181, (Philippine_Tarsier:0.0295425, ((((tiger:0.00911675, cat:0.00346237):0.019884, dog:0.00552053):0.0212035, (camel:0.0201789, rhino:0.0309182):0.00245174):0.00214144, ((((baiji_dolphin:0.0126797, sperm_whale:0):0.000511953, minke_whale:0.00787482):0.000597203, (orca:0.00375068, dolphin:0.0045828):0.0025521):0.0222505, ((giraffe:0.030299, okapi:0.0034659):0.00771831, ((goat:0.000308341, tibetan_Aatelope:0.00384968):0.0135723, (water_buffalo:0.00470648, (cow:0.00421536, yak:0):0.00364454):0.00754964):0.00965143):0.0191975):0.00471539):0.00686056):0.00281634):0.00283215):0.0483704);



Locus name: Calcipressin-3 (RCAN3)

Locus Name: CDC42 Effector Protein (Rho GTPase Binding) 2 (CDC42EP2; BORG1)

ENSBTAT00000045518 CDC42EP2-201 rho GTPase inhibit CDC42 heart
no mutations in m/h; highly expressed in heart

PSG: (Giraffe) F62L 0.932, Q74R 0.935, E80Q 0.937, P142L 0.933, T163P 0.931, A169T 0.933
PP2: Giraffe, P142L

Giraffe: N49K UPS, F62L UIS, Q74E UPS, E80Q UPS, L163P UPS, A169T UPS
Okapi: G78V UPS, T137A UPS

Protein sequence Alignment of Cow, Giraffe and Okapi CDC42EP2

```
Cow          1     MSTKVPIYLKRGSRKGKKEKLRDLLSSDMISPPLGDFRHTIHIGSGGGNDTFGDISFLQG  60
Giraffe      1     ................................................K...........  60
Okapi        1     ............................................................  60

Cow          61    KFHLLPGTAVDETQEDSGFEMPFQFTRTATLCGRELPDGPSPLLKNAISLPVIGGPQALT  120
Giraffe      61    .L..........AR.....Q........................................  120
Okapi        61    ............A....V..........................................  120

Cow          121   LPAAQAPPKPPRLHLETPQASPQEAGTVDVWRIPEAGAAHSELTTESGAEEPFLSHASSL  180
Giraffe      121   ...................P.L..........V........GP.P...T...........  180
Okapi        121   ................A..S.....................G..P...............  180

Cow          181   LSLHVDLGPSILDDVLQIMDQDLGHLQIPT     210
Giraffe      181   ..............................     210
Okapi        181   ..............................     210
```

Newick Tree of Mammalian CDC42EP2

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human:0.00496303):0.00894311):0.00121776):0.0175749):0.00913156, ((((giraffe:0.0348769,
(okapi:0.0137486, ((tibantelope:0.00435601, gerenuk:0.00521358):0.00589585,
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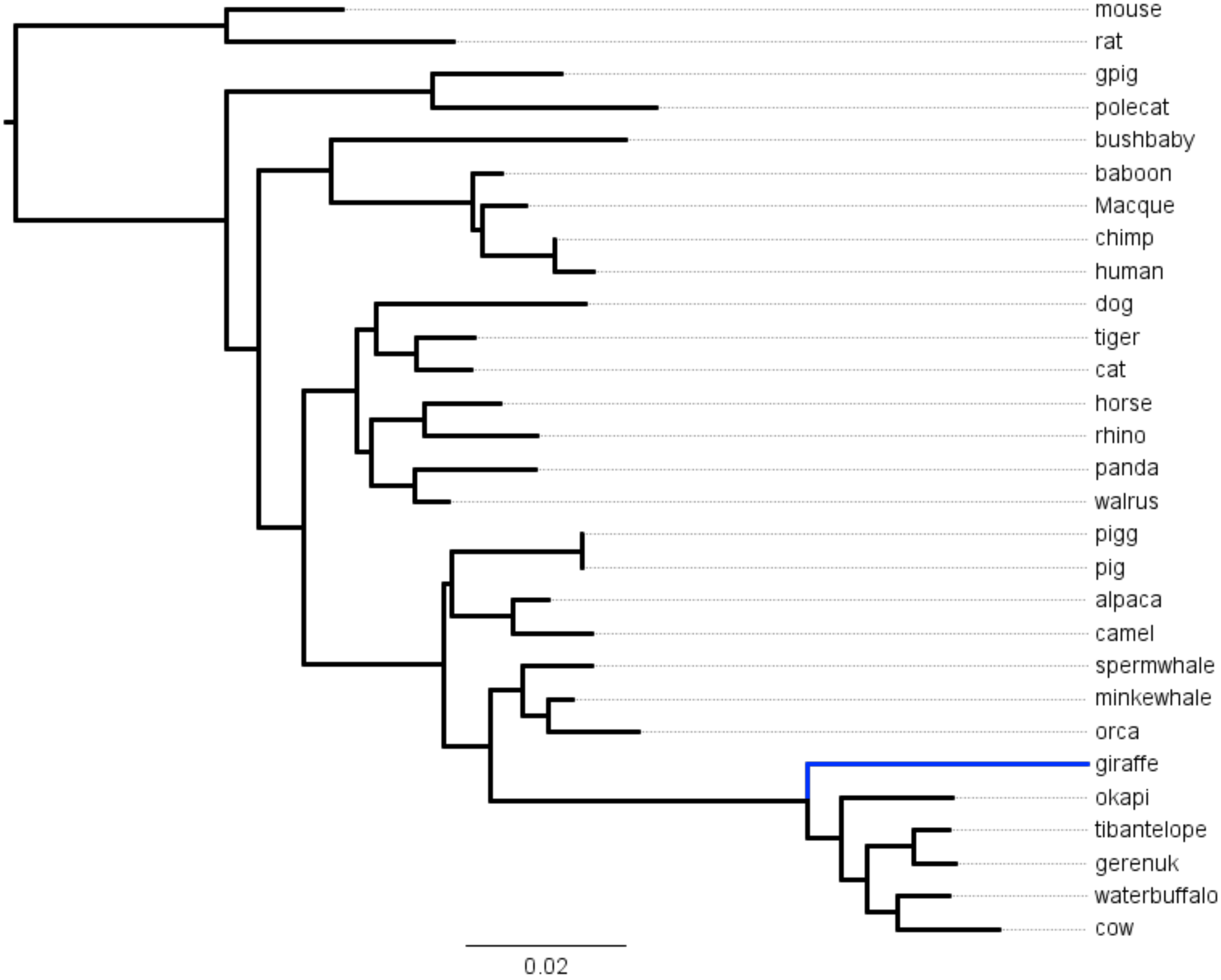
(spermwhale:0.00857386, (minkewhale:0.00288067,
orca:0.0112377):0.00324813):0.00395618):0.00592918, ((pigg:0, pig:0):0.0162874,
(alpaca:0.00438069, camel:0.00980442):0.00761974):0.000994792):0.0175427, ((dog:0.026105,
(tiger:0.0072252, cat:0.00689315):0.00494486):0.00250318, ((horse:0.00953455,
rhino:0.0141094):0.00664547, (panda:0.0150295,
walrus:0.00420301):0.00556832):0.00179352):0.00665173):0.00552213):0.00407209):0.0262331);



Locus Name: CDC42 Effector Protein (Rho GTPase Binding) 2 (CDC42EP2; BORG1)

Locus Name: Urotensin-2 (UTS2B)

ENSBTAT00000061012 UTS2B-201 urotensin 2, vasoconstrictor regulates blood pressure in the brain
no mutations in m/h described

PP2: (Giraffe) L81Q, L103V; (Okapi) L75V

Giraffe: L81Q UPS, S97F UIS, G102S UPS, L103V UPS
Okapi: L75V UIS

Protein sequence Alignment of Cow, Giraffe and Okapi UTS2B

```
Cow      1    MNVILSTTLSFGLLTLLSVMIFLESVHGVPYFVQGNELLPDKEDADGEELLLALLNKNFG  60
Giraffe  1    .........C..................L...I...........T...............  60
Okapi    1    .........C..........F.......L...I...........T...............  60

Cow      61   FQRPSNIDIELADKLEELNQLEKLKEQLMEAKDAEMSYAIDGLSSSHPNKRACFWKYCV  119
Giraffe  61   ............N.......Q...............F....SV................  119
Okapi    61   ............N.V.............I..............................  119
```

Newick Tree of Mammalian UTS2B

```
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walrus:0.0517476):0.0163016, panda:0.0510553):0.0126691, (((dog:0.0744576,
bushbaby:0.208502):0.0216221, ((polecat:0.115453, tiger:0.107241):0.0275348, (human:0.0317029,
(baboon:0.00266853, rhesus_monkey:0.0144267):0.0484187):0.128325):0.00521252):0.00442636,
((rabbit:0.16054, manatee:0.233692):0.0177839, ((pig:0.0880933, camel:0.107285):0.0154182,
(((sperm_whale:0, (baiji_dolphin:0, (orca:0.00849078,
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((sheep:0.00905644, tibetan_antelope:0.018346):0.00470059,
goat:0.0230067):0.0310677):0.00427655):0.000482062):0.0319728):0.0211113):0.0108759):0.00849987):
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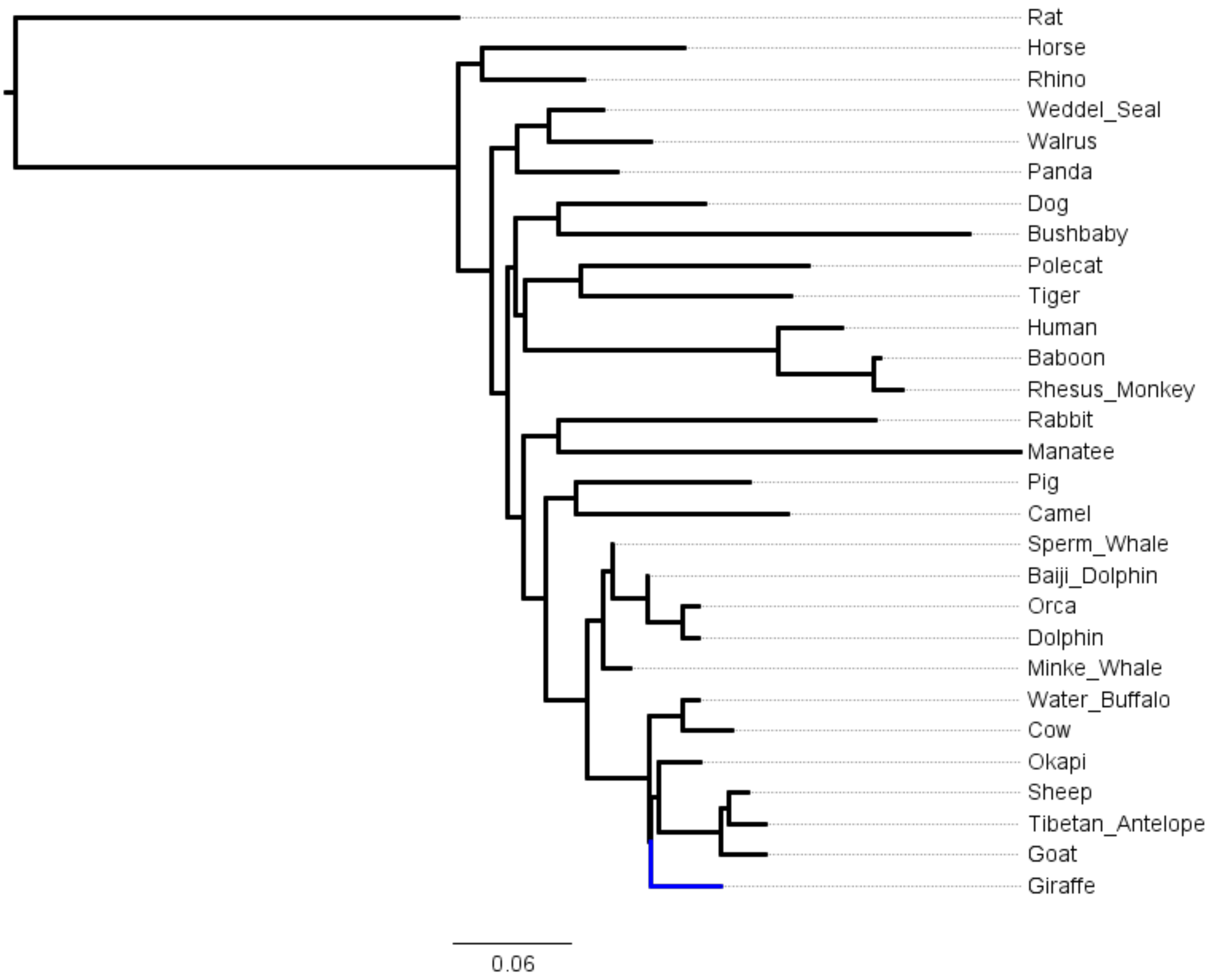


Locus Name: Urotensin-2 (UTS2B)

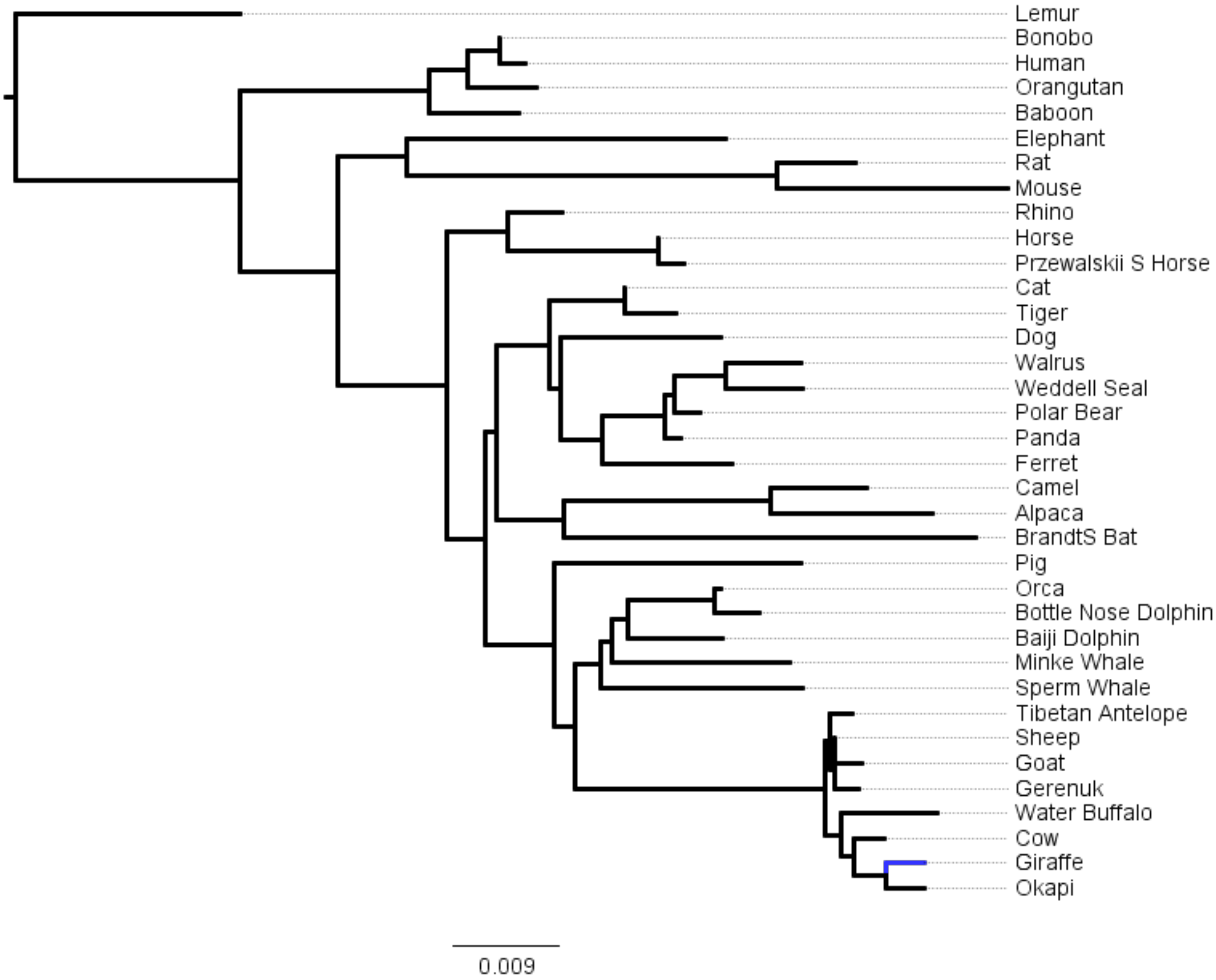
Locus Name: Alpha 1 Adrenergic Receptor **ADRA1A**

ENSBTAT00000044849 ADRA1A-201   adrenergic receptor regulation of blood pressure
mouse: hypotension in mouse KO

PP2: (Giraffe) A422S
PSG: (Giraffe) A422S
Giraffe: A422S UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ADRA1A

```
Cow          1     MVFLSGNASDSSNCTHPPPPVNISKAILLGVILGGLILFGVLGNILVILSVACHRHLHSV  60
Giraffe      1     ............................................................  60
Okapi        1     ............................................................  60

Cow          61    THYYIVNLAVADLLLTSTVLPFSAIFEILGYWAFGRVFCNVWAAVDVLCCTASIMGLCII  120
Giraffe      61    ............................................................  120
Okapi        61    ............................................................  120

Cow          121   SIDRYIGVSYPLRYPTIVTQKRGLMALLCVWALSLVISIGPLFGWRQPAPEDETICQINE  180
Giraffe      121   ............................................................  180
Okapi        121   ............................................................  180

Cow          181   EPGYVLFSALGSFYVPLTIILVMYCRVYVVAKRESRGLKSGLKTDKSDSEQVTLRIHRKN  240
Giraffe      181   ............................................................  240
Okapi        181   ............................................................  240

Cow          241   AQVGGSGVTSAKNKTHFSVRLLKFSREKKAAKTLGIVVGCFVLCWLPFFLVMPIGSFFPD  300
Giraffe      241   .P.......N..................................................  300
Okapi        241   .A.......N..................................................  300

Cow          301   FRPSETVFKIAFWLGYLNSCINPIIYPCSSQEFKKAFQNVLRIQCLRRKQSSKHTLGYTL  360
Giraffe      301   ............................................................  360
Okapi        301   ............................................................  360

Cow          361   HAPSHVLEGQHKDLVRIPVGSAETFYKISKTDGVCEWKIFSSLPRGSARMAVARDPSACT  420
Giraffe      361   .....A......................................................  420
Okapi        361   .....A..................L...................................  420

Cow          421   TARVRSKSFLQVCCCLGPSTPSRGENHQIPTIKIHTISLSENGEEV               467
Giraffe      421   .S.............................................               467
Okapi        421   ...............................................               467
```



Locus Name: Alpha 1 Adrenergic Receptor **ADRA1A**

Locus Name: Alpha-2B adrenergic receptor (ADRA2B)

ENSBTAT00000012514 ADRA2B-201 adrenergic receptor regulation of vasoconstriction
mouse: Homozygous null mice exhibit poor survival and breeding, lack the vasoconstrictor response to alpha2-adrenergic receptor agonists, and display background strain dependent postnatal respiratory failure. human: emotional stress response

PP2: S332G

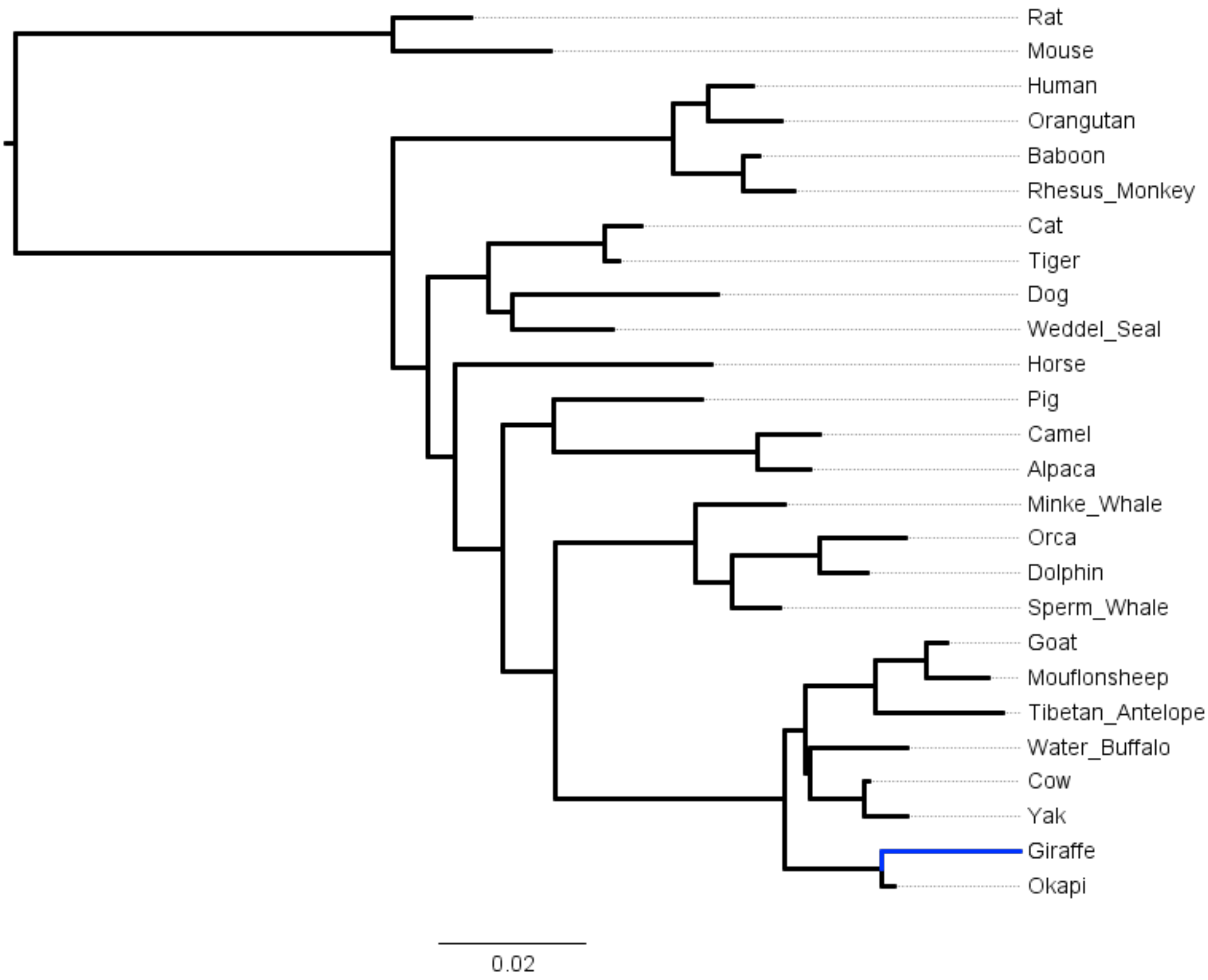
Giraffe: P267R UPS, A317V UIS, G329S UPS, R331Q UIS, G347A UIS, A349V UPS, H402Y UPS
Giraffe/Okapi: A314S UPS, V400A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ADRA2B

```
Cow         1     MDHQEPYSVQATAAIAAVITFLILFTIFGNALVILAVLTSRSLRAPQNLFLVSLAAADIL  60
Giraffe     1     ............................................................  60
Okapi       1     ............................................................  60

Cow         61    VATLIIPFSLANELLGYWYFWRTWCEVYLALDVLFCTSSIVHLCAISLDRYWAVSRALEY  120
Giraffe     61    ......................A.....................................  120
Okapi       61    ......................A.....................................  120

Cow         121   NSKRTPRRIKFIILIVWLIAAVISLPPLIYKGDQGPQPLARPQCKLNQEAWYILASSIGS  180
Giraffe     121   ............................................................  180
Okapi       121   ............................................................  180

Cow         181   FFAPCLIMILVYLRIYLIAKRSHCRGPRAKGGPGERESKQPHPVPGEVSDSAKLPTLASQ  240
Giraffe     181   .............................AR.............................  240
Okapi       181   .............................AR.............................  240

Cow         241   LATPGEANGCSQPRPGEKGDGETPEAPGTPALPPSWPAIPKSGQGQKEGVCGSSPEEEAE  300
Giraffe     241   .............H.....E.....DR.............N...................  300
Okapi       241   ...................E.....D..............N...................  300

Cow         301   EEEEEGCEPQALPASPASACSPPLQQPQGSRVLATLRGQVLLGRGTGTAGAQWWRRRTQL  360
Giraffe     301   .....S.......S..V.......P...S.Q...............A.V...........  360
Okapi       301   .............S..........P...................................  360

Cow         361   SREKRFTFVLAVVIGVFVLCWFPFFFSYSLGAICPQHCKVPHGLFQFFFWIGYCNSSLNP  420
Giraffe     361   .......................................A.Y..................  420
Okapi       361   .......................................A....................  420

Cow         421   VIYTVFNQDFRRAFRRILCREWTQTAW      447
Giraffe     421   ....I...............Q......      447
Okapi       421   ....I...............Q......      447
```

Newick Tree of Mammalian ADRA2B

((Rat:0.0104148, Mouse:0.0213392):0.0511955, (((Human:0.00598824, Orangutan:0.00979629):0.00481354, (Baboon:0.00215937, Rhesus_Monkey:0.00687016):0.00947309):0.0377786, (((Cat:0.00489578, Tiger:0.00191474):0.0156221, (Dog:0.0278336, Weddel_Seal:0.0136589):0.00306395):0.00838064, (Horse:0.0347292, ((Pig:0.0199742, (Camel:0.00859486, Alpaca:0.00715415):0.0274931):0.00686307, ((Minke_Whale:0.0120515, ((Orca:0.0115844, Dolphin:0.00647579):0.0118757, Sperm_Whale:0.00637478):0.00508485):0.0189107, ((((Goat:0.00286248, Mouflonsheep:0.00838647):0.00671911, Tibetan_Antelope:0.0171775):0.00965908, (Water_Buffalo:0.0131733, (Cow:0.00079359, Yak:0.00594049):0.00723812):0.00074093):0.0027817, (Giraffe:0.0186536, Okapi:0.00168747):0.0131997):0.0309802):0.00707524):0.00643335):0.00381393):0.00454996):0.0511955);



Locus Name: Alpha-2B adrenergic receptor (ADRA2B)

Locus name: Angiotensin converting enzyme **(ACE)**

ENSBTAT00000061106 ACE-201 angiotensin I converting enzyme regulation of blood pressure mouse: reduced systemic blood pressure, normocytic anemia, renal abnormalities, inability to concentrate urine, and reduced male fertility

PP2: (Giraffe) W628G, R1242H; (Giraffe/Okapi) P405H; (Okapi) H861P

Giraffe: W628G UIS, A insertion 1045 UIS, R1242H UIS
Giraffe/Okapi: R242S UPS, T563P UPS, PDV866-888AEL UIS, P1151S UIS, (GP.V..GR)1235-1247(ST.Q..SH) UIS, S1287G UPS

Protein sequence Alignment of Cow, Giraffe and Okapi ACE

```
Cow          1     MGAASGRRSPPLLLPLLLLLLPPPPVILELDPALQPGNFPADEAGAQIFAASFNSSAEQV  60
Giraffe      1     ........W.................V.......................D.........  60
Okapi        1     ........W.................V.......................D.........  60

Cow          61    LFQSTAASWAHDTNITEENARLQEEAALLSQEFSEAWGQKAKDLFDPVWQNFTDPTLLRI  120
Giraffe      61    .....................R.........................I............  120
Okapi        61    .....................R....................N....I............  120

Cow          121   IGAVRTLGPANLDLEKRQKYNSLLSNMSRIYSTAKVCFPNKTAPCWSLDPELTNILASSR  180
Giraffe      121   ......................................................V.....  180
Okapi        121   ......................................................V.....  180

Cow          181   SYTLLLYAWEGWHNAAGIPLKPLYQDFTALSNEAYKQDGFSDTGAYWRSWYDSPTFTEDL  240
Giraffe      181   ..A................................R........................  240
Okapi        181   ..A.........................................................  240

Cow          241   ERLYQQLEPLYLNLHAYVRRALHRRYGDRYINLRGPIPAHLLGNMWAQSWENIYDTVVPF  300
Giraffe      241   .S....................Y.....K..........................M....  300
Okapi        241   .S..................T.Y................................M....  300

Cow          301   PDKPNLDVTDVMVQKGWNATHMFRVAEEFFTSLGLLPMPPEFWAESMLEKPSDGREVVCH  360
Giraffe      301   .........ST.................................................  360
Okapi        301   .........ST.................................................  360

Cow          361   ASAWDFYNRKDFRIKQCTRVTMDQLSTVHHEMGHVQYYLQYKGQHVSLRRGANPGFHEAI  420
Giraffe      361   ..........................................D.................  420
Okapi        361   ..........................................D.................  420

Cow          421   GDVLALSVSTPAHLHKIGLLDQVTNDTESDINYLLKMALEKIAFLPFGYLVDQWRWGVFS  480
Giraffe      421   ............................................................  480
Okapi        421   ............................................................  480

Cow          481   GRTPPSRYNYDWWYLRTKYQGICPPVVRNETHFDAGAKFHVPNVTPYIRYFVSFVLQFQF  540
Giraffe      481   ......L.....................................................  540
Okapi        481   ......L.....................................................  540

Cow          541   HEALCKEAGHQGPLHQCDIYQSTQAGAKLRALLQAGSSRPWQEVLKDMVGSDNLDARPLL  600
Giraffe      541   ......................P.....................................  600
Okapi        541   ......................P.....................................  600

Cow          601   SYFQPVTQWLEEQNQQNGEVLGWPEYQWRPPMPDNYPEGIDLVSDEDEARKFVEEYDRRS  660
Giraffe      601   ...........................G......S.........................  660
Okapi        601   ..........Q...........................N.....................  660

Cow          661   QVVWNEYAEANWNYSTDISTDNSKLLMEKNLQMANHTVKYGTWARKFDVTNFQNATMKRM  720
Giraffe      661   ..............N.N...........................K...............  720
Okapi        661   ..............N.N...........................K...............  720

Cow          721   IKKIQDLERAALPTKELEEYNQILLDMETVYSVASVCHENGTCLRLEPDLTNLMATSRNY  780
Giraffe      721   .............V..................M.....K.....Q......K......S.  780
Okapi        721   .............V........................K............K......S.  780

Cow          781   QDLAWAWKSWRDKVGRSILPYFPKYVELTNKAARLNGYQDGGDSWRSMYEMPFLEEELEQ  840
Giraffe      781   .................V...................F............T.........  840
Okapi        781   .................V...................F............T.........  840
```

```
Cow          841    LFQELQPLYLNLHAYVRRALHRHYGPDVINLEGPIPAHLLGNMWAQSWSNIYDLVAPFPS  900
Giraffe      841    .........................AEL................................  900
Okapi        841    ....................P....AEL................................  900

Cow          901    APKMDATEAMIKQGWTPLRMFKEADNFFTSLGLLPMPPEFWNKSMLEKPTDGREVVCHAS  960
Giraffe      901    ............................................................  960
Okapi        901    ............................................................  960

Cow          961    AWDFFNGKDFRIKQCTSVNMEDLVVAHHEMGHIQYFMQYKDLPVTFREGANPGFHEAIGD  1020
Giraffe      961    ............................................................  1020
Okapi        961    ............................................................  1020

Cow          1021   VLALSVSTPTHLHKINLLSSGDGGYEEDINFLMKMALEKIAFIPFSFLVDQWRWRVFDGS  1080
Giraffe      1021   .....................................D......................  1081
Okapi        1021   .....................................D......................  1080

Cow          1081   VTRENYNQEWWSLRLKYQGVCPPLARSQDDFDPGAKFHIPASVPYVRYFVSFVIQFQFHQ  1140
Giraffe      1082   .......................V....................................  1141
Okapi        1081   .......................V....................................  1140

Cow          1141   ALCQAAGHQGPLHKCDIYQSKEAGKLLADAMKLGFSQPWPEAMRLITGQSNMSAAAMMTY  1200
Giraffe      1142   ..........S.................................................  1201
Okapi        1141   ..........S.................................................  1200

Cow          1201   FKPLLDWLVTENGRHGEKLGWPQYNWTPNSARLEGPFVGSGRVNFLGLNLEEQQARVGQW  1260
Giraffe      1202   ............E.....................ST.Q..SH..................  1261
Okapi        1201   ............E.....................ST.Q..S...................  1260

Cow           1261  VLLFLGVALLVATLGLTQRLFSIRHHSLRRPHRGPQFGSEVELRHS      1306
Giraffe       1262  ..........................G.....H.............      1307
Okapi         1261  ..........................G.....H.............      1306
```

Newick Tree of Mammalian ACE

```
(Elephantulus_edwardii:0.0411946, (elephant:0.0704335, ((((human:0.0120756,
(orangutan:0.00370523, macaque:0.015684):0.00825184):0.0565632, lemur:0.06645):0.00623678,
(rat:0.0281724, mouse:0.0361543):0.0652831):0.00574888, ((horse:0.0444316, (dog:0.0164191,
(walrus:0.00850943, Weddell_seal:0.0130814):0.0109381):0.0501477):0.00829452, ((pig:0.0635755,
camel:0.058586):0.00494567, (((((orca:0.00252518, bottle_nose_dolphin:0.0121079):0.0144663,
baiji_dolphin:0.0248234):0.0121141, sperm_whale:0.0311566):0.0161918, (((yak:0, (cow:0.00327061,
water_buffalo:0.00518782):0.00377227):0.00640482, (tibetan_antelope:0.023739, (sheep:0.0060831,
goat:0.0188735):0.0480138):0.0306322):0.00449784, (giraffe:0.00558065,
okapi:0.00365032):0.0180445):0.0371664):0.00510038):0.017292):0.00969575):0.0150436):0.0411946);
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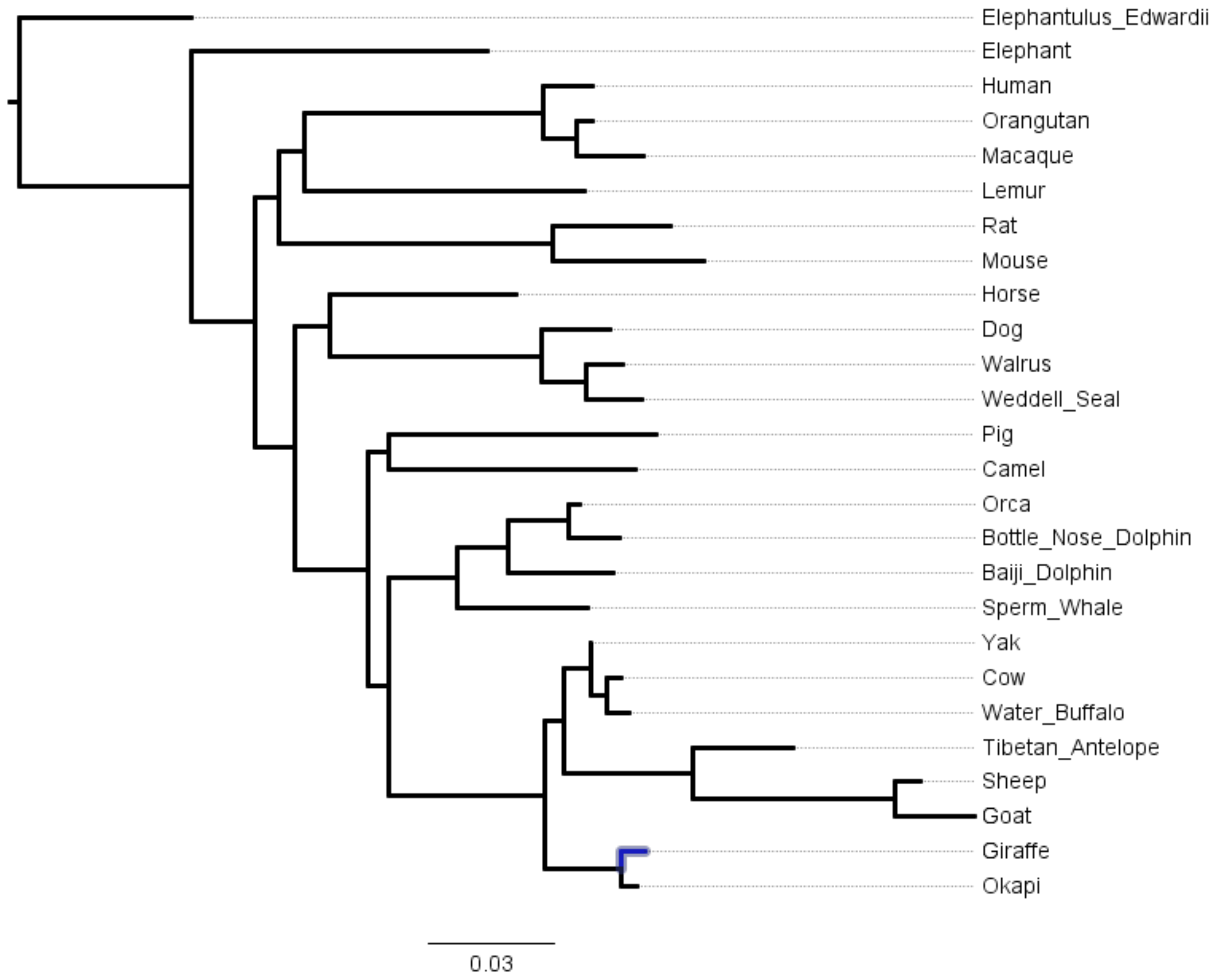

Locus name: Angiotensin converting enzyme **(ACE)**

Locus name: Somatostatin Receptor 2 (SSTR2)

ENSBTAT00000022785 SSTR2-201   somatostatin receptor   behavior, eye, pancreas
mouse: Homozygotes for a null allele show elevated anxiety and locomotor and exploratory deficits

PP2: All benign

Giraffe: P12S UPS, V24M UPS, G25E UPS, I29V UPS, F229L UIS, D336E UIS

Protein sequence Alignment of Cow, Giraffe and Okapi SSTR2

```
Cow          1     MDLVSELNETQPWLTAPFDLNGSVGAANISNQTEPYYDLASNVVLTFIYFVVCIIGLCGN  60
Giraffe      1     ...A..F....S...S.......MET.DV..............A......A.........  60
Okapi        1     ...............S...........D...............A..L...A.........  60

Cow          61    TLVIYVILRYAKMKTITNIYILNLAIADELFMLGLPFLAMQVALVHWPFGKAMCRVVMTV  120
Giraffe      61    ....................................................I.......  120
Okapi        61    ....................................................I.......  120

Cow          121   DGINQFTSIFCLTVMSIDRYLAVVHPIKSAKWRRPRTAKMINVAVWGVSLLVILPIMIYA  180
Giraffe      121   ............................................................  180
Okapi        121   ............................................................  180

Cow          181   GLRSNQWGRSSCTINWPGESGAWYTGFIIYAFILGFLVPLTIICLCYLFIIIKVKSSGIR  240
Giraffe      181   ................................................L...........  240
Okapi        181   ............................................................  240

Cow          241   VGSSKRKKSEKKVTRMVSIVVAVFIFCWLPFYIFNVSSVSVAISPTPALKGMFDFVVVLT  300
Giraffe      241   ............................................................  300
Okapi        241   ............................................................  300

Cow          301   YANSCANPILYAFLSDNFKKSFQNVLCLVKVSGTDDGERSDSKQDKSRLNETTETQRTLL  360
Giraffe      301   .................................A.E........................  360
Okapi        301   .................................A.....T....................  360

Cow          361   NGDLQTSI    368
Giraffe      361   ........    368
Okapi        361   ........    368
```

Newick Tree of Mammalian SSTR2

```
((rat:0.00992787, mouse:0.00922574):0.0141798, ((((alpaca:0.00168148,
camel:0.00652659):0.0127307, (pig:0.00350426, ((minke_whale:0.000650498,
sperm_whale:0.00478433):0.00208782, (dolphin:0.00106841, (orca:0.00246721,
baiji_dolphin:0.00296761):0.001649):0.00749814):0.00504175):0.00103442):0.00201469,
((((horse:0.00567714, rhino:0.00796606):0.00198576, elephant:0.00896672):0.0026655,
((((panda:0.00449213, dog:0.00640737):0.000763132, walrus:0.000586227):0.00464178,
tiger:0.00629546):0.00905596, (manatee:0.00727576, ((human:0.000189696, (baboon:4.28727e-05,
rhesus_monkey:0.00267084):0.00525256):0.000559442,
orangutan:0.00489409):0.0203181):0.001936):0.00276139):0.000444939,
bushbaby:0.0249858):0.00341257):0.00315909, ((tibetan_antelope:0.00772093, (goat:0.00272831,
sheep:0):0.000476007):0.00248115, ((giraffe:0.0223613, okapi:0.00790698):0.00842764,
(cow:0.00274314, yak:0):0.00543617):0.00169616):0.0135158):0.0141798);
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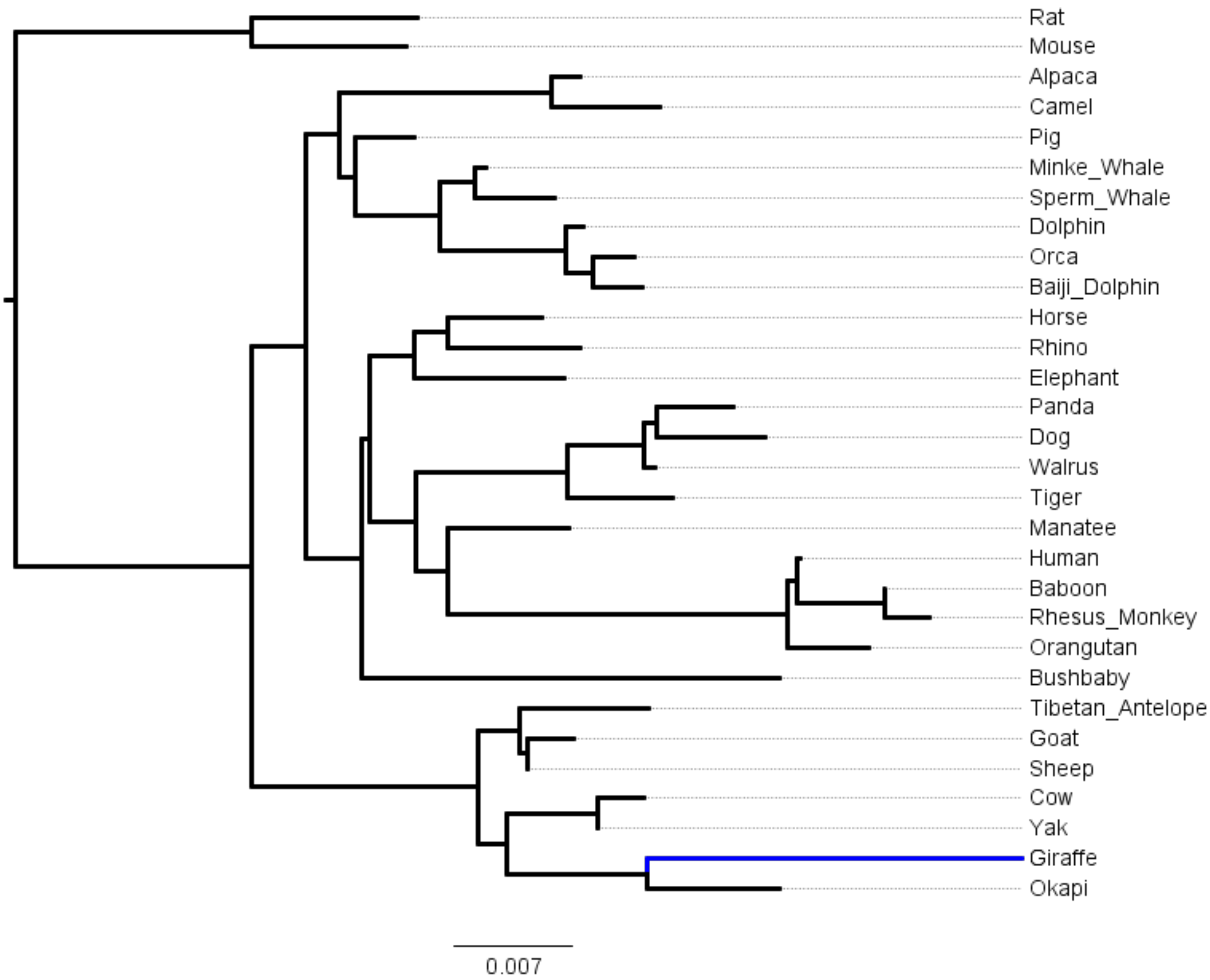

Locus name: Somatostatin Receptor 2 (SSTR2)

Locus Name: fascin actin-bundling protein 1 (FSCN1)

ENSBTAT00000004145 FSCN1-201 fascin, organizes filamentous actin nervous system, eye
mouse: impaired migration of mature dendritic cells.

PP2: (Giraffe) A129T, S439W

Giraffe: A129T UIS, I346V UPS, S350C UIS, S439W UIS, V465A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi FSCN1

```
Cow         1     MTANGTAEALQIQFGLINCSNKYLTAETFGFKVNASASSLKKKQIWTLEQPPDEAGSAAV  60
Giraffe     1     ............................................................  60
Okapi       1     ...................G........................................  60

Cow         61    CLRSHLGRYLAADKDGNVTCEHEAPGADCRFLIVAHDDGRWSLQSEVHRRYFGGTEDRLS  120
Giraffe     61    .........................S....................A.............  120
Okapi       61    ..............................................A.............  120

Cow         121   CFAQTVSPAEKWSVHIAMHPQVNIYSLARKRYAHLGARPADEISVDRDVPWGVDSLITLA  180
Giraffe     121   ........T...................................................  180
Okapi       121   ............................................................  180

Cow         181   FQDQRYSLQTADHRFLRHDGRLVAHPEPATGYTLEFRSGKVAFRDCEGRYLAPSGPSGTL  240
Giraffe     181   ............................................................  240
Okapi       181   ............................................................  240

Cow         241   KAGKATKVGKDELFALEQSCAQVVLQAANERNVSTRQGMDLSANQDEETDQETFQLEIDR  300
Giraffe     241   ............................................................  300
Okapi       241   ............................................................  300

Cow         301   DTKKCAFRTHSGKYWTLTTTGGVQSTASTKDARCYFDIEWRDRRIILRASNGKFVTAKKN  360
Giraffe     301   .............................................V...C..........  360
Okapi       301   ............................................................  360

Cow         361   GQLAASVETAGDSELFLMKLINRPIIVFRGEHGFIGCRKVTGTLDANRSNYDVFQLEFRD  420
Giraffe     361   ............................................................  420
Okapi       361   ............................................................  420

Cow         421   GAYNIKDSTGKYWMVGNDSSVTSSSDSPVDFFLEFCDYNKVAIKVGGHYLKGDHAGVLKA  480
Giraffe     421   ................S.W.......A.................A...............  480
Okapi       421   ..........................T.................................  480

Cow         481   CADTIDPTTLWEY       493
Giraffe     481   .............       493
Okapi       481   .............       493
```

Newick Tree of Mammalian FSCN1

```
(rat:0.0137084, ((dog:0, (polecat:0,
walrus:0.00409865):0.00206885):0.00355177,((galago:0.00929261, (human:0.0023545,
(baboon:0.0006747, rhesus:0.00135576):0.00171471):0.0102139):0.00248441,(starnosedmole:0.0106757,
(rhino:0.00825516, (pig:0.021789, ((giraffe:0.0133866, (okapi:0.00129707,(waterbuffalo:0.0022269,
(cow:0, yak:4.95575e-05):0.00184229):0.00277217) :0.00196795):0.00884849, (dolphin:0,minkewhale:
0.00617017) :0.00616312):0.00298791):0.0244847):0.00245079):0.00217459):0.00226142):0.0137084);
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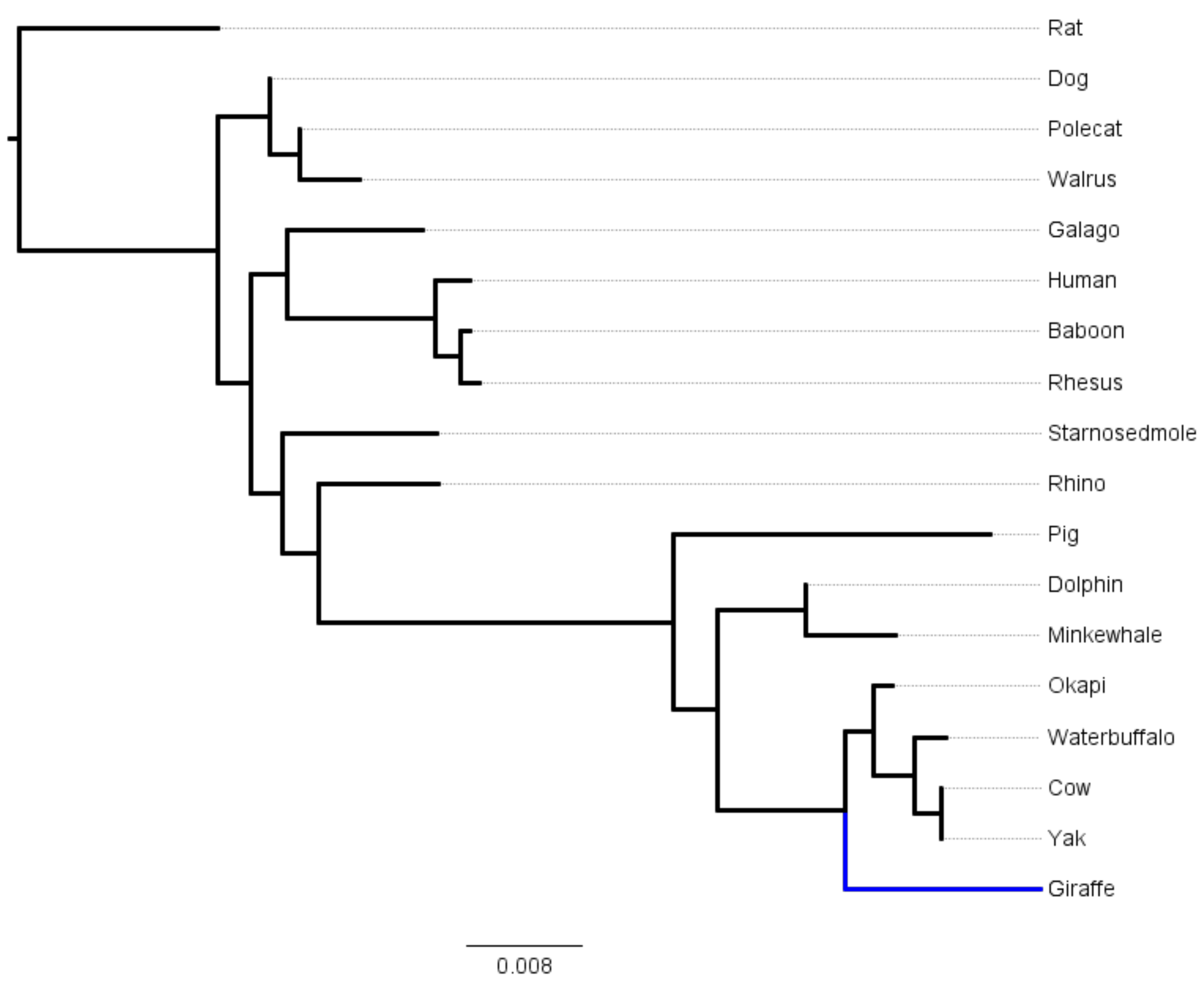

Locus Name: fascin actin-bundling protein 1 (FSCN1)

Locus name: neurofibromin 2 (**NF2)**

ENSBTAT00000017489 NF2-201 merlin regulator of hippo pathway auditory functions
human: neurofibromatosis, deafness and balance disorder humans

PP2: All benign

Giraffe: L453P UIS, M457T UPS, K514R UIS, M522A UPS, N527S UIS, D529E UIS

Protein sequence Alignment of Cow, Giraffe and Okapi NF2

```
Cow          1     MKWKGKDLFDLVCRTLGLRETWFFGLQYTIKDTVAWLKMDKKVLDHDVSKEEPVTFHFLA  60
Giraffe      1     ............................................................  60
Okapi        1     ............................................................  60

Cow          61    KFYPENAEEELVQEITQHLFFLQVKKQILDEKIYCPPEASVLLASYAVQAKYGDYDPSVH  120
Giraffe      61    ............................................................  120
Okapi        61    ............................................................  120

Cow          121   KRGFLAQEELLPKRVINLYQMTPEMWEERITAWYAEHRGRARDEAEMEYLKIAQDLEMYG  180
Giraffe      121   ............................................................  180
Okapi        121   ............................................................  180

Cow          181   VNYFTIRNKKGTELLLGVDALGLHIYDPENKLTPKISFPWNEIRNISYSDKEFTIKPLDK  240
Giraffe      181   ..............................R.............................  240
Okapi        181   ..............................R.............................  240

Cow          241   KIDVFKFNSSKLRVNKLILQLCIGNHDLFMRRRKADSLEVQQMKAQAREEKARKQMERQR  300
Giraffe      241   ............................................................  300
Okapi        241   ............................................................  300

Cow          301   LAREKQMREEAERTRDELERRLLQMKEEATMANEALMRSEETADLLAEKAQITEEEAKLL  360
Giraffe      301   ............................................................  360
Okapi        301   ............................................................  360

Cow          361   AQKAAEAEQEMQRIKATAIRTEEEKRLMEQKVLEAEVLALKMAEESERRAKEADQLKQDL  420
Giraffe      361   ............................................................  420
Okapi        361   ............................................................  420

Cow          421   QEAREAERRAKQKLLEITTKPTYPPMNPLPAPLPPDMASFSLTGDSLSFDFKDTDMKRLS  480
Giraffe      421   ................................P...T...N.I.................  480
Okapi        421   ........................................N.I.................  480

Cow          481   MEIEKEKVEYMEKSKHLQEQLNELKTEIEALRLKERETALDMLHNENSDRGGGGSKHNTI  540
Giraffe      481   .................................R.......A....SAE........S..  540
Okapi        481   ............................................................  540

Cow          541   KKLTLQSAKSRVAFFEEL  558
Giraffe      541   ..................  558
Okapi        541   ..................  558
```

Newick Tree of Mammalian NF2

```
(sheep:0.0072789, (okapi:0, (cow:0.00516242, (giraffe:0.012789, (minke_whale:0.00257861,
(rhino:0.000713123, ((pig:0, camel:0.00721896):0.00113334, ((walrus:0.00117661,
((baboon:0.000782206, (rat:0.00155475, mouse:0.00744633):0.00827791):0.000850732,
(orangutan:0.00146506, (bushbaby:0.00238309,
human:0):0.000333503):0.000281676):0.00118389):0.000570996, ((cat:0,
tiger:0.00360505):0.00176099, (manatee:0.00361199, (dog:0.000892328,
horse:0.00269835):0.00088528):4.24795e-
05):0.000208882):0.000454465):0.000691512):0.00108222):0.00830701):0.00170362):0.00026333):0.0072
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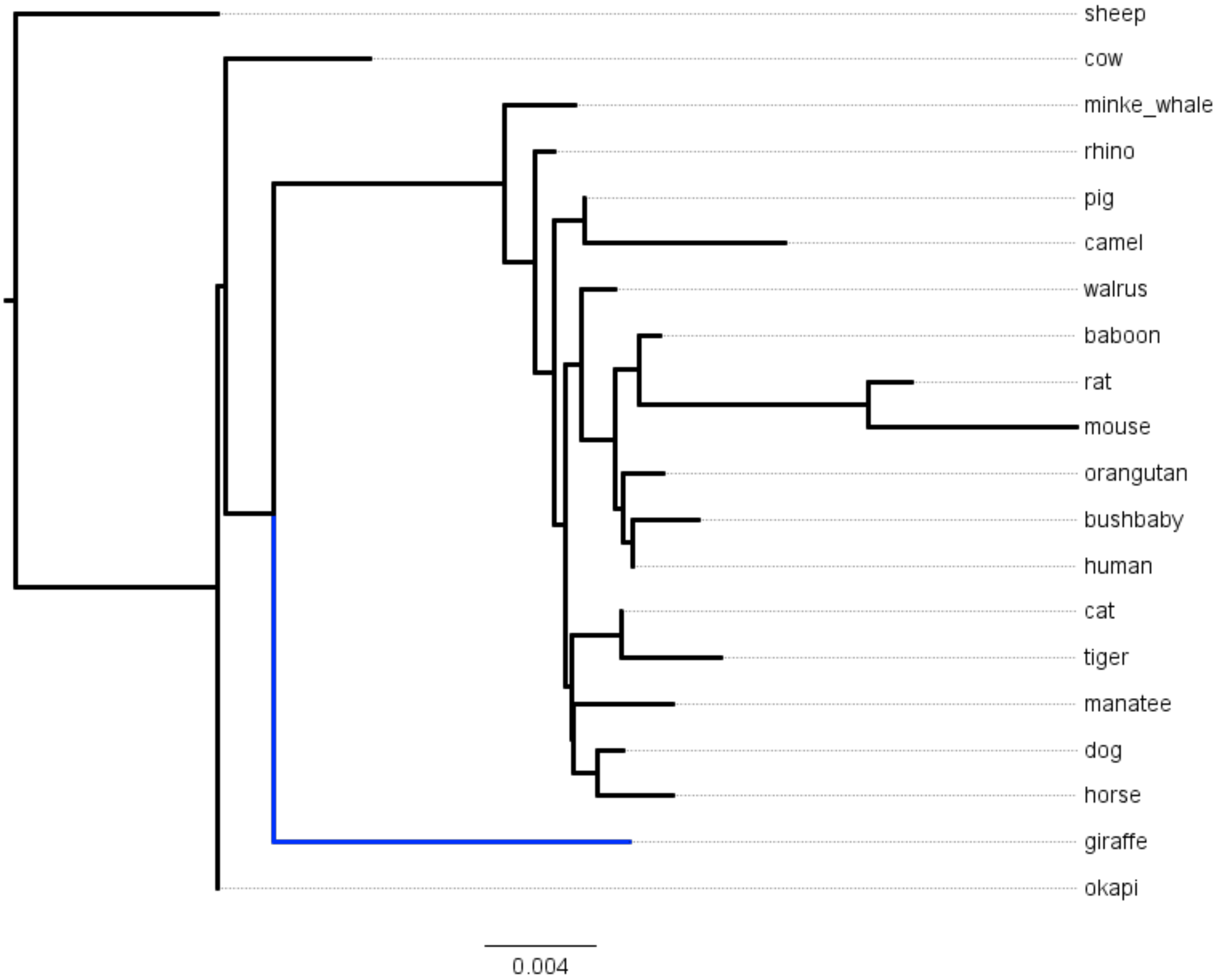


Locus name: neurofibromin 2 (**NF2)**

Locus name: Cholinergic receptor nicotinic acid type 10 (CHRNA10)

ENSBTAT00000061577 CHRNA10-201 neuronal acetylcholine receptor auditory functions, pain reception
mouse: impaired synaptic function and integrity of the olivocochlear system

PP2: (Giraffe) F412S

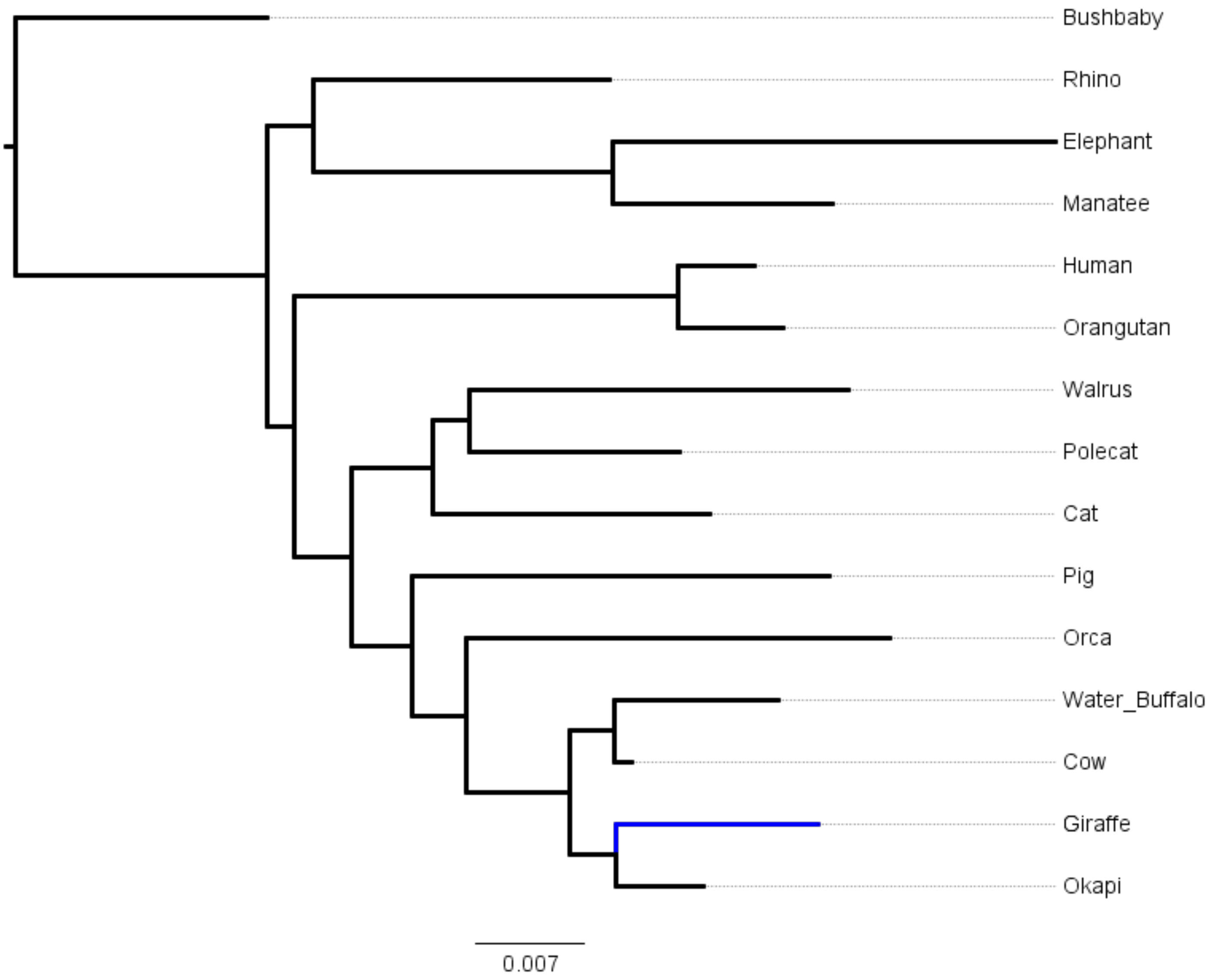
Giraffe: R369Q UPS, F412S UIS, M419V UIS

Protein sequence Alignment of Cow, Giraffe and Okapi CHRNA10

```
Cow          2     PECLGAEGRLAHKLFRDLFANYTSALRPVADTDQALNVTLEVTLSQIIDMDERNQVLTLY  61
Giraffe      2     ............................................................  61
Okapi        2     ............................................................  61

Cow          62    LWIRQEWTDAYLRWDPDTYGGLDAIRIPSSLVWRPDIVLYNKADAQAPASASTNVVLRHD  121
Giraffe      62    ............................................................  121
Okapi        62    ............................................................  121

Cow          122   GAVRWDAPAITRSSCRVDVSAFPFDAQRCGLTFGSWTHGGHQLDVRPRGAAASLADFVEN  181
Giraffe      122   ............................................................  181
Okapi        122   ............................................................  181

Cow          182   VEWRVLGMPARRRVLTYGCCSEPYPDVTFTLLLRRRAAAYVCNLLLPCVLISLLAPLAFH  241
Giraffe      182   ............................................................  241
Okapi        182   .................................H..........................  241

Cow          242   LPADSGEKVSLGVTVLLALTVFQLILAESMPPAESVPLIGKYYMATMTMVTFSTALTILI  301
Giraffe      242   ............................................................  301
Okapi        242   ............................................................  301

Cow          302   MNLHYCGPSARPVPAWARALLLGRLARGLCVRERGEPCGQSRPPESSPSPQPPDRGTGPP  361
Giraffe      302   ..........................Q.................Q...............  361
Okapi        302   ............................................Q..............Q  361

Cow          362   AGPCHEPRCLCHQEALLRHVATIANAFHSHRAAQRRHEDWKRLARVMDRFFLGIFFSMAL  421
Giraffe      362   .......Q...R...............Q......................S......V..  421
Okapi        362   ............................................................  421

Cow          422   VMSLLVLVRAL                                                   432
Giraffe      422   ........Q..                                                   432
Okapi        422   ........Q..                                                   432
```

Newick Tree of Mammalian CHRNA10

(bushbaby:0.0161892, ((rhino:0.0191045, (elephant:0.0284532, manatee:0.0141192):0.0192858):0.00303032, ((human:0.00489306, orangutan:0.00674878):0.0247126, (((walrus:0.0244484, polecat:0.01357):0.00229231, cat:0.0178311):0.00522417, (pig:0.0268766, (orca:0.0272514, ((water_buffalo:0.0105222, cow:0.00111961):0.00290069, (giraffe:0.0130554, okapi:0.00563779):0.00300523):0.0066197):0.00354559):0.00383643):0.00371258):0.00178816):0.0161892);



Locus name: Cholinergic receptor nicotinic acid type 10 (**CHRNA10)**

Locus Name: PARK2 co-regulated-like (PACRGL)

ENSBTAT00000047431 PACRGL-201   E3 ubiquitin protein ligase parkin-like unknown substrate
expressed in brain
no mutations in m/h

PP2: (Giraffe) L156I

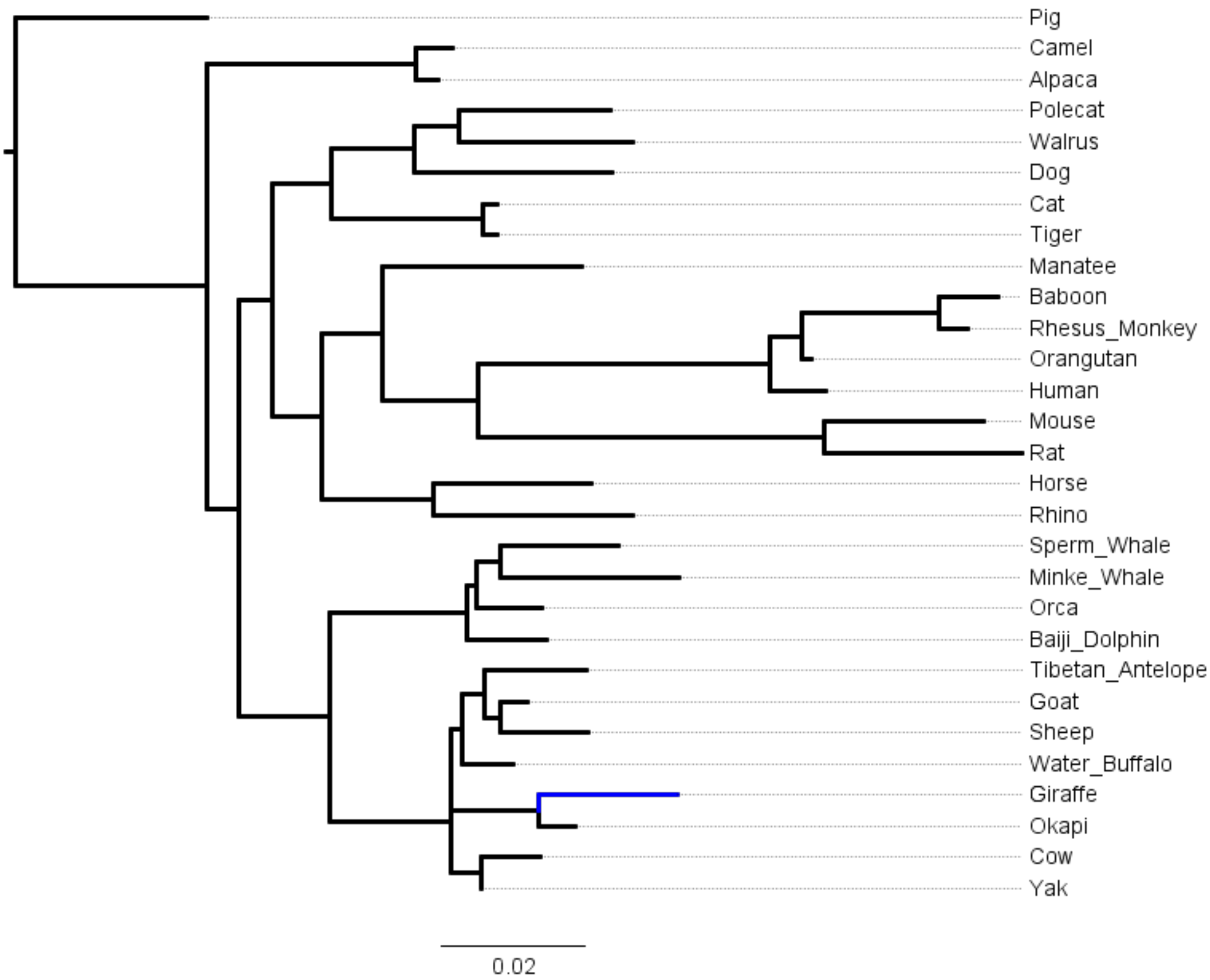
Giraffe: D21G UIS, L156I UIS, T219A UPS
Giraffe/Okapi: G9A UPS, D171N UIS

Protein sequence Alignment of Cow, Giraffe and Okapi PACRGL

```
Cow          1     MQKSEFHRGVQMRSRLTDNCDQRTSSSAQVKHGTTVQQSKSSSSTSSPESARKLHPRPSD  60
Giraffe      1     .....C..A....N......G.......................................  60
Okapi        1     .....C..A....N..............................................  60

Cow          61    KLNPKTINPFGEQSRAPSAFAAIYSKGGIPCRLVHGSVKHRLQWECPPEKLPFDPLLITL  120
Giraffe      61    ............................................................  120
Okapi        61    .........................................................V..  120

Cow          121   AEGLRETKHPYTFVSKEGFRELLLVTGAPEKAVPLLPRLIPVLKAALVHVDDEVFERGLN  180
Giraffe      121   ............................H......I.K............N.........  180
Okapi        121   .....................................K............N.........  180

Cow          181   ALVQLSVVVGPALNDHLKHLLTSLSKRLRDKKFKEPITTALQKLEQHGGSGSLIIIKSKI  240
Giraffe      181   ...........S..........................A..............S......  240
Okapi        181   ...........S................................................  240

Cow          241   PTYCSICC     248
Giraffe      241   ........     248
Okapi        241   ........     248
```

Newick Tree of Mammalian PACRGL

(pig:0.0268583, ((camel:0.00508934, alpaca:0.00304088):0.0291624, (((((polecat:0.0210547, walrus:0.0243295):0.00631024, dog:0.0277088):0.0114588, (cat:0.00202021, tiger:0.00202021):0.0209913):0.00821082, ((manatee:0.0279144, ((((baboon:0.00822717, rhesus_monkey:0.00394367):0.0191261, orangutan:0.00135305):0.00447901, human:0.00785994):0.0407379, (mouse:0.0223182, rat:0.0275053):0.0482884):0.0133719):0.00837059, (horse:0.0220272, rhino:0.0277962):0.0155863):0.00689242):0.00484492, ((((sperm_whale:0.0163535, minke_whale:0.0248162):0.00342143, orca:0.00906974):0.00124775, baiji_dolphin:0.0109736):0.0192152, (((giraffe:0.0193302, okapi:0.00506371):0.012119, ((tibetan_antelope:0.0142917, (goat:0.0039665, sheep:0.0122947):0.00207989):0.00316881, water_buffalo:0.0070155):0.00148076):0.000167112, (cow:0.0081629, yak:0):0.00437129):0.0168449):0.0127507):0.00427376):0.0268583);



Locus Name: PARK2 co-regulated-like (PACRGL)

Locus Name: slit homolog 2 (SLIT2)

ENSBTAT00000061059 SLIT2-201 secreted axon guidance replusive protein axonal guidance in the nervous system
mouse: perinatal lethality, abnormal ureteric bud development, multiple fused kidneys, multiple ureters, and hydroureter; DKO with slit1 shows retinal axon guidance defects

PP2: (Giraffe) I488V, G1435E; (Giraffe/Okapi) V1405I

Giraffe: I486V UIS, G1433E UIS
Giraffe/Okapi: V1405I UIS

Protein sequence Alignment of Cow, Giraffe and Okapi SLIT2

```
Cow          1      MHGVGWQTLSLSLGLVLAILNEVAPQACPAQCSCSGSTVDCHGLALRSVPRNIPRNTERL  60
Giraffe      1      ............................................................  60
Okapi        1      ............................................................  60

Cow          61     DLNGNNITRITKTDFAGLRHLRVLQLMENKITTIERGAFQDLKELERLRLNRNHLQLFPE  120
Giraffe      61     ............................................................  120
Okapi        61     ............................................................  120

Cow          121    LLFLGTSKLYRLDLSENQIQAIPRKAFRGAVDIKNLQLDYNHISCIEDGAFRALRDLEVL  180
Giraffe      121    .........................................Q..................  180
Okapi        121    .........................................Q..................  180

Cow          181    TLNNNNITRLSVASFNHMPKLRTFRLHSNNLYCDCHLAWLSDWLRQRPRVGLYTQCMGPS  240
Giraffe      181    ............................................................  240
Okapi        181    ............................................................  240

Cow          241    HLRGHNVAEVQKREFVCSGHQSFMAPSCSVLHCPAACTCSNNIVDCRGKGLTEIPTNLPE  300
Giraffe      241    ............................................................  300
Okapi        241    ............................................................  300

Cow          301    TITEIRLEQNSIKVIPPGAFSPYKKLRRIDLSNNQISELAPDAFQGLRSLNSLVLYGNKI  360
Giraffe      301    ............................................................  360
Okapi        301    ............................................................  360

Cow          361    TELPKSLFEGLFSLQLLLLNANKINCLRVDAFQDLHNLNLLSLYDNKLQTIAKGTFSPLR  420
Giraffe      361    ............................................................  420
Okapi        361    ............................................................  420

Cow          421    AIQTMHLAQNPFICDCHLKWLADYLHTNPIETSGARCTSPRRLANKRIGQIKSKKFRCSA  480
Giraffe      421    ............................................................  480
Okapi        421    ............................................................  480

Cow          481    KEQYFIPGTEDYRSKLSGDCFADLACPEKCRCEGTTVDCSNQKLTKIPDHIPQYTAELRL  540
Giraffe      481    .....V......................................................  540
Okapi        481    ............................................................  540

Cow          541    NNNEFTVLEATGIFKKLPQLRKINFSNNKITDIEEGAFEGASGVNEILLTSNRLENVQHK  600
Giraffe      541    ............................................................  600
Okapi        541    ............................................................  600

Cow          601    MFKGLESLKTLMLRSNRISCVGNDSFIGLSSVRLLSLYDNQITTIAPGAFDTLHSLSTLN  660
Giraffe      601    ............................................................  660
Okapi        601    ............................................................  660

Cow          661    LLANPFNCNCYLAWLGEWLRKKRIVTGNPRCQKPYFLKEIPIQDVAIQDFTCDDGNDDNS  720
Giraffe      661    ............................................................  720
Okapi        661    ............................................................  720

Cow          721    CSPLSRCPAECTCLDTVVRCSNKALKVLPKGIPRDVTELYLDGNQFTLVPKELSNYKHLT  780
Giraffe      721    .............................R..............................  780
Okapi        721    ............................................................  780
```

```
Cow          781    LIDLSNNRISTLSNQSFSNMTQLLTLILSYNRLRCIPPRTFDGLKSLRLLSLHGNDISVV  840
Giraffe      781    ..........................................................I.  840
Okapi        781    ..........................................................I.  840

Cow          841    PEGAFNDLAALSHLAIGANPLYCDCNMQWLSDWVKSEYKEPGIARCAGPGEMADKLLLTT  900
Giraffe      841    ............................................................  900
Okapi        841    ...V........................................................  900

Cow          901    PSKKFTCQGPVDVNILAKCNPCLSNPCKNDGTCNNDPVDFYRCTCPYGFKGQDCDVPIHA  960
Giraffe      901    ............................................................  960
Okapi        901    ............................................................  960

Cow          961    CISNPCKHGGTCHLKEGEKDGFWCICADGFEGENCEINVDDCEDNDCENNSTCVDGINNY  1020
Giraffe      961    ............................................................  1020
Okapi        961    ............................................................  1020

Cow          1021   TCLCPPEYTGELCEEKLDFCAQDLNPCQHDSKCILTPKGYKCDCTPGYIGEHCDIDFDDC  1080
Giraffe      1021   ............................................................  1080
Okapi        1021   ............................................................  1080

Cow          1081   QDNKCKNGAHCTDAVNGYTCTCPEGYSGLFCEFSPPMVLPRTSPCDNFDCQNGAQCIIRI  1140
Giraffe      1081   ............................................................  1140
Okapi        1081   ............................................................  1140

Cow          1141   NEPICQCLPGYQGEKCEKLVSVNFVNKESYLQIPSAKVRPQTNITLQIATDEDSGILLYK  1200
Giraffe      1141   ............................................................  1200
Okapi        1141   ............................................................  1200

Cow          1201   GDKDHIAVELYRGRVRASYDTGSHPASAIYSVETINDGNFHIVELLALDQSLSLSVDGGS  1260
Giraffe      1201   ............................................................  1260
Okapi        1201   ..............................................T.............  1260

Cow          1261   PKIITNLSKQSTLNFDSPLYVGGMPGKNNVAAALRQAPGQNGTSFHGCIRNLYINSELQD  1320
Giraffe      1261   ............................................................  1320
Okapi        1261   ............................................................  1320

Cow          1321   FRKVPMQTGILPGCEPCHKKVCAHGTCQPSSQAGFTCECEEGWTGPLCDQRTNDPCLGNK  1380
Giraffe      1321   ............................................................  1380
Okapi        1321   ............................................................  1380

Cow          1381   CVHGTCLPINAFSYSCKCLEGHGGVLCDEEEDLFNPCQAIKCKHGKCRLSGLGQPYCECS  1440
Giraffe      1381   ........................I...........................E.......  1440
Okapi        1381   ........................I...................................  1440

Cow          1441   SGYTGDSCDREISCRGERIRDYYQKQQGYAACQTTKKVSRLECRGGCAGGQCCGPLRSKR  1500
Giraffe      1441   ............................................................  1500
Okapi        1441   ............................................................  1500

Cow          1501   RKYSFECTDGSSFVDEVEKVVKCGCTRCAS                                1530
Giraffe      1501   ..............................                                1530
Okapi        1501   ..............................                                1530
```

Newick Tree of Mammalian SLIT2

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(((tiger:0.0042252, (polar_bear:0.00526635, (ferret:0.00454093,
walrus:0.00597185):0.000651015):0.00483798):0.000552789, (horse:0.00498033,
rhino:0.00421225):0.00201584):0.000443819, (((sheep:0, tibetan_antelope:0.00196769):0.000648594,
((cow:3.18391e-06, yak:0.00130486):0.000652231, water_buffalo:2.00589e-06):6.93232e-06):9.87529e-
06, (giraffe:0.00194604,
okapi:0.00132729):0.00130188):0.0046268):0.000258086):0.000559053):0.000665248):0.00579445);
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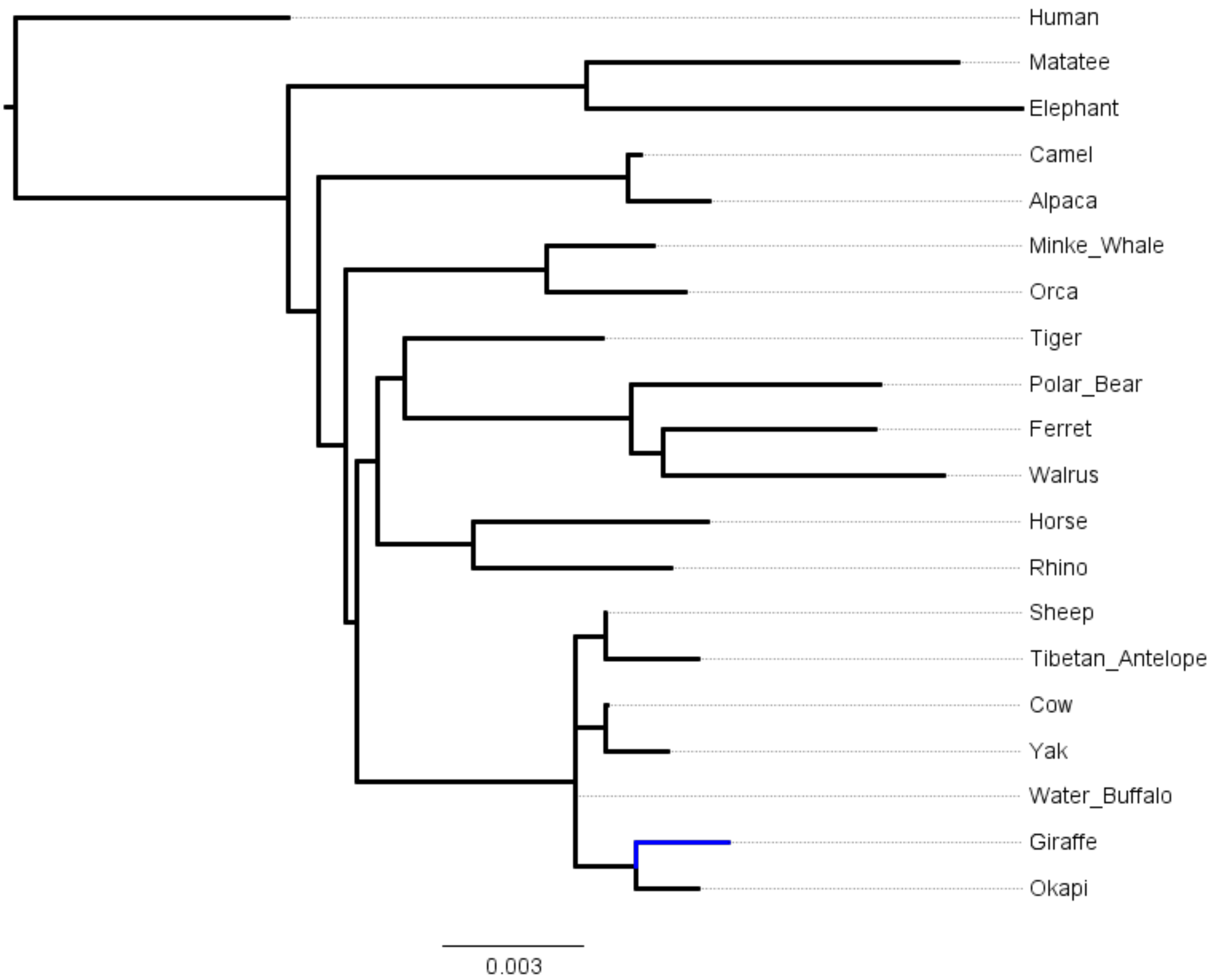

Locus Name: slit homolog 2 (SLIT2)

Locus Name: Semaphorin 3A (**SEMA3A)**

ENSBTAT00000024139 SEMA3A-201 semaphorin 3A axonal guidance
mouse: patterning abnormalities of sensory and sympathetic neurons, abnormal embryonic bones and cartilaginous structures, cardiac defects, and high postnatal mortality

PP2: (Giraffe) L514F

Giraffe: I292V UIS, L514F UIS,
Giraffe/Okapi: H579Y UIS, I628V UIS, I629F UIS
Okapi: N43D UPS, A52D UPS

Protein sequence Alignment of Cow, Giraffe and Okapi SEMA3A

```
Cow        1    MGWFARIVCLFWGVLLTARANYQNGKNNVPRLKLSYKEMLESNNVITFNGLANSSSYHTF  60
Giraffe    1    ....T.......................................................  60
Okapi      1    ....T.....................................D........D........  60

Cow        61   LLDEERSRLYVGAKDHIFSFNLVNIKDFQKIVWPVSYTRRDECKWAGKDILKECANFIKV  120
Giraffe    61   ............................................................  120
Okapi      61   ............................................................  120

Cow        121  LKAYNQTHLYACGTGAFHPVCTYIEIGHHPEDNIFKLQDSHFENGRGKSPYDPKLLTASL  180
Giraffe    121  ............................................................  180
Okapi      121  .......................V....................................  180

Cow        181  LIDGELYSGTAADFMGRDFAIFRTLGHHHPIRTEQHDSRWLNDPRFISAHLIPESDNPED  240
Giraffe    181  ............................................................  240
Okapi      181  ............................................................  240

Cow        241  DKVYFFFRENAIDGEHTGKATHARIGQICKNDFGGHRSLVNKWTTFLKARLICSVPGPNG  300
Giraffe    241  ...................................................V........  300
Okapi      241  ............................................................  300

Cow        301  IDTHFDELQDVFLMNSKDPKNPVVYGVFTTSSNIFKGSAVCMYSMSDVRRVFLGPYAHRD  360
Giraffe    301  ............................................................  360
Okapi      301  ............................................................  360

Cow        361  GPNYQWVPYQGRVPYPRPGTCPSKTFGGFDSTKDLPDDVITFARSHPAMYNPVFPINNRP  420
Giraffe    361  ............................................................  420
Okapi      361  ............................................................  420

Cow        421  IMIKTDVNYQFTQIVVDRVDAEDGQYDVMFIGTDVGTVLKVVSIPKETWHDLEEVLLEEM  480
Giraffe    421  ............................................................  480
Okapi      421  ............................................................  480

Cow        481  TVFREPTTISAMELSTKQQQLYIGSTTGVTQLPLHRCDIYGKACAECCLARDPYCAWDGS  540
Giraffe    481  .................................F..........................  540
Okapi      481  ............................................................  540

Cow        541  SCSRYFPTAKRRTRRQDIRNGDPLTHCSDLQHHDNHHGHSFEERIIYGVENSSTFLECSP  600
Giraffe    541  ......................................Y.....................  600
Okapi      541  ......................................Y.....................  600

Cow        601  KSQRALVYWQFQRRNEEPKEEIRVDDHIIRTEQGLLLRSLQRKDSGNYLCHAVEHGFMQT  660
Giraffe    601  .................R.........VF...............................  660
Okapi      601  .................R.....A...VF...............................  660

Cow        661  LLKVTLEVIDTEHLEELLHKDDDGDGSKTKETSNSMTPSQKVWYRDFMQLINHPNLNTMD  720
Giraffe    661  ............................................................  720
Okapi      661  ............................................................  720

Cow        721  EFCEQVWKRDRKQRRQRPGHTQGNSNKWKHLQENKKGRNRRTHEFERAPRSV          772
Giraffe    721  ....................................................          772
Okapi      721  ....................................................          772
```

Newick Tree of Mammalian SERMA3A
((rat:0.00126554, mouse:0.00523226):0.00771245, (aardvark:0.0109108, (Brandt_s_bat:0.0132348, (((rhino:0.00888282, (macaque:0.00515895, (human:0.00259225,

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orangutan:0.0013064):0.0118789):0.00557789):0.00109964, lemur:0.0130289):8.98605e-05,
((manatee:0.00491042, elephant:0.00944127):0.00344414, (((camel:0.00195809,
alpaca:0.00323675):0.00514718, horse:0.00858057):0.00227274, (((tiger:7.82861e-05,
cat:0.00121789):0.00508394, black_flying_fox:0.00796299):0.000553852, ((Weddell_seal:0.00210906,
walrus:0.00308578):0.000939603, ((panda:0.00325176, polar_bear:0.00194308):0.00328084,
(((orca:0.000157567, baiji_dolphin:0.00243647):0.00266046, minke_whale:0.00384584):0.00319759,
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okapi:0.00512959):0.00519282):0.000473033):0.00359753):0.00129819):0.000914216):0.000906283):0.00
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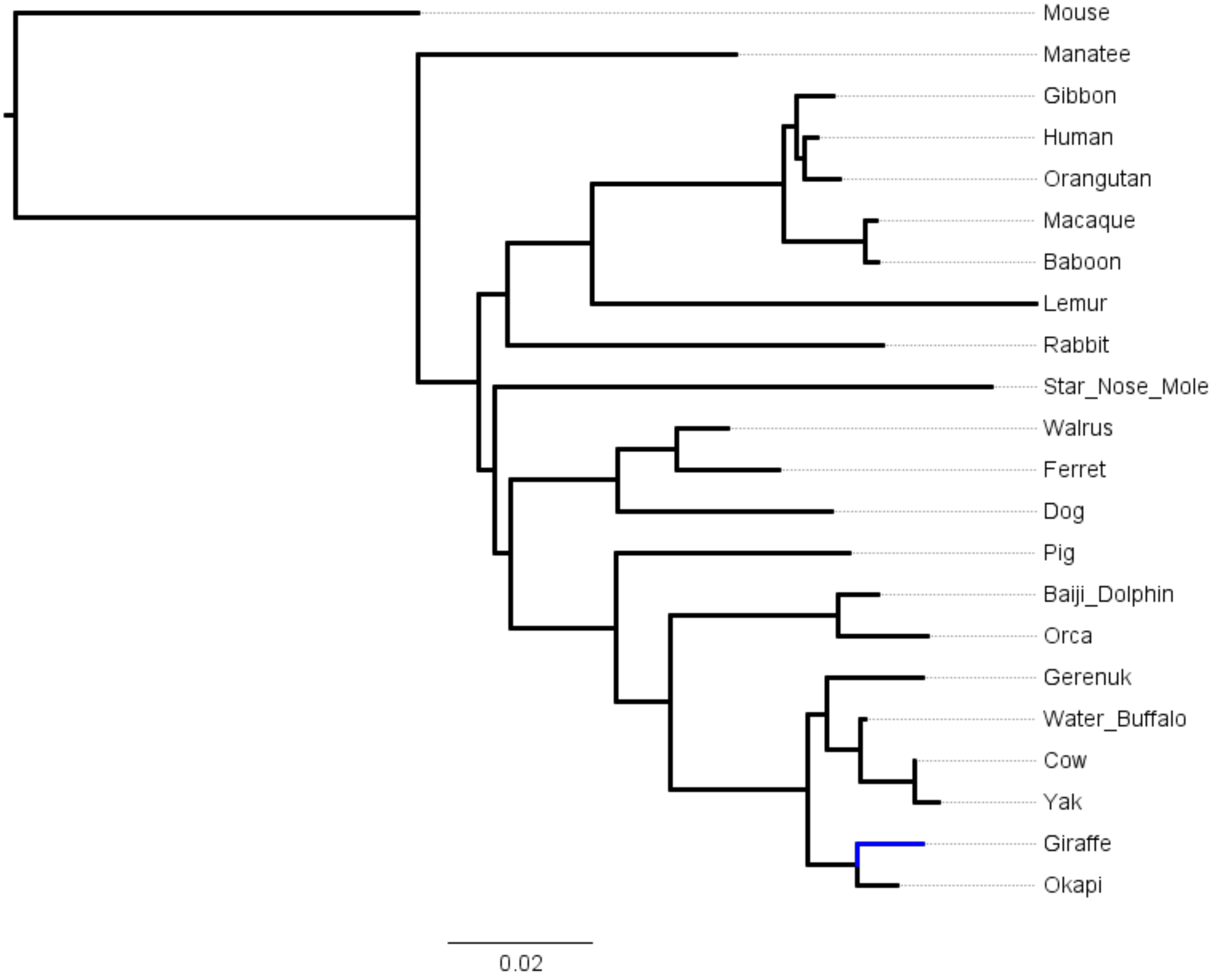


Locus Name: Semaphorin 3A (**SEMA3A)**

Locus Name: Monooxygenase DBH-like 1 (**MOXD1)**

ENSBTAT00000025923 MOXD1-201 monooxygenase dopamine β-hydroxylase dopamine metabolism human: episodic memory SNP

PSG: S20K|AGC/AAG

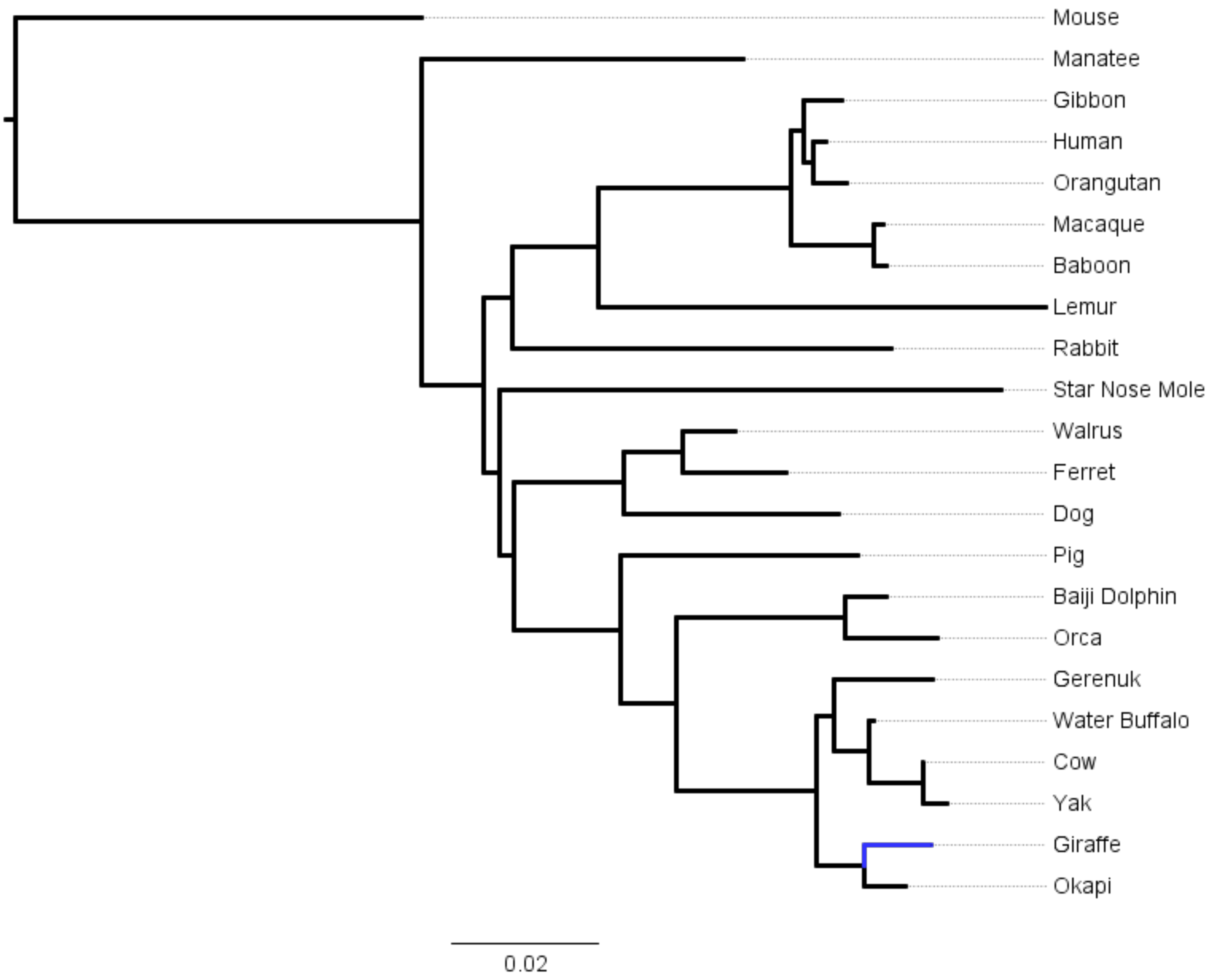
Giraffe: W23L UPS, S40K UPS, P43L UPS, A49V UIS
Giraffe/Okapi: S606A UPS, W613C UPS
Okapi: WP 23-24 deletion

Protein sequence Alignment of Cow, Giraffe and Okapi MOXD1

```
Cow          1      MCRWPLLLLWGLLPRAAAGGSGWPFPHRTLLDSEGKYWLSWGPRGGRLAFRLEVRTAGYV  60
Giraffe      1      ............F.........L.L..............K..L...Q.V...........  60
Okapi        1      ......................--L...................................  58

Cow          61     GFGFSSTGAMAAADIVVGGVARGRPYLQDYFTNANRELRKDAQQDYHLEYAMENSTHTVI  120
Giraffe      61     .....P......................................................  120
Okapi        59     .....P......................................................  118

Cow          121    EFTRELHTCDINDKSISESTVRVIWAYHHEDVGEAGPKYHESNRGTKSLRLLNPEKTSML  180
Giraffe      121    ..A.............T........................................N..  180
Okapi        119    ..A.......M.....T........................................NT.  178

Cow          181    STAIPYFDLVNQDVSIPNKGTTYWCQMFKIPMLQEKHHVIKVEPVIQKGHESLVHHILLY  240
Giraffe      181    ...V..........P.............................................  240
Okapi        179    ...V..........P.............................................  238

Cow          241    QCSSNFSDSVLDDGHECYHPNMPDAFLTCETVIFAWAIGGEGFSYPPHVGLSLGTPLDPH  300
Giraffe      241    ............................................................  300
Okapi        239    ............................................................  298

Cow          301    YVLLEVHYDNPTYKEGLIDNSGLRLFYTADIRKYDAGVIEAGLWVSLFHTIPPGLPDFRS  360
Giraffe      301    ............................................................  360
Okapi        299    ............................................................  358

Cow          361    EGHCTLECLEEALEAEKPSGIHVFAVLLHAHLAGRGIRLRHFRKGEEMRLLAYDDDFDFN  420
Giraffe      361    ............................................................  420
Okapi        359    ............................................................  418

Cow          421    FQEFQYLKEEQTILPGDNLITECRYNTKDRARMTWGGLSTRNEMCLSYLLYYPRINLTRC  480
Giraffe      421    ......................................................V.....  480
Okapi        419    ......................................................V.....  478

Cow          481    ASIPDIMEQLQFIGVKEIYRPVTTWPFIIKSPKQYRNLSFMDAMNKFKWTKKEGLAFNKL  540
Giraffe      481    ...................................K........................  540
Okapi        479    ...................................K........................  538

Cow          541    VLSLPVNVRCSKTDNAEWSIQGMTALPPDIERPYQAEPLVCGASSTSLRGNVCLELLLSF  600
Giraffe      541    .........................................R..................  600
Okapi        539    ..............................D..........R......H...........  598

Cow          601    VVLGSSLSTRSLWP                                                615
Giraffe      601    .....A..A...C.                                                615
Okapi        599    .....A..A...C.                                                613
```

Newick Tree of Mammalian MOXD1

(Mouse:0.0557461, (Manatee:0.0440954, (((((Gibbon:0.00527691, (Human:0.00179691, Orangutan:0.00474981):0.0012874):0.0015707, (Macaque:0.00144472, Baboon:0.00182327):0.0112338):0.026656, Lemur:0.0614215):0.0117028, Rabbit:0.0519559):0.00396277, (Star Nose Mole:0.0688574, (((Walrus:0.00711941, Ferret:0.0143175):0.00813753, Dog:0.0296408):0.0149364, (Pig:0.0323803, ((Baiji Dolphin:0.00560225, Orca:0.0125361):0.023139, ((Giraffe:0.00921503, Okapi:0.00557624):0.00667794, (Gerenuk:0.0134029, (Water Buffalo:0.00067413, (Cow:0, Yak:0.00327022):0.00751611):0.00475624):0.00254256):0.0190802):0.00763236):0.014648):0.00212052):0.00215234):0.00852775):0.0557461);



Locus Name: Monooxygenase DBH-like 1 (**MOXD1)**

Locus Name: Methylenetetrahydrofolate Dehydrogenase (NADP+ Dependent) 1 (MTHFD1)

ENSBTAT00000012704 MTHFD1-201   C-1-tetrahdrofolate synthase   folate metabolism
human: SNP association with neural tube defects and congenital heart defects, mouse: knockout is an embryonic lethal and heterozygotes exhibit ventricular septal defects

PP2: (Giraffe) A335V; (Okapi) V754I
Giraffe: A335V UIS, P367L UIS, Q548L UIS, D817N UIS, A893V UIS, A119T UPS, N248D UPS, S266R UPS
Giraffe/Okapi: L717I UIS

Protein sequence Alignment of Cow, Giraffe and Okapi MTHFD1

```
Cow          1      MAPAEILNGKVVSAQIKERLKNQVIQMKEEVPGFIPGLAILQVGNRDDSNLYINMKLKAA  60
Giraffe      1      .............TR.R.................T.........................  60
Okapi        1      .............TR.R.................T.........................  60

Cow          61     EEIGIKATHIKLPRTATESEVLKCITSLNEDLTVHGFIVQLPLDSENPINTETLVNAIAP  120
Giraffe      61     ..V...........M...........................................T.  120
Okapi        61     ..V....K....S.R..........................................V..  120

Cow          121    EKDVDGLNSISAGKLARGDLSNCFIPCTPKGCLELIKETGVQIAGRHAVVVGRSKIVGAP  180
Giraffe      121    ............................................................  180
Okapi        121    ............................................................  180

Cow          181    MHDLLLWNHATVTTCHSKTANLKEEISKGDILVVAAGQPEMVKGEWIKPGAIVIDCGINY  240
Giraffe      181    ......................N............I........................  240
Okapi        181    ......................N..V.........V........................  240

Cow          241    VTDDTKPNGKKIVGDVAYTEAKERASFITPVPGGVGPMTVAMLMQSTVESAKRFLENFKP  300
Giraffe      241    .P.....D...V......L......R..............................K..T  300
Okapi        241    .P.....G...V....V.L.....................................K...  300

Cow          301    GKWIIQYNKLNLKTPVPSDIDISRSYKPKPIGNLAREVGLRTEEVELYGETKAKVLLSAL  360
Giraffe      301    .N.M....T......................S..V..I.....D..............V.  360
Okapi        301    .N.M....T......................S.....I.....D................  360

Cow          361    ERLKHQPDGKYVVVTGITPTPLGEGKSTTTIGLVQALGTHLHQNVFACVRQPSQGPTFGI  420
Giraffe      361    ......L...............................A...L.................  420
Okapi        361    .W....................................A.....................  420

Cow          421    KGGAAGGGYSQVIPMEEFNLHLTGDIHAITAANNLVAAAIDARMFHEETQTDKALFNRLV  480
Giraffe      421    ............................................................  480
Okapi        421    ............................................................  480

Cow          481    PSVNGVRKFSDIQIRRLRRLGIEKTDPATLTDEEINRFARLDIDPETITWQRVLDTNDRF  540
Giraffe      481    ............................................................  540
Okapi        481    ............................................................  540

Cow          541    LRKITIGQAPTEKGHSRTAQFDISVASEIMAVLALTSSLEDMRERLGKMVVASSKKGEPI  600
Giraffe      541    .......L....................................................  600
Okapi        541    ....................................N.........S.............  600

Cow          601    STEDLGVSGALTVLMKDAIKPNLMQTLEGTPVFVHAGPFANIAHGNSSIIADRIALKLVG  660
Giraffe      601    .....................................................V......  660
Okapi        601    ............................................................  660

Cow          661    PEGFVVTEAGFGADIGMEKFFNIKCRYSGLRPHVVVLVATVRALKMHGGGPTVTAGLPLP  720
Giraffe      661    ........................................................I...  720
Okapi        661    ........................................................I...  720

Cow          721    KAYIEEDLELVGKGFSNLKKQIENARMFGVPVVVAVNAFKTDTEAELDLVSRLAKEHGAF  780
Giraffe      721    ...........E................................................  780
Okapi        721    ...V.......E.....................I..........................  780

Cow          781    DAVKCTHWAEGGKGALALAEAVQRAAAAPSSFQLLYDLKLPVEDKIRIIAQKIYGADNIE  840
Giraffe      781    ...................R................N....I...............D..  840
Okapi        781    ...................K.....................................D..  840
```

```
Cow           841    LLPEAQHKAEVYTKQGFGNLPICMAKTHLSLSHNPELKGVPTGFVLPIRDIRASVGAGFL  900
Giraffe       841    ....................................................V.......  900
Okapi         841    ........V...........................V.......................  900

Cow           901    YPLVGTMSTMPGLPTRPCFYDIDLDPETEQVNGLF                           935
Giraffe       901    ...................................                           935
Okapi         901    ...................................                           935
```

Newick Tree of Mammalian MTHFD1

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(walrus:0.0175229, (dog:0.0142511,
cat:0.0150552):0.00154813):0.00367981):0.00207875):0.000659632, (pig:0.0301979,
((camel:0.00368962, alpaca:0.00490345):0.0306392, (orca:0.0240727, (((cow:0.003035,
yak:0.000178719):0.00422325, (tibetan_antelope:0.00668483, (sheep:0.00352919,
goat:0.00183277):0.00192923):0.00496905):0.00714463, (giraffe:0.0163896,
okapi:0.0139862):0.0110166):0.0144768):0.00232705):0.00182985):0.00446379):0.0233642);
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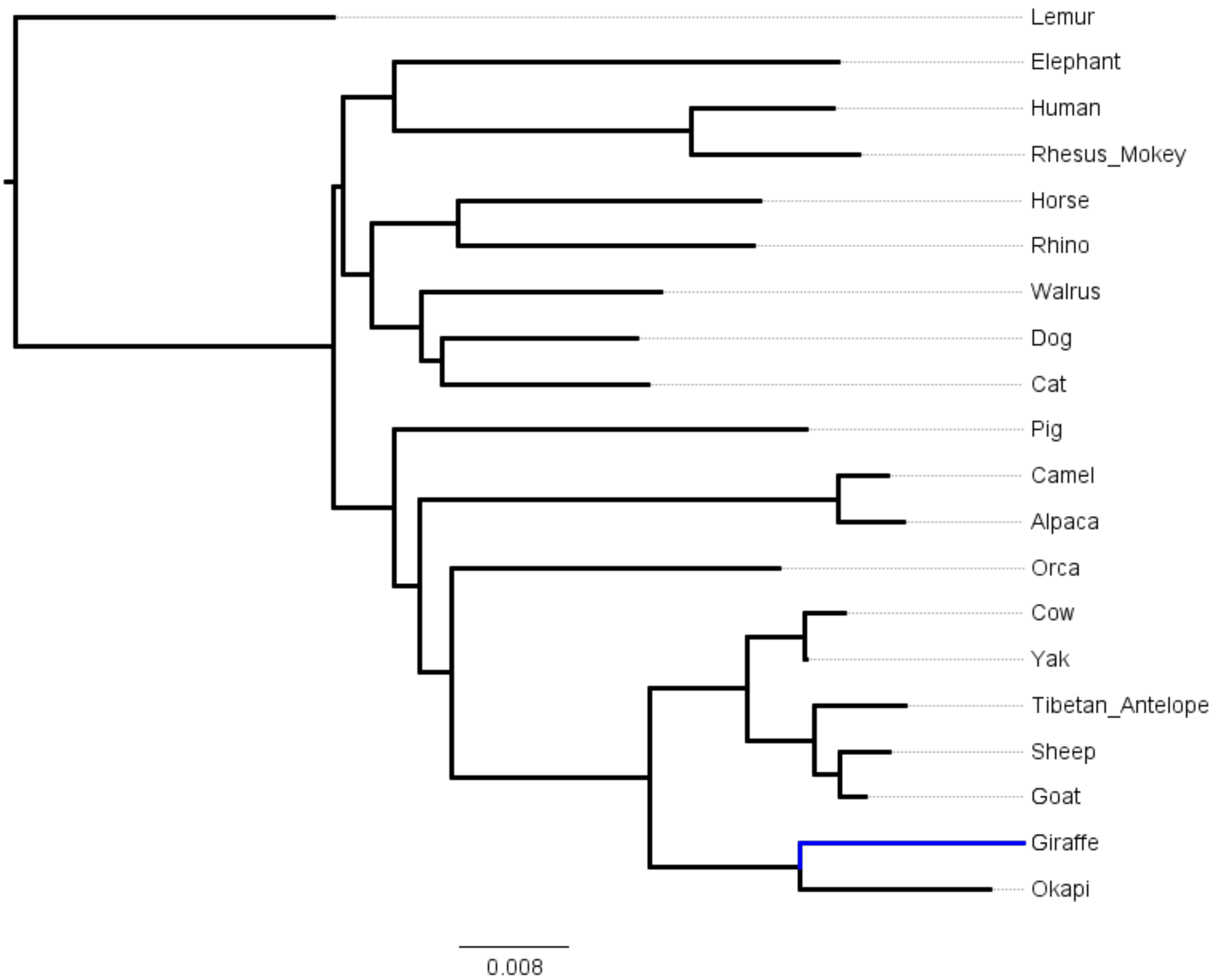


Locus Name: Methylenetetrahydrofolate Dehydrogenase (NADP+ Dependent) 1 (MTHFD1)

Locus name: SLC17A1

ENSBTAT00000064064 SLC17A1-201 phosphate-sodium cotransporter   kidney
no mutation in m/h described; human SNP for cholesterol homeostasis and hyperhomocysteinaemia

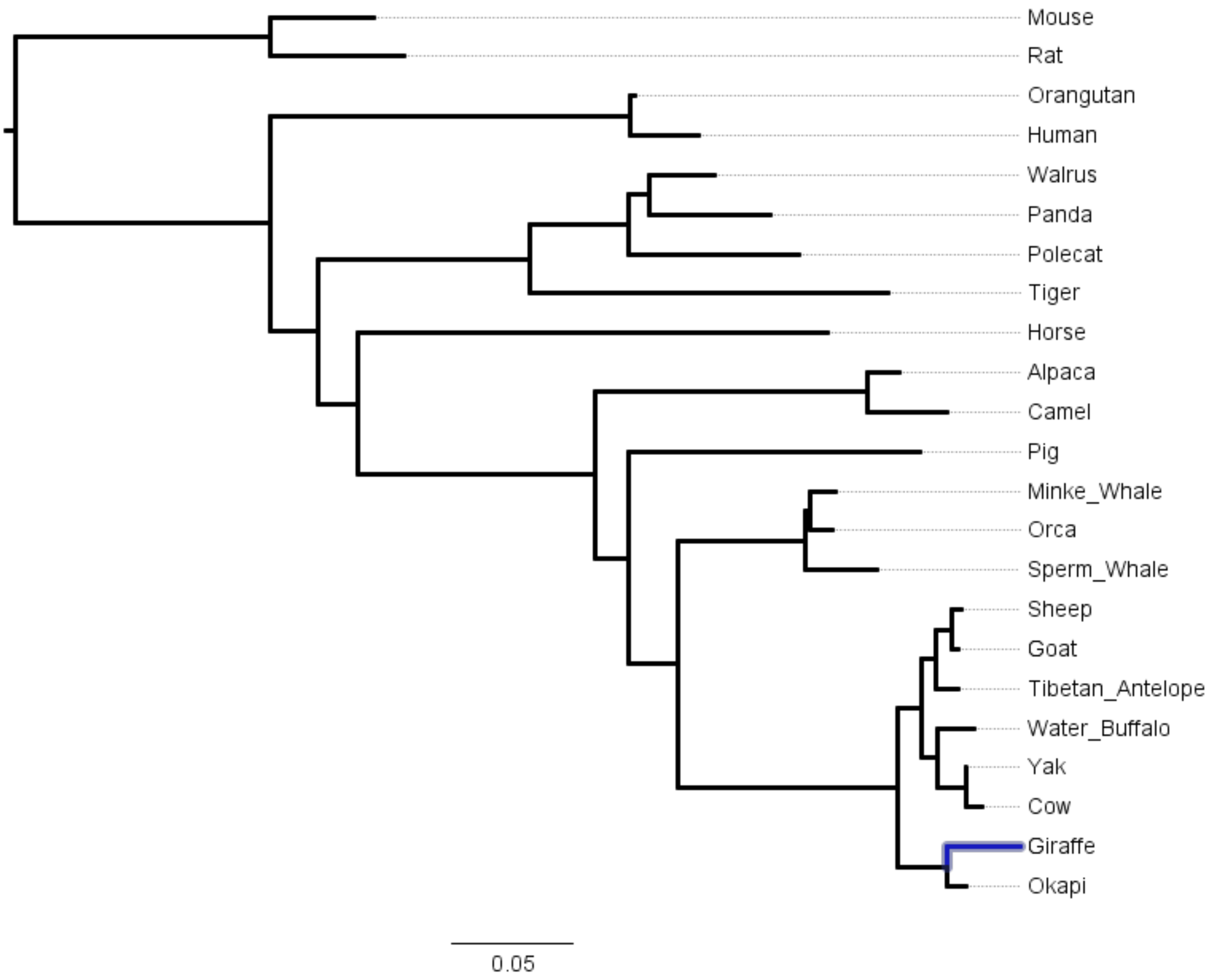
Giraffe: **I142V UPS, G168A UPS, I204V UIS**
Giraffe/Okapi: T263V UPS, S283G UPS, A365G, **L389V UIS**

Protein sequence Alignment of Water Buffalo, Giraffe and Okapi SLC17A1

```
Water Buffalo1      MQVDNQVSPGKVPYFCSVRYGIAVFLLLCNVIIMSQRVCLSLTMIAMVNSTEPHGLSNTS  60
Giraffe       1     .........R.......I..............V......M....................  60
Okapi         1     .........R.......I.....................M....................  60

Cow           61    TKELQDNIKNPVYNWSTEIQGIMLSSIFYGVLISQIPAGYLSGIYSLKKMIGFALLLSSL  120
Giraffe       61    ............................................................  120
Okapi         61    ............................................................  120

Cow           121   FTLLLPLAAEFGEILVIICRVIKGLFQGITLTTQQVIWIKWAPPLELGRLTALSLSGLLL  180
Giraffe       121   .............TW......V..........A.............IA...S........  180
Okapi         121   .............T..................V...V..............S........  180

Cow           181   GPCIVLLITGFICDSLGWPMVFYIFGACGCALSVLWFILFYEDPKDHPFISNREKEYITS  240
Giraffe       181   .......................V..........F.............Y..I........  240
Okapi         181   ..................................F.............Y..I........  240

Cow           241   ALTQQVSSSTLIKVPIKAMLKSTPLWVISLCNFAFFWSNTFLSIYIPIYIDYKLHVDVEE  300
Giraffe       241   .................S....V........S..........G..T.L........N.K.  300
Okapi         241   .................S....V...................G..T..........N.K.  300

Cow           301   NGLLSSLPHLFAWIFAVLAGYMADIFQTRNTFSLVTIRKLFTSLGLLLPSLFSLCLLYLS  360
Giraffe       301   ...........G..IS..................I.......T.................  360
Okapi         301   ...........G......................I.......T.................  360

Cow           361   SSYYATIIFLILANSTGSFAMGGIIINVLDIAPRYYGFLRGITNVIGLTGGLIASTVTGI  420
Giraffe       361   .NF.G...........A......LM...V............V........A.........  420
Okapi         361   .NF.G...........A......LM...V...............................  420

Cow           421   ILSEDAESPWLKIFLLMIANNMISLIFYLIFAKAEVQEWAKERQNTYL              468
Giraffe       421   ........A.....F...G..................D..........              468
Okapi         421   ...K..........F......................D..........              468
```

Newick Tree of Mammalian SLC17A1

((mouse:0.0421916, rat:0.0549928):0.103869, ((orangutan:0.00219056, human:0.0282513):0.14669, ((((walrus:0.0263727, panda:0.0491226):0.00835653, polecat:0.0695857):0.0405544, tiger:0.146416):0.086042, (horse:0.191911, ((alpaca:0.0133032, camel:0.0329261):0.110951, (pig:0.118924, (((minke_whale:0.0101336, orca:0.00941223):0.00187525, sperm_whale:0.0289616):0.0522884, ((((sheep:0.00399679, goat:0.00243415):0.00621533, tibetan_antelope:0.00890019):0.00599475, (water_buffalo:0.0147732, (yak:8.59446e-05, cow:0.00634499):0.0112915):0.0066585):0.00990888, (giraffe:0.0293547, okapi:0.0075743):0.0203731):0.0898591):0.0199903):0.0135566):0.0967838):0.0160838):0.019755):0.10
3869);



Locus name: SLC17A1

Locus name: Succinic semialdehyde dehydrogenase (**ALDH5A1)**

ENSBTAT00000029203 ALDH5A1-201 succinic semialdehyde dehydrogenase brain, clearance of GABA and hydroxybutryic acid
human: mental retardation, ataxia, seizures humans; mouse: reduced body weight, ataxia, seizures, gliosis of the hippocampus, and early death.

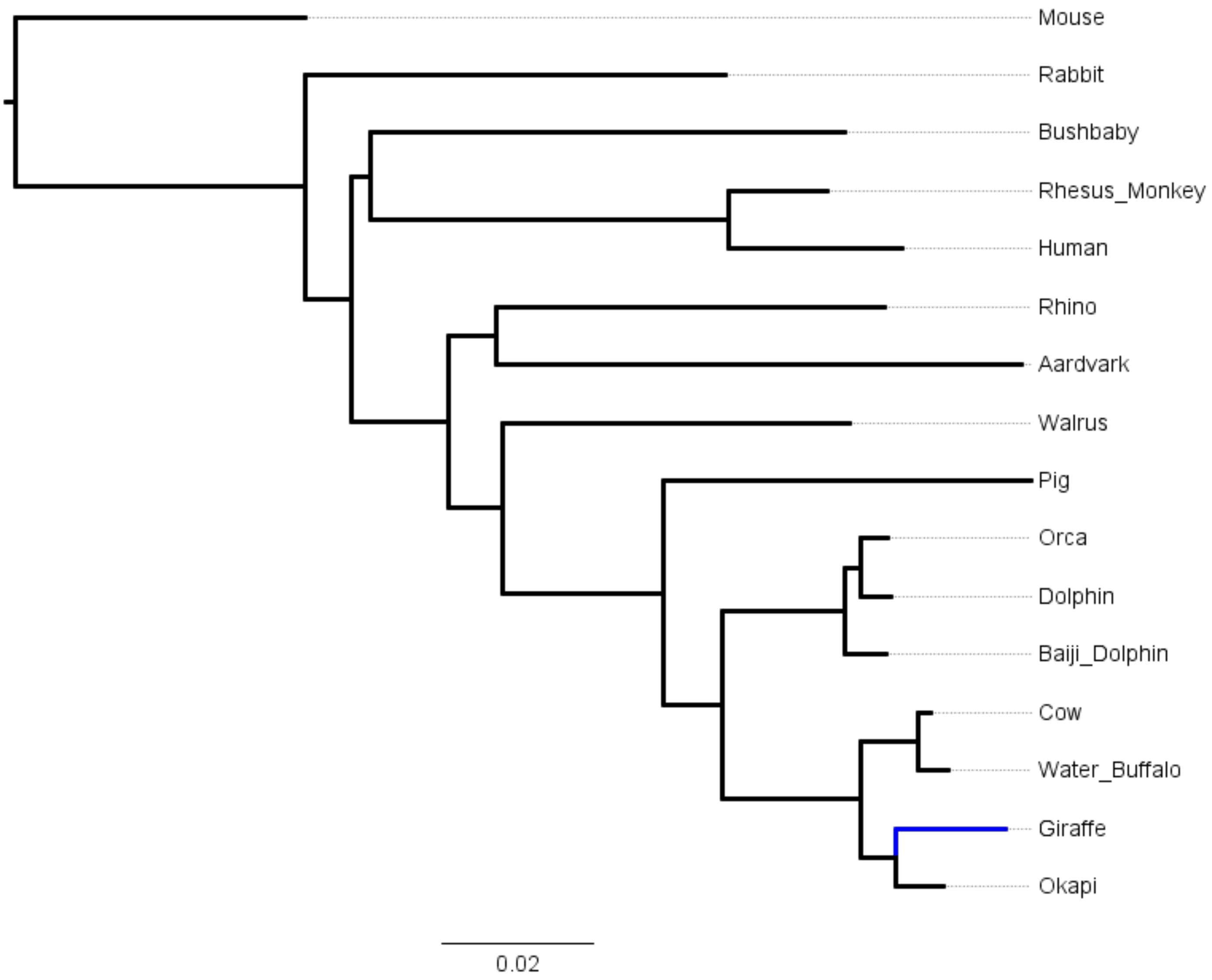
PP2: (Giraffe) A34I, V95M
Giraffe: R8L UPS, P31A UPS, V86M UPS, K402R UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ALDH5A1

```
Cow          1     MATCLRLRSCAAPHLRRAPPSRICRPRADCPVAPIRGYARGPAGLSSALLRTDGFVGGLW  60
Giraffe      1     .......L.RP..C........V.......A........L....................  60
Okapi        1     ..........PS.Y.......QV...H.................................  60

Cow          61    VSAAATFPVHDPASGAELGLVADCGVPEARAAVRAAYEAFCSWRGVSAKERSSLLRKWYD  120
Giraffe      61    .........................M..................................  120
Okapi        61    ............................................................  120

Cow          121   LMIQNKDDLAKIITAESGKPLKEAQGEILYSANFLEWFSEEARRVYGDIISTPAKERRAL  180
Giraffe      121   ............................................................  180
Okapi        121   ............................................................  180

Cow          181   VLKQPVGVAAVITPWNFPSAMITRKVGAALAAGCTVVVKPAEDTPFSALALAELANQAGI  240
Giraffe      181   .....L....I.................................................  240
Okapi        181   .....L......................................................  240

Cow          241   PPGVYNVIPCSQKKAKEVGEALCTDPLVSKISFTGSTATGKVLLHHAANSVKRVSMELGG  300
Giraffe      241   ............................................................  300
Okapi        241   ............................................................  300

Cow          301   HAPFIVFDSANVDQAVAGAMASKFRNSGQTCVCSNRFLVQSGIHDSFVKKFAEAIKTNLH  360
Giraffe      301   ............................................................  360
Okapi        301   ............................................................  360

Cow          361   VGNGFDERTTQGPLINAKAVEKVEKHVSDAISKGATVVTGGKRHHVGKNFFEPTLLSNVT  420
Giraffe      361   .....E.........................A.........R..Q...............  420
Okapi        361   .....E.........................A............Q...............  420

Cow          421   RDMLCSQEETFGPVAPVIKFNTEEEAVAIANAANVGLAGYFYSQDPAQIWRVAERLEVGM  480
Giraffe      421   .................................D..........................  480
Okapi        421   .................................D..........................  480

Cow          481   VGVNEGLISSVECPFGGVKQSGLGREGSKYGIDEYLELKYVCFGGL    527
Giraffe      481   ..............................................    527
Okapi        481   ..............................................    527
```

Newick Tree of Mammalian ALDH5A1

(mouse:0.0385124, (rabbit:0.0560646, ((bushbaby:0.063082, (rhesus_monkey:0.0130375, human:0.0231304):0.04769):0.00264939, ((rhino:0.0515391, aardvark:0.0698163):0.00643962, (walrus:0.0459987, (pig:0.048716, (((orca:0.00366381, dolphin:0.00396989):0.00213718, baiji_dolphin:0.00551862):0.0163367, ((cow:0.00160601, water_buffalo:0.00411377):0.00756038, (giraffe:0.0146236, okapi:0.00647175):0.00455776):0.0185197):0.00768945):0.0213988):0.00733916):0.0129637):0.00610414):0.0385124);



Locus name: Succinic semialdehyde dehydrogenase (**ALDH5A1)**

Locus Name: 3-hydroxyisobutyrate dehydrogenase **HIBADH (3HIDH)**

ENSBTAT00000001374 HIBADH-201 3-hydroxyisobutyrate dehydrogenase mitochondrial, amino acid degradation
no mutation in m/h described

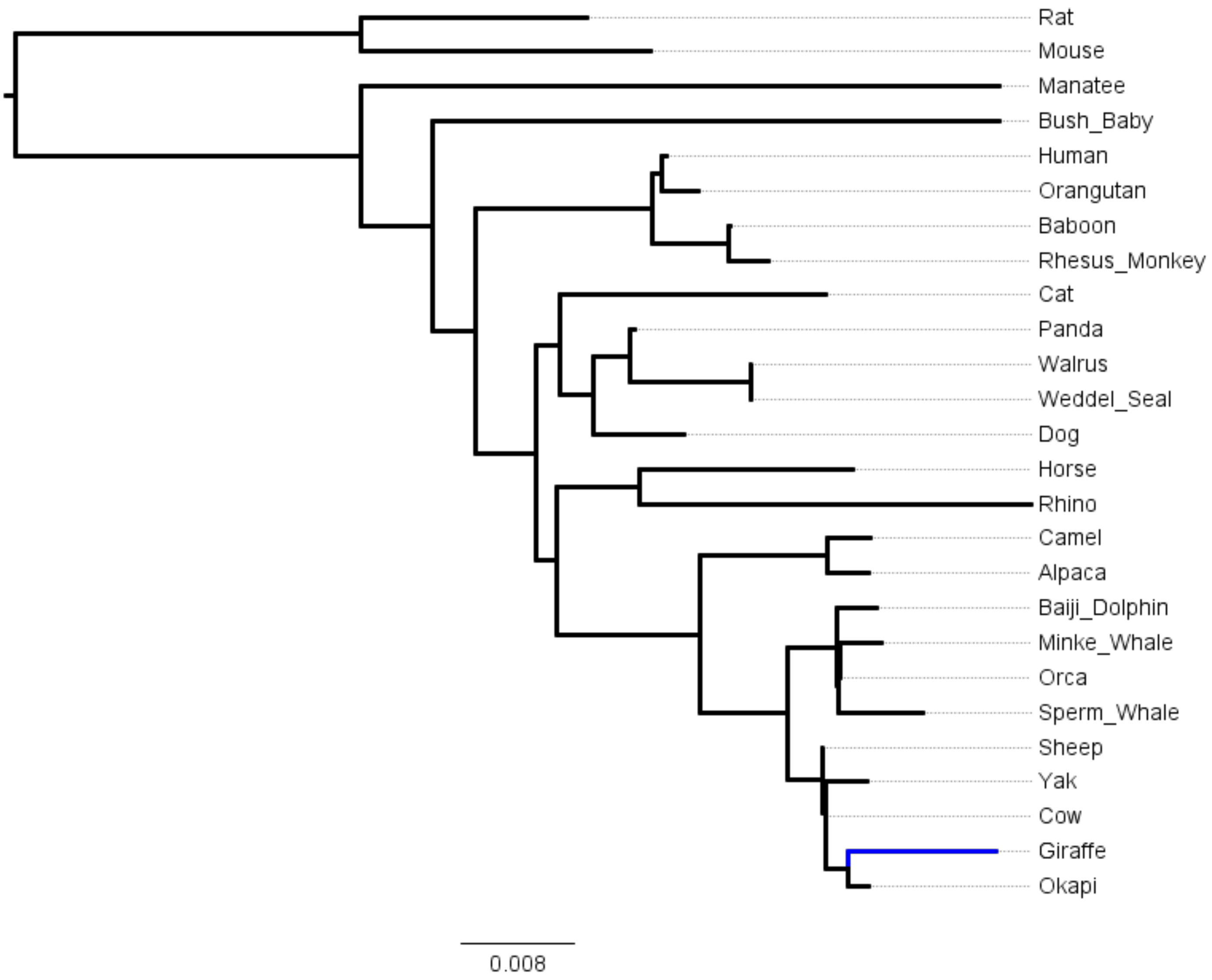
PP2: (Giraffe) A10V
Giraffe: A10V UPS, D265E UIS, D291E UPS

Protein sequence Alignment of Cow, Giraffe and Okapi HIBADH

```
Cow          1     MAASLRLRGAASGLRYWSRRQPPAVASLAAVCSRSMASKTPVGFIGVGNMGNPMAKNLMK  60
Giraffe      1     .........V..................................................  60
Okapi        1     ............................................................  60

Cow          61    HGYPLIIYDVFPDACKEFLDAGEQVVSSPADVAEKADRIITMLPTSINAIEAYSGANGIL  120
Giraffe      61    ............................................................  120
Okapi        61    ............................................................  120

Cow          121   KKVKKGSLLIDSSTIDPMVSKELAKEVEKMGAVFMDAPVSGGVGAARSGNLTFMVGGVEE  180
Giraffe      121   ............................................................  180
Okapi        121   ............................................................  180

Cow          181   EFAAAQELLGCMGSNVVYCGAVGTGQAAKICNNLLLAISMIGTAEAMNLGIRLGLDPKLL  240
Giraffe      181   ............................................................  240
Okapi        181   ............................................................  240

Cow          241   AKILNMSSGRCWSSDTYNPVPGVMDGVPSANNYQGGFGTTLMAKDLGLAQDSATSTKSPI  300
Giraffe      241   .......................TE.........................E.........  300
Okapi        241   .......................I....................................  300

Cow          301   LLGSQAHQIYRMMCAKGYSKKDFSSVFQFLREEETF    336
Giraffe      301   ....................................    336
Okapi        301   ....................................    336
```

Newick Tree of Mammalian HIBADH

((rat:0.0159911, mouse:0.0204952):0.024398, (manatee:0.0452255, (bush_baby:0.0400822, (((human:0.000360217, orangutan:0.00262042):0.00063753, (baboon:0.000153016, rhesus_monkey:0.00282762):0.0053529):0.0125365, ((cat:0.0188311, ((panda:0.000329437, (walrus:0, weddel_seal:0):0.00863935):0.00257591, dog:0.00643383):0.00234697):0.00171167, ((horse:0.0149812, rhino:0.0275912):0.00590892, ((camel:0.00306073, alpaca:0.00290947):0.00900709, ((baiji_dolphin:0.00284379, ((minke_whale:0.0029966, orca:0):5.56646e-05, sperm_whale:0.00592352):0.000143565):0.00351705, (sheep:0, (yak:0.00296328, (cow:0, (giraffe:0.0104891, okapi:0.00145161):0.00154322):3.97966e-05):0.000191481):0.0025478):0.00617726):0.0101173):0.00149611):0.00426352):0.00304448):0.00510457):0.024398);



`Locus Name: 3-hydroxyisobutyrate dehydrogenase` **`HIBADH (3HIDH)`**

Locus Name: Monocarboxylic acid transporter 1, **(SLC16A1; MCT1)**

ENSBTAT00000020102 SLC16A1-201 monocarboxylate transporter rumen epithelium, transport volatile fatty acids, butyrate
human: Symptomatic deficiency in lactate transport (SDLT) [MIMOUSE:245340]: Deficiency of lactate transporter may result in an acidic intracellular environment created by muscle activity with consequent degeneration of muscle and release of myoglobin and creatine kinase.

PP2: (Giraffe) G192E, A335P

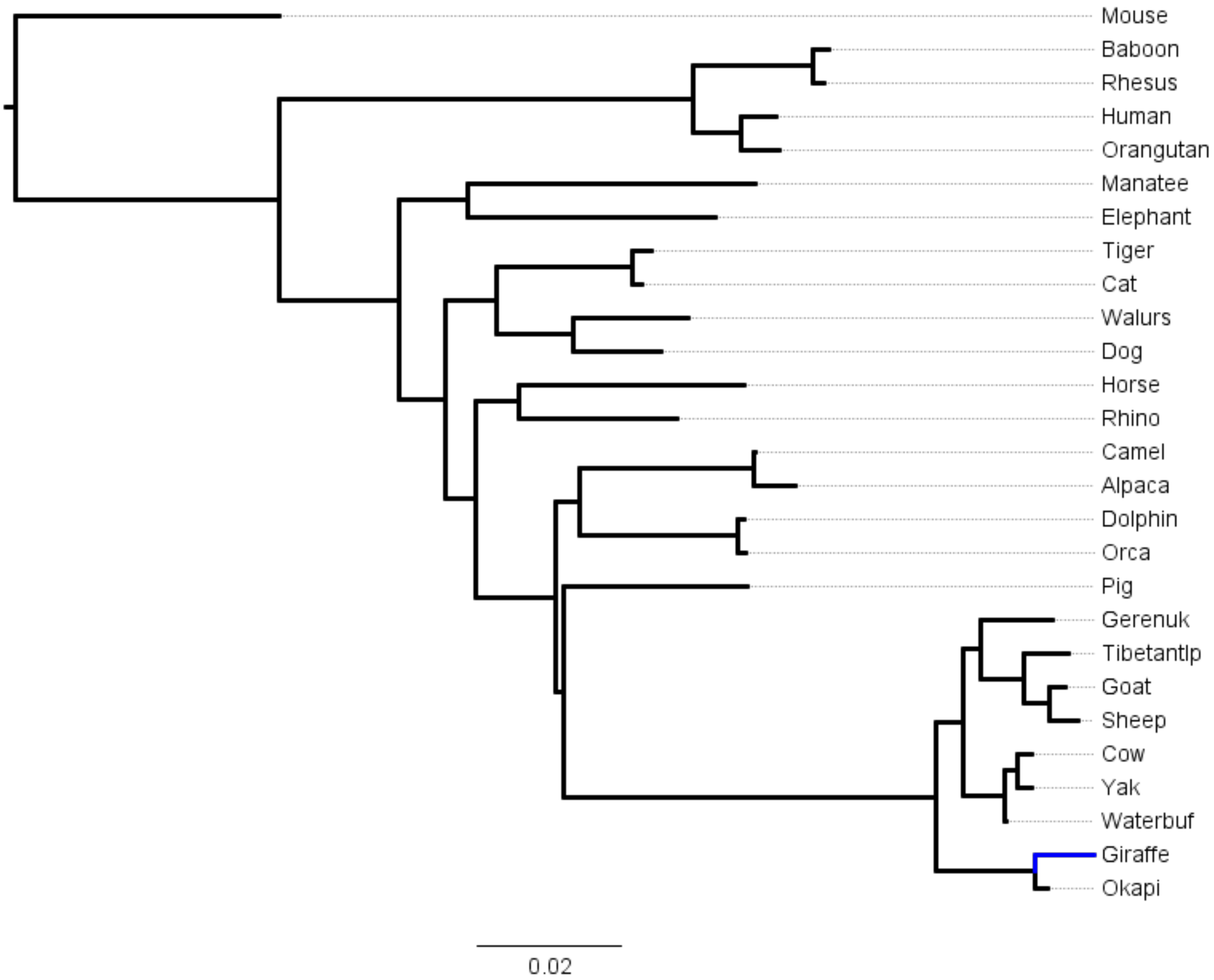
Giraffe: G192E UIS, F246L UIS, W324R UPS, A335P UIS
Giraffe/Okapi: I171T UIS

Protein sequence Alignment of Cow, Giraffe and Okapi MCT1

```
Cow        1     MPPAVGGPVGYTPPDGGWGWAVVIGAFISIGFSYAFPKSITVFFKEIEGIFNATTSEVSW  60
Giraffe    1     .......................V....................................  60
Okapi      1     .......................V....................................  60

Cow        61    ISSIMLAVMYGGGPISSVLVNKYGSRPVMIVGGILSGSGLIAASFCNTVQELYFSVGVIG  120
Giraffe    61    .........................................................F..  120
Okapi      61    .........................................................F..  120

Cow        121   GLGLAFNLNPALTMIGKYFYKRRPLANGLAMAGSPVFLSTLAPLNQAFFMIYGWRGSFLI  180
Giraffe    121   ..................................................T.........  180
Okapi      121   ...................F..............................T.........  180

Cow        181   LGGLLLNCCVAGALMRPIGPKPTTAEKEKSKGSLQEAGKYETKKGASDANTDLIGGNPKE  240
Giraffe    181   ...........E................................................  240
Okapi      181   ............................................................  240

Cow        241   EKKSIFQTLNTFLDLSLFKHRGFLLYLSGNVLMFFGLFTPLVFLSNYGKSKHYSSEKAAF  300
Giraffe    241   .....L........F.............................................  300
Okapi      241   ..............F.............................................  300

Cow        301   LLSILAFVDMVARPSMGLVANTKWVRPRVQYFFAASIIANGLCHLAAPLSSTYIELCIYA  360
Giraffe    301   .......................RI.........P..V......................  360
Okapi      301   ........................I............V......................  360

Cow        361   GFFGFAFGWLSSVLFETLMDLVGPQRFSSAVGLVTIVECCPVLLGPPVLGRLNDIYGDYK  420
Giraffe    361   ............................................................  420
Okapi      361   ............................................................  420

Cow        421   YTYWACGIILIVAGIYLFIGMGINYRLLEKEQKAEKQQKKESKDEETNVDVAEKPKEVID  480
Giraffe    421   ............................A............G.E..............T.  480
Okapi      421   ............................A............G.E..............T.  480

Cow        481   AAESPEHKATEEDPKEAESPV    502
Giraffe    481   .........I.V.........    502
Okapi      481   .........I.V.........    502
```

Newick Tree of Mammalian MCT1

(mouse:0.0366203, (((baboon:0.00234744, rhesus:0.00166059):0.016673, (human:0.00488244, orangutan:0.00516807):0.00676165):0.0578562, ((manatee:0.0401926, elephant:0.0346005):0.00957182, (((tiger:0.00272322, cat:0.00129286):0.0189166, (walurs:0.0162081, dog:0.012311):0.0105875):0.00718989, ((horse:0.0313634, rhino:0.0220628):0.00614059, (((camel:0.000177447, alpaca:0.00582861):0.0241509, (dolphin:0.000964546, orca:0.00103346):0.0220117):0.00336736, (pig:0.0255272, (((gerenuk:0.0101736, (tibetantlp:0.00632708, (goat:0.00205463, sheep:0.00395143):0.00372973):0.00600986):0.00229364, ((cow:0.00200294, yak:0.00199708):0.0018109, waterbuf:0.000189113):0.00578455):0.00395114, (giraffe:0.00821691, okapi:0.00179335):0.0138139):0.05178):0.00113645):0.0113143):0.00418234):0.00638919):0.0168504):0.0366203);



Locus Name: Monocarboxylic acid transporter 1, **(SLC16A1; MCT1)**

Locus Name: Acyl-CoA Synthetase Medium-Chain Family Member 3 (ACSM3)

ENSBTAT00000008455 ACSM3-201 acyl-CoA synthetase medium-chain mitochondrial
mouse: deficiency is asymptomatic

PP2: All benign

Giraffe: K217T UIS, T433S UPS
Giraffe/Okapi: F246Y UIS, V282L UPS, F283Y UIS, A320P UIS, S345T UIS, N543S UPS

Protein sequence Alignment of Cow, Giraffe and Okapi ACSM3

```
Cow          1     MKILLCAKYFQCPVIPGSMRALHKDYRTVTPQNFSNYESMKQDFKLEIPEYFNFAKDVLD  60
Giraffe      1     .....R......LA.....................D........................  60
Okapi        1     .....R......LA..............................................  60

Cow          61    QWTSMEKAGKKPSNPAFWWTNGNGEEVRWSFEELGSLSRKFANILTEACGLQRGDRVILL  120
Giraffe      61    ...N......R........I......................................VI  120
Okapi        61    ...N......R........I......................................VI  120

Cow          121   LPRIPEWWLANIACLRTGTVLIPGTTQMTQKDILYRLQSSKAKCIITNEVLAPAVDAVAS  180
Giraffe      121   ..K.........................................................  180
Okapi        121   ............................................................  180

Cow          181   KCENLHSKLIVSQSPREGWENLKEMMKHASDNHTCVKTKHNEMMAIFFTSGTSGYPKMTG  240
Giraffe      181   ................D..Q................T.................S.....  240
Okapi        181   ......................................................S.....  240

Cow          241   HTHSSFGLGLSINGRFWLDLTPLDVMWNTSDTGWAKSAWSSVFSPWIQGACVFAHYLPRF  300
Giraffe      241   .....Y...................................LY.................  300
Okapi        241   .....Y...................................LY.................  300

Cow          301   EPTSILQTLSKFPITVFCSAPTAYRMLVQNDKASYKFKSLKHCVSAGEPINPEVTEQWRN  360
Giraffe      301   ...................P........................T...............  360
Okapi        301   ...................P........................T...............  360

Cow          361   RTGLDIYEGYGQTETVLICGNFKGMKIKPGSMGKPSPAFDVKILDVNGNVLPPGKEGDIG  420
Giraffe      361   ............................................................  420
Okapi        361   ............................................................  420

Cow          421   IRVRPNRPLGLFTHYIDNPTKTASTLRGNFYITGDRGYMDEDGYFWFVSRADDIILSSGY  480
Giraffe      421   ............S...............................................  480
Okapi        421   ............................................................  480

Cow          481   RIGPFEVESALIEHPAVAESAVVSSPDPIRGEVVKAFIVLNPDYKSHDQEQLKKEIQEHV  540
Giraffe      481   ..................................................K.........  540
Okapi        481   ............................................................  540

Cow          541   KRNTAPYKYPRKVEFIQELPKTISGKIKRNELRKKEWETI    580
Giraffe      541   ..S...................V.................    580
Okapi        541   ..S...................V.................    580
```

Newick Tree of Mammalian ACSM3

```
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(human:0.0236649, baboon:0.0276509):0.0436566):0.00444697, (elephant:0.0397854,
manatee:0.0467067):0.0287065):0.00736451, ((horse:0.0266564, rhino:0.0337895):0.0125289,
(((polecat:0.0297458, (panda:0.0139341, walrus:0.0211644):0.000399972):0.00719307,
dog:0.022576):0.00317441, (tiger:0.00182893,
cat:0.00509157):0.0333636):0.0158113):0.00277917):0.00272705):0.00507594,
(((tibetan_antelope:0.00509388, (goat:0.00164453, sheep:0.0104982):0.000114797):0.000176325,
(gerenuk:0.00616657, ((cow:0, yak:0.00174123):0.00252245,
water_buffalo:0.00614327):0.00427353):0.0006959):0.00518214, (giraffe:0.0114731,
okapi:0.000648542):0.0135766):0.02136):0.036346);
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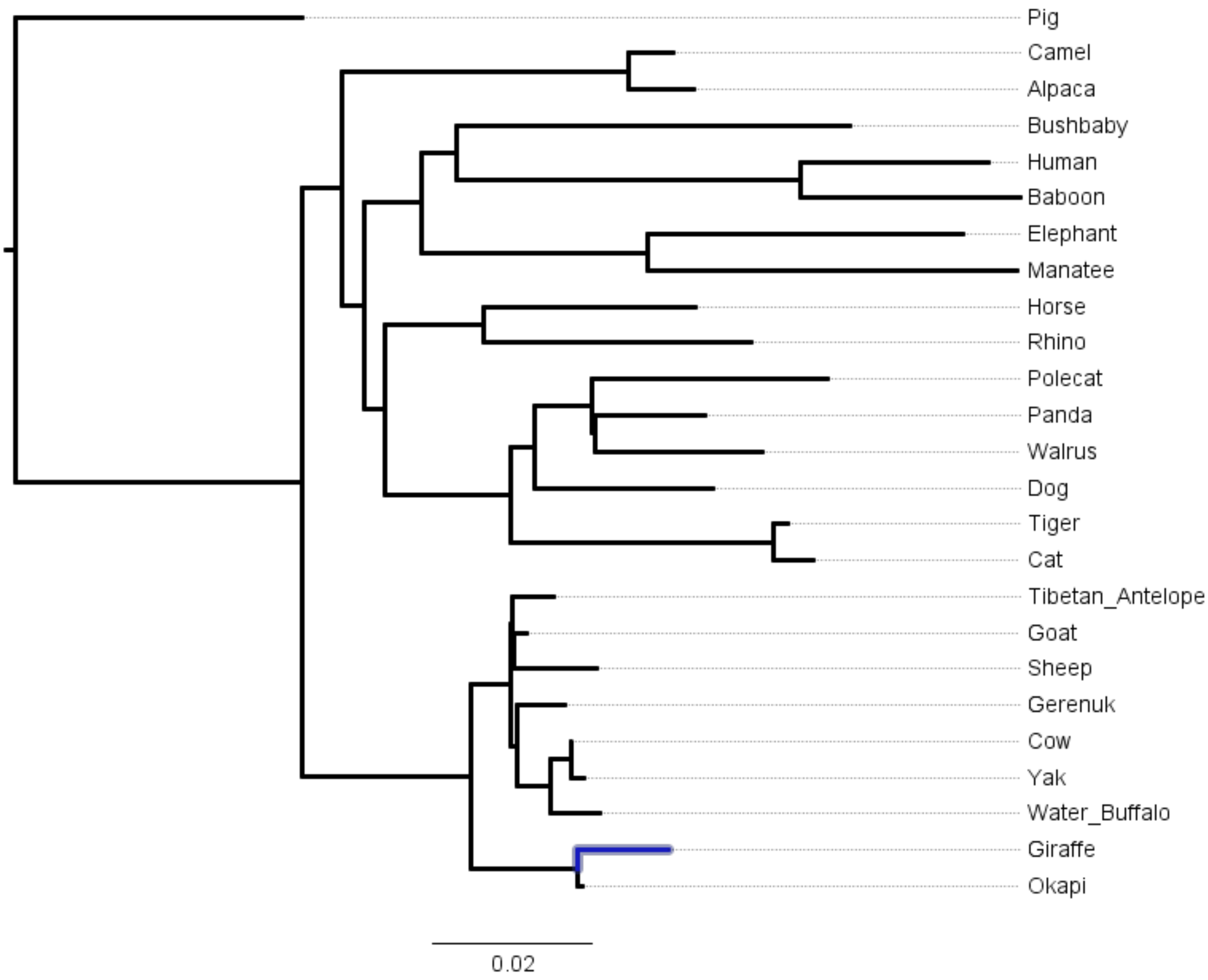


Locus Name: Acyl-CoA Synthetase Medium-Chain Family Member 3 (ACSM3)

Locus Name: Acyl-CoA Dehydrogenase (**ACADS)**

ENSBTAT00000009844 ACADS-201   acyl-CoA dehydrogenase short chain   mitochondrial
mouse: viable but exhibit organic aciduria and develop hypoglycemia and fatty livers after fasting

Giraffe: A9T UIS, H206R UPS
Giraffe/Okapi: E76K UPS, I186V UIS, S236T UIS, A318V UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ACADS

```
Cow          1      MAATLLARACGLVRGAPCPWGWRRLHTVYQSVELPETHQMLRQTCRDFAEKELFPIAAQV  60
Giraffe      1      ........T........W..........................................  60
Okapi        1      .................W.........................................L  60

Cow          61     DKEHRFPAAQVKKMGELGLMAMNVPEELSGAGLDYLAYSIAMEEISRGCASTGVIMSVNN  120
Giraffe      61     ...............K......D.....................................  120
Okapi        61     ...............K......D.....................................  120

Cow          121    SLYLGPILKFGTKEQKQRWVAPFTSGDKIGCFALSEPGNGSDAGAAATTARADGDSWVLS  180
Giraffe      121    ...................T........................................  180
Okapi        121    ...................T........................................  180

Cow          181    GTKAWITNAWEASAVVVFASTDRSLHNKGISAFLVPMPTPGLTLGKKEDKLGIRASSTAN  240
Giraffe      181    .....V..S.....A..........R.............................T....  240
Okapi        181    .....V........A...........................M............T....  240

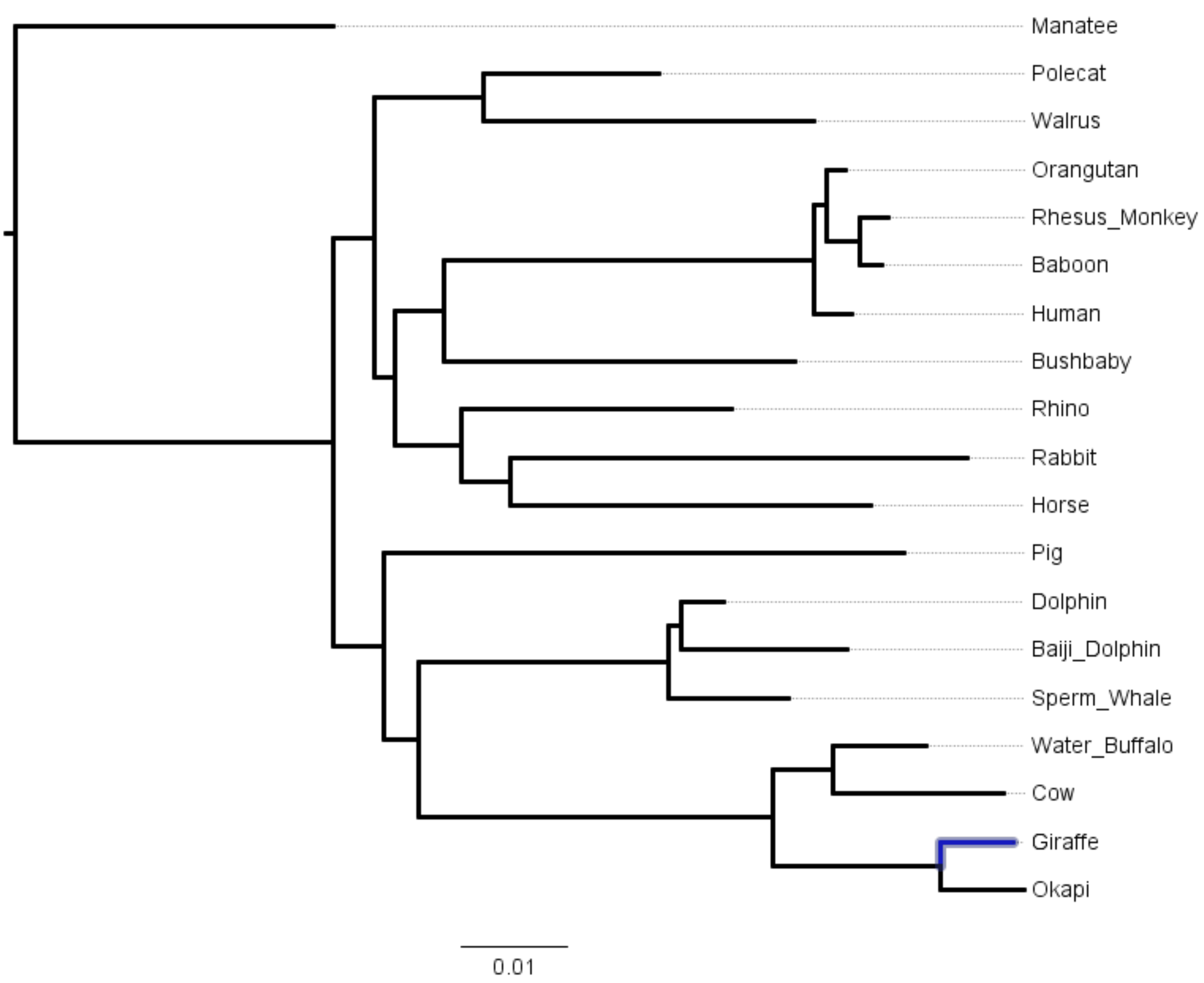
Cow          241    LIFEDCRIPKDSLLGEPGLGFKIAMQTLDTGRIGIASQALGIAQAALDCAVTYAENRSAF  300
Giraffe      241    ....E.....................S..M.....................S........  300
Okapi        241    ....E.....................S..M.....................S.....N..  300

Cow          301    GAPLTKLQAIQFKLADMALALESARLLTWRAAMLKDNKKPFTKEAAMAKLAASEAATAIT  360
Giraffe      301    ........G........V..........................................  360
Okapi        301    ........G........V..........................................  360

Cow          361    HQAMQILGGMGYVKEMPAERHYRDARITEIYEGTSEIQRLVVAGHLLKSYRS          412
Giraffe      361    .............T......................................          412
Okapi        361    .............T......................................          412
```

Newick Tree of Mammalian ACADS

(manatee:0.0297308, (((polecat:0.0164476, walrus:0.0307837):0.010229, ((((orangutan:0.0018263, (rhesus_monkey:0.00275351, baboon:0.0021127):0.00304885):0.00122994, human:0.00364823):0.0344429, bushbaby:0.0327112):0.00463058, (rhino:0.0253092, (rabbit:0.0427137, horse:0.0337335):0.00463544):0.00614534):0.00193616):0.00378163, (pig:0.0484722, (((dolphin:0.00406857, baiji_dolphin:0.0155412):0.00110867, sperm_whale:0.0111876):0.0233502, ((water_buffalo:0.00862668, cow:0.0159471):0.00567232, (giraffe:0.00683494, okapi:0.00779998):0.0156148):0.0330674):0.00320999):0.00473364):0.0297308);



Locus Name: Acyl-CoA Dehydrogenase (**ACADS**)

Locus Name: NADH dehydrogenase [ubiquinone] 1 beta subcomplex subunit 8 (**NDUFB8)**

ENSBTAT00000000100 NDUFB8-201 NADH dehydrogenase- ubiquinone subunit mitochondria electron transport
no mutation in m/h described; putative QTL for nutrient transformation in cattle

PP2: Giraffe, K34E; Giraffe/Okapi, L24M

Giraffe: K34E UIS, Y72F UIS, L128F UPS

Protein sequence Alignment of Cow, Giraffe and Okapi NDUFB8

```
Cow          1     MAAARAGVLGVRWLQKAARNVVPLGARTASHITKDMLPGPYPKTPEERAAAAKKYNMRVE  60
Giraffe      1     .......................M.........E..........................  60
Okapi        1     .......................M............F.......................  60

Cow          61    DYEPYPDDGTGYGDYPKLPDRSQQERDPWYDWDHPDLRLNWGEPMHWDLDMYIRNRVDTS  120
Giraffe      61    .........M.F................................................  120
Okapi        61    .........M..................................................  120

Cow          121   PTPVNWNLMCKHLFGFVAFMLFMFWVGETYPAYQPVGPKQYPYNNLYLERGGDPNKEPEP  180
Giraffe      121   .......F........I..............T............................  180
Okapi        121   ................I..............T............................  180

Cow          181   VVHYEI  186
Giraffe      181   ......  186
Okapi        181   ......  186
```

Newick Tree of Mammalian NDUFB8

```
(rat:0.0466707, ((rhesus_monkey:0.031416, (human:0.0161791,
orangutan:0.0334381):0.0309388):0.0499067, (bushbaby:0.038833, ((alpaca:0.00311812,
camel:0.00769301):0.0373299, (((manatee:0.0117701, elephant:0.0435207):0.0227242,
pig:0.0488404):0.00452384, (((horse:0.0094675, rhino:0.0289028):0.0025596, (tiger:0.0101734,
((panda:0.0118206, walrus:0.0209751):0.00499692,
dog:0.0310593):0.00621582):0.013458):0.000986827, (((minke_whale:0.000394348,
(baiji_dolphin:0.00572374, orca:0.0105375):0.00501122):0.00093587,
sperm_whale:0.0154388):0.00886842, (((tibetan_antelope:0, sheep:0.0109117):0.00602838,
(cow:0.00580861, water_buffalo:0.0104526):0.00494835):0.00257955, (giraffe:0.0163783,
okapi:0.00536341):0.00850647):0.00998073):0.007611):0.00488463):0.00821824):0.0108945):0.00873181
):0.0466707);
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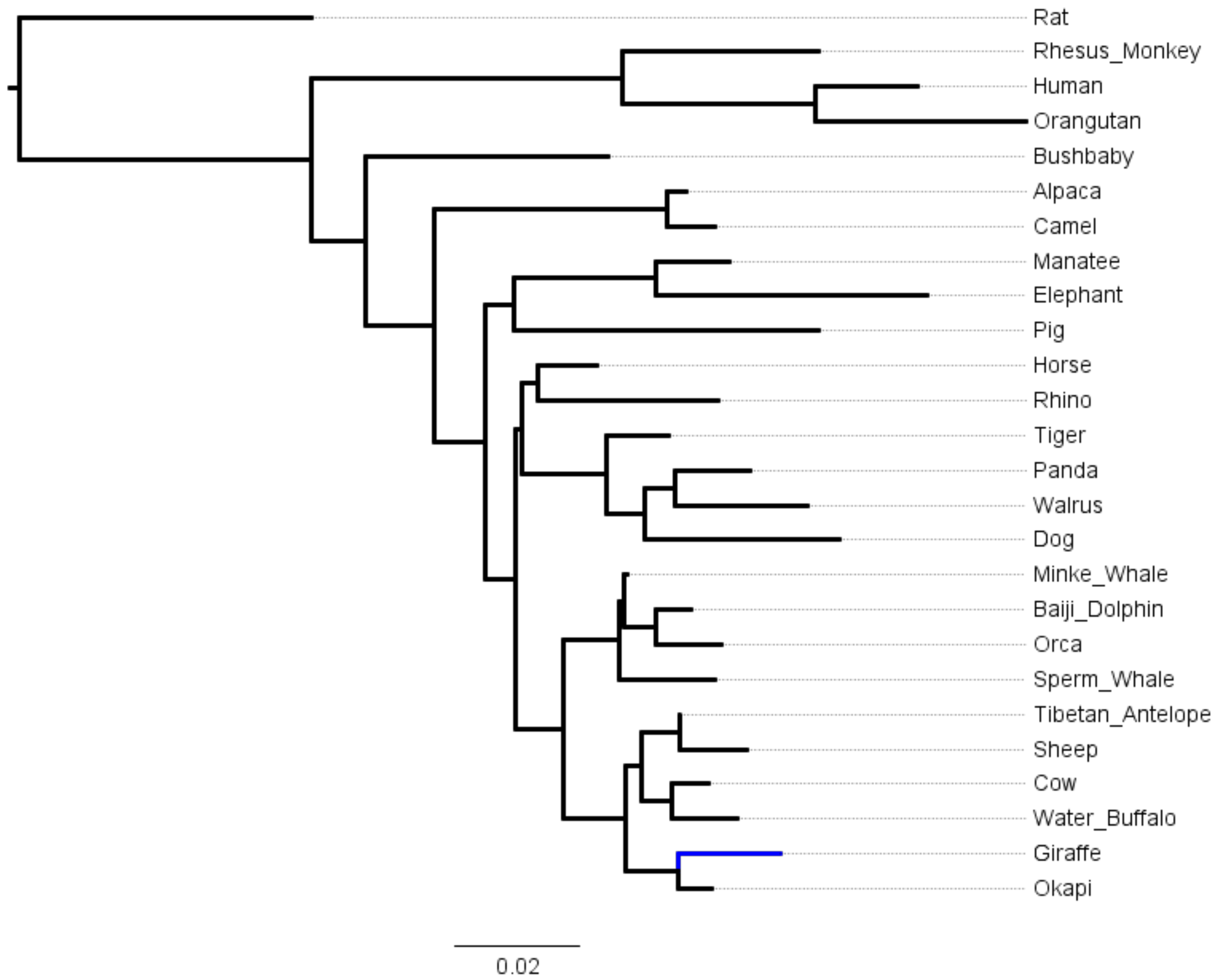


Locus Name: NADH dehydrogenase [ubiquinone] 1 beta subcomplex subunit 8 (**NDUFB8)**

Locus Name: Succinate dehydrogenase (**SDHB)**

ENSBTAT00000010949 SDHB-201 succinate dehydrogenase ubiquinone complex II mitochondria electron transport and citric acid cycle
human: familial paraganglioma

Note MA1 and NZoo are identical except for C/R in lin1.

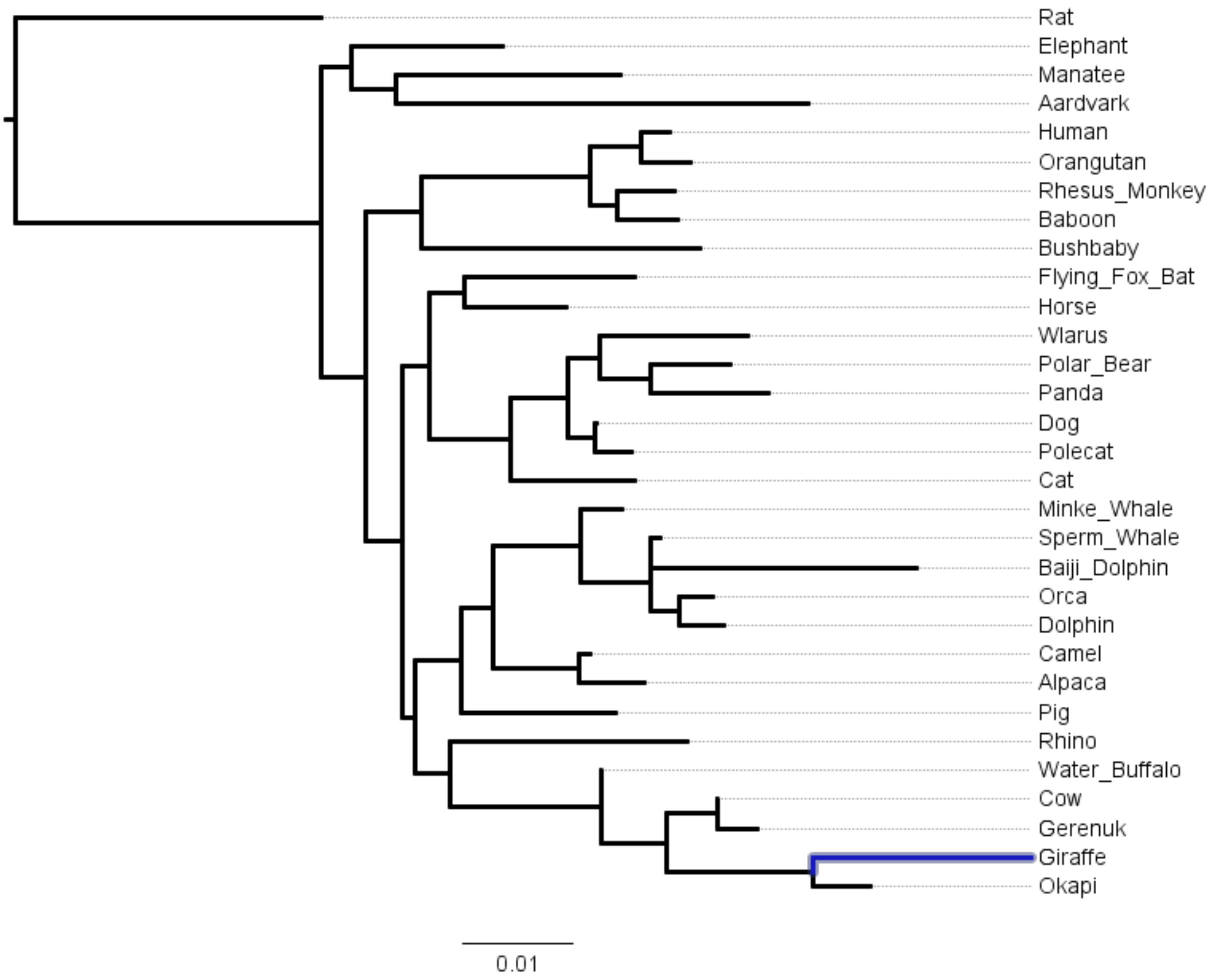
PP2: (Giraffe/Okapi) G20W

Giraffe: R12P UPS, P14S UPS, K55R UIS, A285S UIS, R11C UPS (MA1 only)
Giraffe/Okapi: G19S UPS, G20W UPS, G165R UPS
Okapi: A34V UPS

Protein sequence Alignment of Cow, Giraffe and Okapi SDHB

```
Cow          1     MAAVVALSLRRRFPAAALGGARLQACRGAQTAAAAAPRIKKFAIYRWDPDKTGDKPHMQT  60
Giraffe      1     ...........P.S....SW..................V...............R.....  60
Okapi        1     ..................SW.............V..........................  60

Cow          61    YEIDLNNCGPMVLDALIKIKNEIDSTLTFRRSCREGICGSCAMNINGGNTLACTRRIDTN  120
Giraffe      61    ............................................................  120
Okapi        61    ............................................................  120

Cow          121   LSKVSKIYPLPHMYVIKDLVPDLSNFYAQYKSIEPYLKKKDESQGGKEQYLQSIEDREKL  180
Giraffe      121   .N..........................................R...............  180
Okapi        121   .N..........................................R...............  180

Cow          181   DGLYECILCACCSTSCPSYWWNGDKYLGPAVLMQAYRWMIDSRDDFTEERLAKLQDPFSL  240
Giraffe      181   ............................................................  240
Okapi        181   ............................................................  240

Cow          241   YRCHTIMNCTQTCPKGLNPGKAIAEIKKMMATYKEKQASA   280
Giraffe      241   ...................................RRS..   280
Okapi        241   ...................................R....   280
```

Newick Tree of Mammalian
(rat:0.0281864, ((elephant:0.0140475, (manatee:0.0207438, aardvark:0.0381307):0.00414034):0.00275122, ((((human:0.00262191, orangutan:0.00454664):0.00469757, (rhesus_monkey:0.00524109, baboon:0.00553121):0.00253636):0.0155736, bushbaby:0.0257615):0.00514465, (((flying_fox_bat:0.0158236, horse:0.00949688):0.00310431, (((wlarus:0.0135686, (polar_bear:0.00728323, panda:0.0109332):0.00461818):0.00298046, (dog:0.000146072, polecat:0.00343176):0.00241848):0.00533172, cat:0.0114968):0.00740558):0.00249688, ((((minke_whale:0.00389848, ((sperm_whale:0.000771997, baiji_dolphin:0.0245485):6.3855e-05, (orca:0.00312325, dolphin:0.0040453):0.00269294):0.00647283):0.00807418, (camel:0.00104348, alpaca:0.00612507):0.00790473):0.00294939, pig:0.0143171):0.00421863, (rhino:0.0219161, (water_buffalo:0, ((giraffe:0.0199947, okapi:0.00523451):0.0135203, (cow:0, gerenuk:0.00363408):0.00468624):0.00605696):0.0139869):0.00320491):0.00110757):0.00343791):0.00414917):0.0281864);



`Locus Name: Succinate dehydrogenase (`**`SDHB)`**

Locus Name: Proline Rich 19 (PRR19)

ENSBTAT00000017664 PRR19-201   proline rich protein 19   secreted tannin binding protein
no mutation in m/h described

PSG: (Giraffe) S335H
PP2: (Giraffe) P271T, L340R

Giraffe: P270AV UPS, P271 UIS, G281R UPS, I310T UPS, S335H UPS, L340R UPS
Giraffe/Okapi: S49G UPS, P264S UPS

Protein sequence Alignment of Cow, Giraffe and Okapi PRR19

```
Cow          1      MDPGEPAPKPFQQPEKPGRVRRRKTRRERNEALAGSRQPLTYQHPPVASRDPHMVLRNSV  60
Giraffe      1      .................................V...R..AC....M.G...........  60
Okapi        1      .................................V...RR.A.....M.G...........  60

Cow          61     APTAAKLVVITQGRLSRDHRGLFNHEVKSLDVARLLSSESLELGTPALTTKSSPSPGRGQ  120
Giraffe      61     ......................................G...SA................  120
Okapi        61     ......................................G...S.................  120

Cow          121    QPSLQSRGKENQVPGGSGPGPPSPPQLPDLEQLLGELQCQLILPRAFPRRNLVQEARDAI  180
Giraffe      121    ............................................Q...............  180
Okapi        121    ............................................Q...............  180

Cow          181    VGTLQACHGCVPDLTLVLRGCQPHLPGTDPGALKRQRMTPSWINSPEQAPGEGRQRRRQG  240
Giraffe      181    ............................E...P...........................  240
Okapi        181    ............................E...P...........................  240

Cow          241    TKELTFAVPPTSSTPTVHQVSLAPPKGPWPPPLSSLPSPSGAAWGPPTAFDLLKSIWLVA  300
Giraffe      241    ..................R....S.....AT.........RV..................  300
Okapi        241    ..................R....S.................V..................  300

Cow          301    TPPPPRPWGIGPPQLLPQPPSPLLPRSSALDWSPSPPAPLPSLSWMVAQSSPEAWSFPPM  360
Giraffe      301    .........T........................H....R.....V..............  360
Okapi        301    .............................................V..............  360

Cow          361    RLY    363
Giraffe      361    ...    363
Okapi        361    ...    363
```

Newick Tree of Mammalian PRR19

```
((rat:0.0386238, mouse:0.053525):0.0883841, (((baboon:0.00603163, macaque:0.00811335):0.0116231,
human:0.0185133):0.110478, (((aardvark:0.0830881, elephant:0.0772208):0.0441121,
lemur:0.115863):0.0041864, (((((big_brown_bat:0.023928, Brandt_s_bat:0.01027):0.00653338,
mouse_nose_bat:0.0193772):0.0832193, (large_flying_fox:0.00124157,
black_flying_fox:0.00712677):0.0880732):0.0222939, (horse:0.0732935,
rhino:0.0394889):0.0272606):0.00110741, (((((Weddell_seal:0.0118746,
walrus:0.0223234):0.00971802, (polar_bear:0.00807014, panda:0.0174659):0.0136758):0.00647727,
(dog:0.0500977, ferret:0.0658449):0.00186069):0.010002, (tiger:0.00518627,
cat:0.00608169):0.0313018):0.026254, ((camel:0.0110255, alpaca:0.0169129):0.0632447,
(pig:0.10878, ((((orca:0.0174325, baiji_dolphin:0.0219085):0.0147489,
sperm_whale:0.0193722):0.00833998, minke_whale:0.0237239):0.037262, ((((cow:0.00799261,
water_buffalo:0.00867521):0.00915383, ((musimon_sheep:0, sheep:0.000698761):0.0103752,
tibetan_antelope:0.00989567):0.00886299):0.0016283, gerenuk:0.0191309):0.00752895,
(giraffe:0.0207924,
okapi:0.00431613):0.012737):0.0580005):0.00389828):0.00683237):0.0129994):0.00393652):0.012024):0
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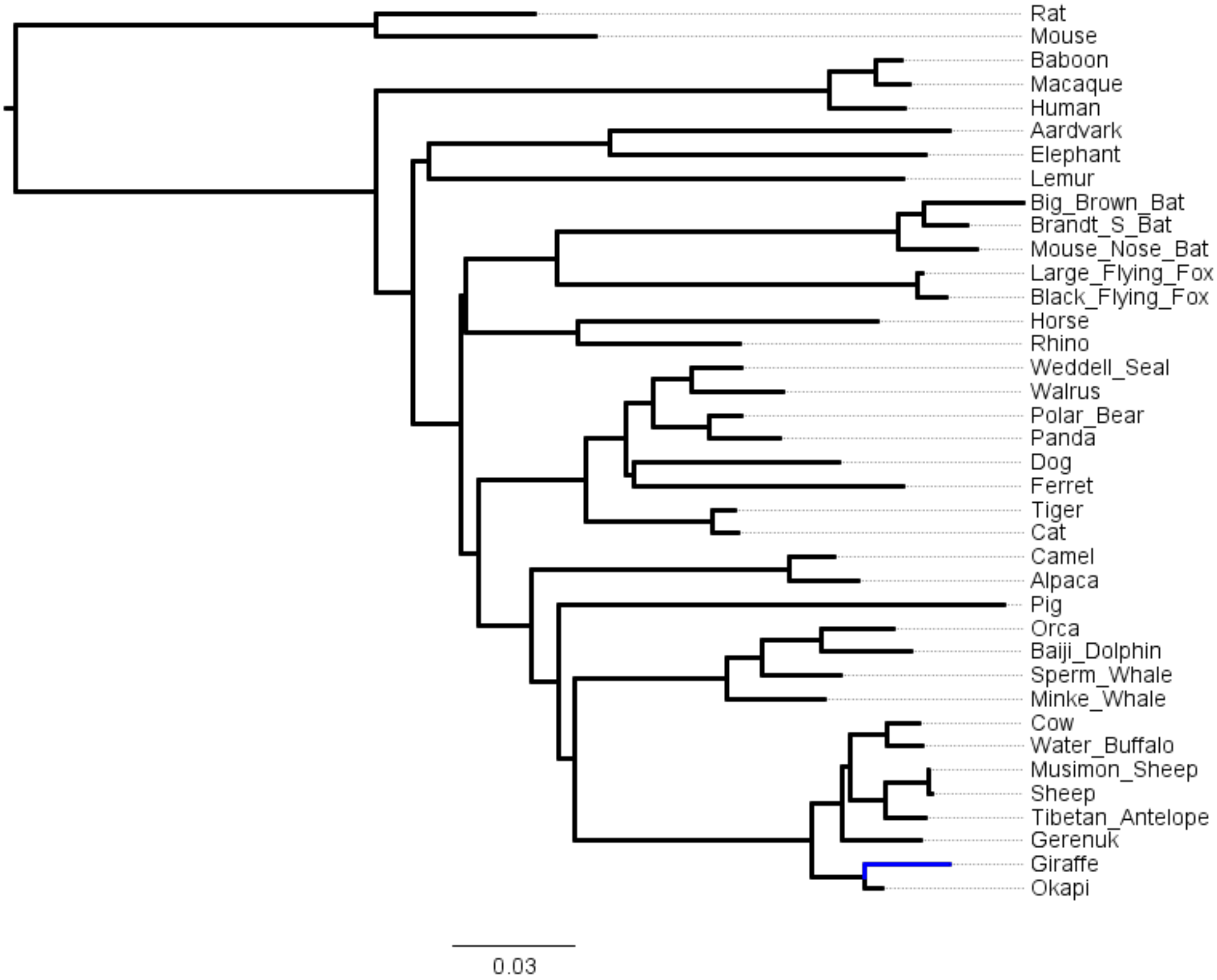

Locus Name: Proline Rich 19 (PRR19)

Locus Name: RIBOSOMAL L10 PROTEIN MITOCHONDRIAL (**MRP10)**

ENSBTAT00000002395 MRPL10-201   ribosomal L10 protein   mitochondrial protein synthesis
no mutation in m/h described; presumed essential gene

PSG: (Giraffe) V5T|GTG/ACG

Giraffe: V5T UPS, Q204L UIS
Giraffe/Okapi: V59L UPS

Protein sequence Alignment of Cow, Giraffe and Okapi MRP10

```
Cow          1      MAAAVAGMLRGGLLPQAGRLPTHQFIRYGSKAVTRHRRVMHFERQKLMAVTEYIAPKPVV  60
Giraffe      1      ....T...................I.................................L.  60
Okapi        1      ........................I.................................L.  60

Cow          61     NPRCLPPPPSPPQEETGLIRLLRREIAAVFRDNRMIAVCQNVAMSAEDKLLMRHQLRKHK  120
Giraffe      61     ......................................................R.....  120
Okapi        61     ............................................................  120

Cow          121    ILMKVFPNQILKPFLEDSKYQNLLPLFVGHNLLLVSEEPKVKEMVRILKSVPFLPLLGGC  180
Giraffe      121    ..................................................M.........  180
Okapi        121    ..................................................M.........  180

Cow          181    IDDTILSRQGFINYSKLPSLALAQGELVGGLTLLTARTHSLLQHHPLQLTALLDQYARQQ  240
Giraffe      181    .......................L.......A............................  240
Okapi        181    ...............................A............................  240

Cow          241    HEGDPVVPASAQPDPPNPVQD      261
Giraffe      241    ..........V..........      261
Okapi        241    .....................      261
```

Newick Tree of Mammalian MRP10

```
(rat:0.0645262, (star_nose_mole:0.099884, (((dog:0.0272981, (((walrus:0.0275417,
Weddell_seal:0.0280568):0.0135599, (panda:0.0165345, polar_bear:0.0109756):0.0171246):0.00912627,
ferret:0.0641004):0.00334294):0.0391503, ((manatee:0.0418545, elephant:0.0505261):0.0290281,
aardvark:0.0581608):0.00625984):0.00470102, (((((gibbon:0.0188812,
orangutan:0.00446826):0.00117767, human:0.0109935):0.00751557, baboon:0.0303341):0.0412679,
armadillo:0.0610013):0.00650589, (gray_mouse_lemur:0.0827197, ((large_flying_fox:0.0548505,
(Brandt_s_bat:0.00579485, mouse_eared_bat:0.0174641):0.089278):0.0122031, (hedgehog:0.0953026,
(camel:0.0578301, ((horse:0.045932, rhino:0.0464486):0.0173674, ((baiji_dolphin:0.0253808,
(orca:0, bottle_nose_dolphin:0.00399924):0.0217992):0.0284092, ((giraffe:0.0127051,
okapi:0.00262143):0.00996322, ((gerenuk:0.0150397, (((sheep:0,
musimon_sheep:0.00389757):0.0106477, tibetan_antelope:0.0126571):0.00366015,
goat:0.0119038):0.00548156):0.00141166, (cow:0.00223277, (yak:0,
bison:0.00385035):0.00161344):0.0055427):0.00084148):0.0401315):0.0115353):0.00501919):0.00175823
):0.00166):0.00394547):0.00450686):0.000830059):0.0133847):0.0645262);
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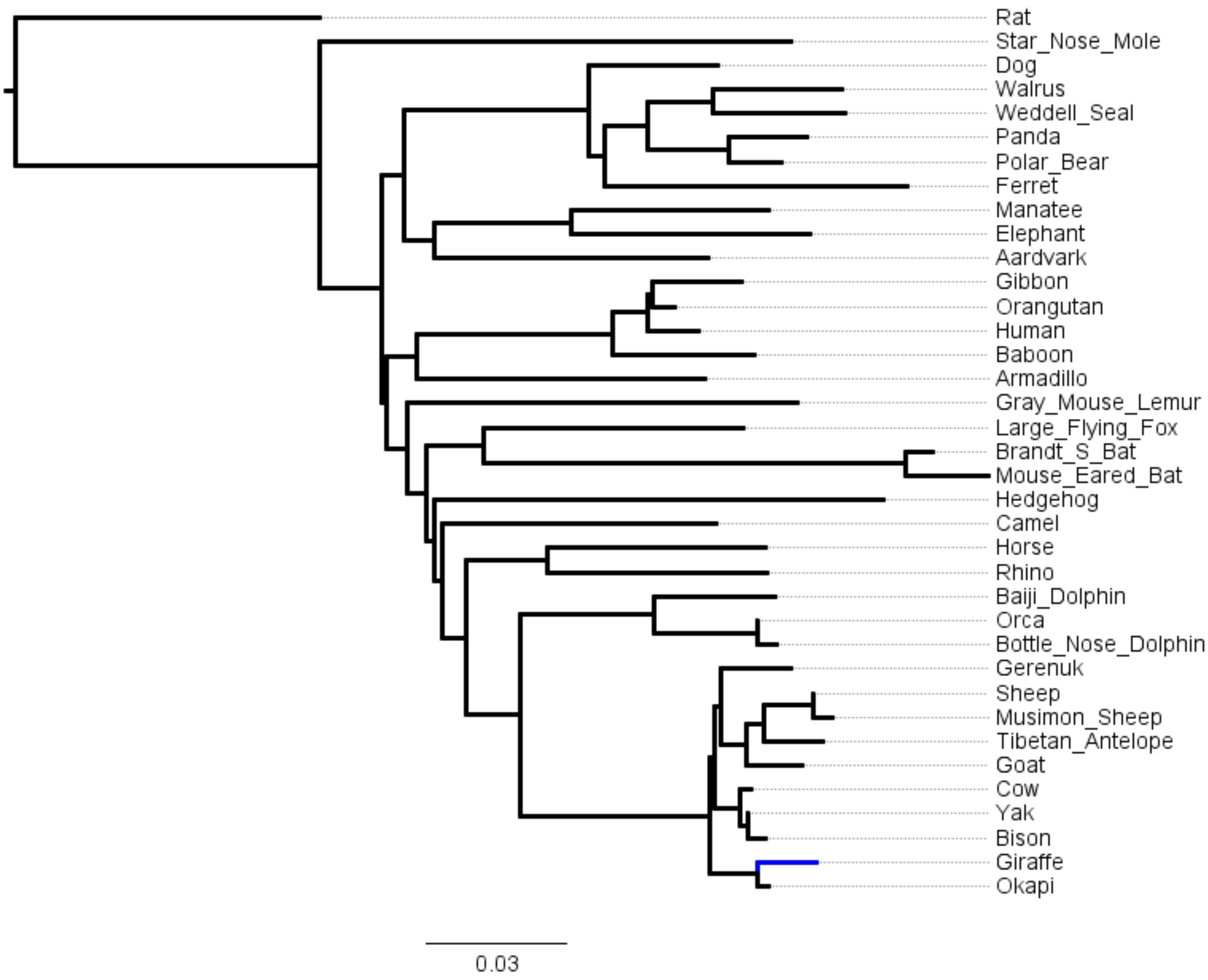

Locus Name: RIBOSOMAL L10 PROTEIN MITOCHONDRIAL (**MRP10)**

Locus Name: Mediator Of DNA-Damage Checkpoint 1 (**MDC1)**

ENSBTAT00000035900 MDC1-201 meditator DNA damage checkpoint dsDNA break repair, scaffold
mouse: growth retardation and display increased susceptibility to ionizing radiation, male infertility, T and B cell abnormalities, and increased genomic instability

PP2: (Giraffe)L175F, S189L, G209R, S235G, V253M, E334K, L369Q, I400M, Q738P, A751S, E873Q, G960S, P969L, P1034S, S1057I, S1095F, R1114P, T1116S, P1136H, T1183R, T1269P, V1449M, T1474P, P1505L, A1785I, E1792D, P1827F, & A1911T. Giraffe and okapi share 15 PRD.

Protein sequence Alignment of Water Buffalo, Giraffe and Okapi MDC1

```
waterbuffalo  1     MEDTQILNWEVEEEEEVEERPSESLGYSLEPLGQLRIFSSSYGPEKDFPLYLGKNMIGRM  60
Giraffe       1     .....V.........V...S...............HV.......................  60
Okapi         1     .....V.........V...S.........K.....H........................  60

Waterbuffalo  61    PDCSVALPFSSISKQHAVIEISAWDKAPVLRDCGSLNGTQILRPPKVLGPGVSHRLRDRE  120
Giraffe       61    .....V........................Q...........................Q.  120
Okapi         61    .....V........................Q...........................Q.  120

Waterbuffalo  121   LILFADLPCQYHRLDVPRPFVSRGPLTVEETPRVQGGTQPPRLLLAEDSEEEVDSFLDKC  180
Giraffe       121   ............................................................  181
                                            \
                                            |
                                            R
Okapi         121   .................Q..........................................  180

Waterbuffalo  181   VVKGPRTSSLATVVPESDEEGPSPAPDGPGPPSAFNLNSDTDEEESQESGAGEASSAPRR  240
Giraffe       182   .............................R.....................A------..  235
Okapi         181   .A.................................................A------..  234

Waterbuffalo  241   GSAAETEQPEPVTAEIQIEKDQCSVKEKNRDTEIERDVRNGVVPTGVILERSQPSGEDSD  300
Giraffe       236   .T.......K..M........................A...........K..........  295
Okapi         235   .TT........................R......K.........I....K...S......  294

Waterbuffalo  301   TDVSDESGPPRRLAGVRPKRAWSCNFIDSDTDGEDEGIPATPAVVPMKERQIFHEAGTQS  360
Giraffe       296   ................P..........G...N.K............V.............  355
Okapi         295   ................P..........G...N.K............V.............  354

Waterbuffalo  361   PQAPGVARQQESPADGDTDIEEGEVPPDRSQASMVIDSNTDDEEEVSAALTLARLRESQA  420
Giraffe       356   ........................A........V.M.....---..A......H....H.  412
Okapi         355   ........R...............A........V.......---..A......H....H.  411

Waterbuffalo  421   GKWTRDPDAEEDRAQPVALLEQSQASAGGDSDTDVEEEGLPVERRGMVPKGHMDREYSKK  480
Giraffe             ------------------------------------------------------------
Okapi               ------------------------------------------------------------

Waterbuffalo  481   SQHPPRDSDTEGKEDKSSPGVHLERSQASAQVEDEVPLGPAVALPEKRQVQGIVWTHHTD  540
Giraffe             ------------------------------------------------------------
Okapi               ------------------------------------------------------------

Waterbuffalo  541   AEAEGGPARLPVLRLEEAWPPLAGDCKLDAENTSSAAAGVRKSQLPAEKDAGTTWDAAVP  600
Giraffe             ------------------------------------------------------------
Okapi               ------------------------------------------------------------

Waterbuffalo  601   EQDRALATGTQGGSSMAPGEQDLLPVSRENLADLVVDTGTPGEPQPQREGAQTTTGRERE  660
Giraffe             ------------------------------------------------------------
Okapi               ------------------------------------------------------------

Waterbuffalo  661   PHGNRATDSGESLHDSEDLDLPATQCFADRKNQSLEAAPSMEDEPTQAFLFTLPQEPGPS  720
Giraffe       410   --------------.F...........V..E......V..V.........LP........  458
Okapi         396   ---------------............VA.E......V............LP........  457

Waterbuffalo  721   CCSSQATGSLNEAWEVLATQPFCPREYEASETQTAVTLLDTRASCPPPSRTAQQEQHPES  780
Giraffe       459   ...FP.....D......S........S..........R...C..................  518
Okapi         458   ...FP.....D...............S..............C..................  517

Waterbuffalo  781   PVRAEALGMEGRGMQTVEKDKGTQRETTERVIPEGGPPQNETKKLPSEGEREDVTGEEEL  840
Giraffe       519   ..H..P..............M..P...A.........L.K....................  578
Okapi         518   ..H..P..............M..P...A.........L.K....................  577
```

```
Waterbuffalo  841   IRGIQGREQNQVLARDTQSQESDKKVKSASTGRGMEIVKLETETPKETQEKEREKQTLAG  900
Giraffe       579   .....D........G.....Q....M.............V.I..................  638
Okapi         578   .....D........V.....Q....M.....I.......V....................  637

Waterbuffalo  901   EIFESEAGKLVVERESEVGGLEVKGPQELLDRGPQMRETEAGGQDQKGQASGPPSEPGAG  960
Giraffe       639   ...........A...N.A......V........L.X...........S......P.L...  698
Okapi         638   ...........A...N.A......I..............G..............P.....  697

Waterbuffalo  961   AGDLQGFTSDPVASGSQAGGGRGAPGSPRRQQRGDLNCEMPPAEKASRGDQESPDACLPP  1020
Giraffe       699   ......LA.......R......................K..........G...S......  758
Okapi         698   ......LA.......R.................................G...S......  757

Waterbuffalo 1021  AAPEASAALPNSLISQIQKHPAPQSLLFPSPAPLELPIPRTRENENQEAPETPFSSELNS  1080
Giraffe       759   .....................T....................Q..S........F.....  818
Okapi         758   .......P.............T....................Q..S......L.F.....  817

Waterbuffalo 1081  VHPEPKVRPQGSSPVSSLPLEPHPTTPTGQPIALEPTSGVSRSGTHSSFDVTASSVVPTA  1140
Giraffe       819   ...K..........I...............H..P.........R..........FI....  878
Okapi         818   ...N..........I.......Y..........P.........R................  877

Waterbuffalo 1141  LALQPSTSTDQPVAPKPTLRAPRGRAQRSSVKTPEPNVRTDQPIAPELTAKATRGRAQRS  1200
Giraffe       879   ............IT...R........H.........S.S....V................  938
Okapi         878   ............II............H.........S.P....V................  937

Waterbuffalo 1201  SVKTPKPDNPTIPKPQPSTSTDQPVTPKPTSRAPRGRTPKSSAKTPEPAVPTASELQPAA  1260
Giraffe       939   ...........TL...................L......R..V.....V...........  998
Okapi         938   ...........T....................L......R..V.....V...........  997

Waterbuffalo 1261  PKDQPVAPELTSRATRGRTQRSSIKTSKPDTSTAPEPQPSTSTDQPVTPKPTSRAPRGRT  1320
Giraffe       999   ........................V.....M..T..........................  1059
                        \
                        |
                        P
Okapi         998   LT......................V.....M..T......F...................  1058
                        \
                        |
                        P

Waterbuffalo  1321  PRSSSKTPEPVVSTASELQPSALTDQPVTPELTSRATRRRAQRSSVKTPDPVTTTTPELQ  1380
Giraffe       1060  ....I.....................L...........G.........S...........  1119
Okapi         1059  ....T.................................G.....................  1118

Waterbuffalo  1381  PSTSTDQLVTPKRPSRAPRGRTRRSSAKTPEPVVPTASELQPSAPADQPVGPWATQCRRH  1440
Giraffe       1120  ............PT........L........S..............N............R  1179
Okapi         1119  ............PT........L.......K............................R  1178

Waterbuffalo  1441  RSSVKTLEPVVPTVPEPQPSTSKDQSVAPEPTSQATQSQTHRSSVKTSQPTEPTAPDLKP  1500
Giraffe       1180  ......P.....A.......................G...K...................  1239
Okapi         1179  ......P.............................G.......................  1238

Waterbuffalo  1501  SSPTDQPVTPKVIAQGGPSRTRRASTASAVLVPTTPEFQCPVPSEQPLSPDPIPEVNCSL  1560
Giraffe       1240  .......................S...............P.........L.........R  1299
Okapi         1239  .......................S...............S.........P.........R  1298

Waterbuffalo  1561  RPRATRKHGSPTAHVHEPCTAPPEPNSRSSRNQTHGAMKAAKLLSTIPEPAFAQLPEAPP  1620
Giraffe       1300  ..................YS.............RR..V...EP..............V..  1359
Okapi         1299  ...................S..........G..RR..V...EP..............V..  1358

Waterbuffalo  1621  HTPQMPKEEAADGSGFTPEPQPRASQNRKRPSATAHSPPLQKRLQRGRVPQKAASLKEEE  1680
Giraffe       1360  .I..I...D.............K.....H..A.IT.........F..K......TI....  1420
                                                                             \
                                                                             |
                                                                             E
Okapi         1359  .I..I.................K.....C..A.IT............K.....V.V....  1419
                                                                             \
                                                                             |
                                                                             E

Waterbuffalo  1681  NPAARPRKEEGVVIPGPGKRKREQTEEESQGRPSRSLRRTKPVQESTAPKVLFTGVVDAR  1740
Giraffe       1421  ...G.....................................LI.................  1480
Okapi         1420  ...G......................................I.................  1479
```

```
Waterbuffalo  1741  GERTVLALGGSLASSVAEASHLVTDRIRRTVKFLCALGRGIPILSLAWLHESRKAGCFLP  1800
Giraffe       1481  ......T.....................................................  1540
Okapi         1480  ............................................................  1539

Waterbuffalo  1801  PDEYLVTDPEQEKNFGFSLREALSRARERRLLEGYEIHVTPGVQPPPPQMGEIINCCGGA  1860
Giraffe       1541  ..........................Q..........Y......................  1600
Okapi         1540  ..........................Q.................................  1599

Waterbuffalo  1861  ILPSMPRSYKPQRVVITCSQDFPRCAIPSRVGLPVLSPEFLLTGVLKQEVKPEAFAFSTV  1920
Giraffe       1601  ............................Y.....I.........................  1660
Okapi         1600  ............................Y.....I.........................  1659

Waterbuffalo  1921  EMSST  1925
Giraffe       1661  .....  1665
Okapi         1660  .V...  1664
```

Newick Tree of Mammalian MDC1

```
(manatee:0.0873606, ((human:0.0506362, (baboon:0.0426609, rhesus:0.0216001):0.0201454):0.130203,
((rhino:0.0885826, horse:0.140875):0.0356451, (((cat:0.013552, tiger:0.0238696):0.10227,
(dog:0.102894, (panda:0.0927121, (polecat:0.082205,
walrus:0.069215):0.0078292):0.00246621):0.0230752):0.0619518, (((giraffe:0.0488042,
(sheep:0.0362649, (waterbuffalo:0.0123944, yak:0.0225):0.019704):0.0140556):0.120944,
(minkewhale:0.032485, (dolphin:0.0209078, fwdolphin:0.0351586):0.0168106):0.0517353):0.0113368,
(pig:0.162404, (camel:0.0307988,
alpaca:0.0352585):0.0830175):0.0077372):0.0354452):0.00777303):0.019268):0.0873606);
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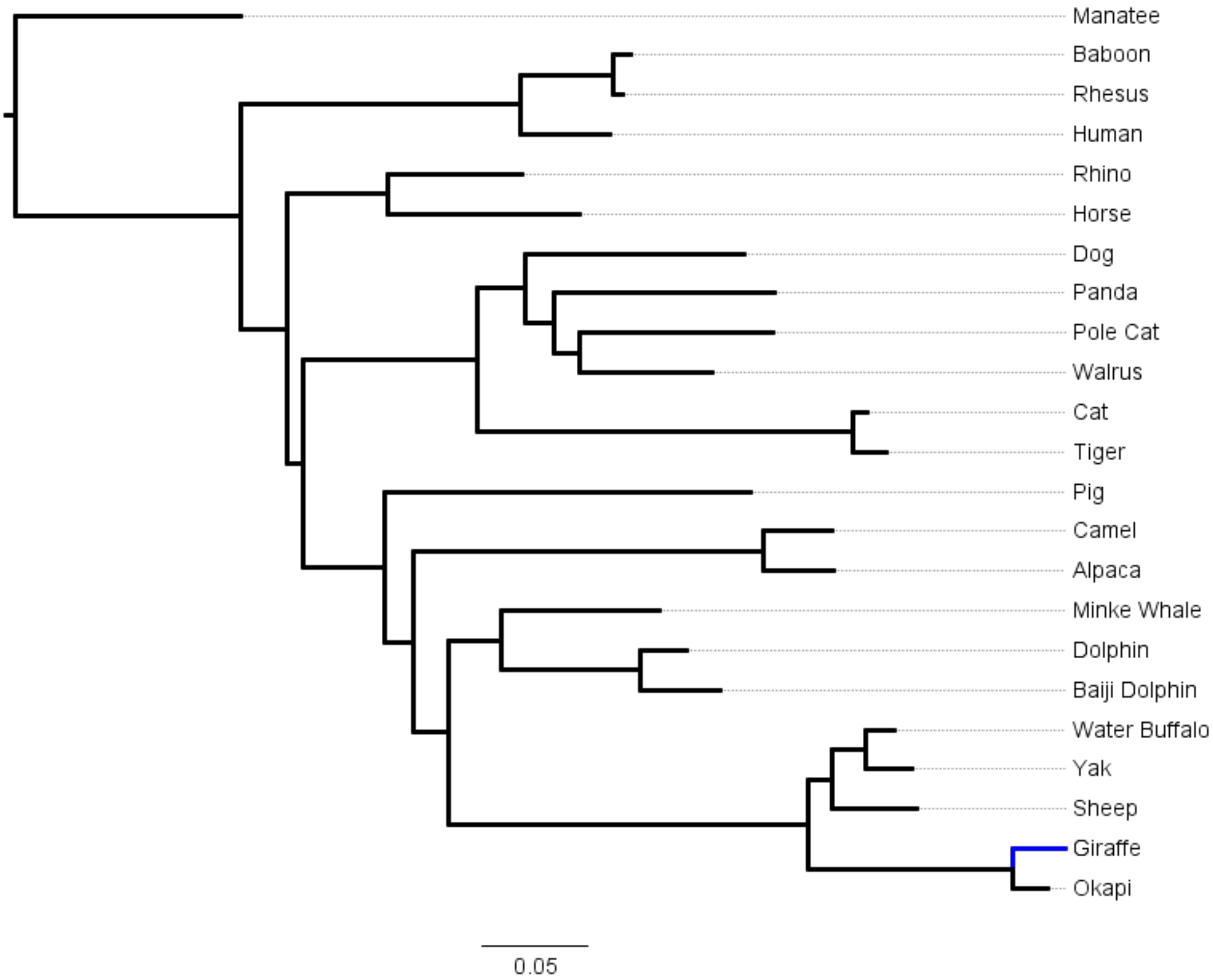

Locus Name: Mediator Of DNA-Damage Checkpoint 1 (**MDC1**)

Locus Name: Exonuclease 1 (EXO1)

ENSBTAT00000012365 EXO1-201   exonuclease 1 DNA mismatch repair, essential for meiosis
mouse: reduced life span, lymphoma development, and male/female sterilty due to defective meiosis

PP2: (Giraffe) P587S

Giraffe: V142I UIS, G495D UIS, S579R UPS, P587S UIS, D639N UPS, S645R UIS, Q663E UPS, H714N UPS, S733I UIS, R750K UIS, P796S UIS
Giraffe/Okapi: E336K UIS, S492R UIS, S459G UPS, I606L UPS, T609A UIS

Protein sequence Alignment of Cow, Giraffe and Okapi Exo1

```
Cow          1      MGIHGLLQFIKEASEPIHIRKYKGQVVAVDTYCWLHKGAVACAEKLAKGEPTEKYVGFCM  60
Giraffe      1      ..................V............................R....D.......  60
Okapi        1      ..................V............................R....D.......  60

Cow          61     KLVNMLLSHGIKPILVFDGCTLPSKKEVEKSRRERRQANLLKGKQLLREGKVSEARECFI  120
Giraffe      61     .F.........................................................T  120
Okapi        61     .F.........................................................T  120

Cow          121    RSINITHTMAHNVIKAARSQGVDCLVAPYEADAQLAYLNKAGIVQAVITEDSDLLAFGCK  180
Giraffe      121    .....................I......................................  180
Okapi        121    ...........S................................................  180

Cow          181    KVILKMDQFGNGLEVDQARLGMCKQLGDVFTEEKFRYMCILSGCDYLSSLRGIGLAKACK  240
Giraffe      181    ............................................................  240
Okapi        181    ............................................................  240

Cow          241    LLRLANNPDILKVVRKIGHYLKMNITVPEDYIKGFIRANNTFLYQLVFDPIKRKLIPLNA  300
Giraffe      241    .............I..............................................  300
Okapi        241    .............I..............................................  300

Cow          301    YEDDVDPKTLSYAGQYVDDSIALQIALGNKDINTLEQIDHYNPDTAMPAQSRSHSWTDKA  360
Giraffe      301    ......Q.............V..............K...D....................  360
Okapi        301    ....................V..............K...D....................  360

Cow          361    CQKSSNINSIWHRNYCPRRELDIVSDTTKVKENPSTVGIKQVISIKGLNLPRKSSIVKRP  420
Giraffe      361    ............................................T...............  420
Okapi        361    ..............F.............................T...............  420

Cow          421    RSEELSEDDMLDQYSTSFTKKIKKNSCEGNKSLNSSELFTPDLVDGTTVKKSLSTPPTTR  480
Giraffe      421    .......................................M....................  480
Okapi        421    .......................................M...........N........  480

Cow          481    NKFAAFLQRKNEESGAVVVPGTRIRFFSNSLDSADCISKKASSQPLAETAVTDKETDAGE  540
Giraffe      481    ....T........RD...I..............T........N.................  540
Okapi        481    ....T........R...................T........N.................  540

Cow          541    PDCLEDKKLVDTSVSHNSSEQIPDDVTVMAEESQSFKTSTFTRTISPPTLGTLRSCFSWS  600
Giraffe      541    ..................G...................R.......S.............  600
Okapi        541    .......T......L...G.........................................  600

Cow          601    GSLGDISRTPSPSPSTALQQFRRKSDSSTSLPENTEKSDIAPLKSDESSDESHPLHDVGC  660
Giraffe      601    .....L..A.........................I.L.NV....R..............W  660
Okapi        601    .....L..A...........................L..V...................W  660

Cow          661    SSQSQESMDLSPHNLNASKLSQPSSKDSDSDESDCNFKSLDKQGNQKSKLHLFHFSKKDT  720
Giraffe      661    ..E...........................E............S.........N......  720
Okapi        661    .......I......................E............S................  720

Cow          721    PLRNKIPGLYKSSSVDSLSTTKIKPLVPARASGLSKKPPSVHKRNHHNAENKPGLQIKIN  780
Giraffe      721    L...........I...N............K........S.I..........Q........  780
Okapi        721    L.....................................S.I..........Q........  780

Cow          781    ELWKNFVFKKDSEKLPSCKKPDPLSPVKDNIQLTPEEEDIFNNSECMLVQRALFQ       835
Giraffe      781    ...............S...............................H.......       835
Okapi        781    ...............................................H.......       835
```

Newick Tree of Mammalian EXO1

```
(manatee:0.0445111, ((bushbaby:0.0799495, (rhesus:0.0269871, (organutan:0.0243306,
(baboon:0.00390335, human:0.00679214):0.00337844):0.0053381):0.0630245):0.0081005,
((((tiger:0.00598482, cat:0.00710319):0.0720242, (dog:0.0512731,
walrus:0.0616718):0.0117469):0.02554, (rhino:0.0587794, horse:0.0801692):0.0144952):0.00572285,
(pig:0.0691076, ((spermwhale:0.0124042, (minkewhale:0.0105979, (dolphinfw:0.00847203,
orca:0.0145474):0.00829768):0.0021954):0.0231251, ((giraffe:0.0170079,
okapi:0.00843537):0.0152493, ((waterbuffalo:0.012766, (cow:0.00382309,
yak:0.00582731):0.00425838):0.0101573, (tibetantlp:0.00874572, (goat:0.000995443,
sheep:0.00501062):0.00333675):0.00833323):0.00294327):0.0335305):0.0202126):0.017265):0.0050006):
0.0445111);
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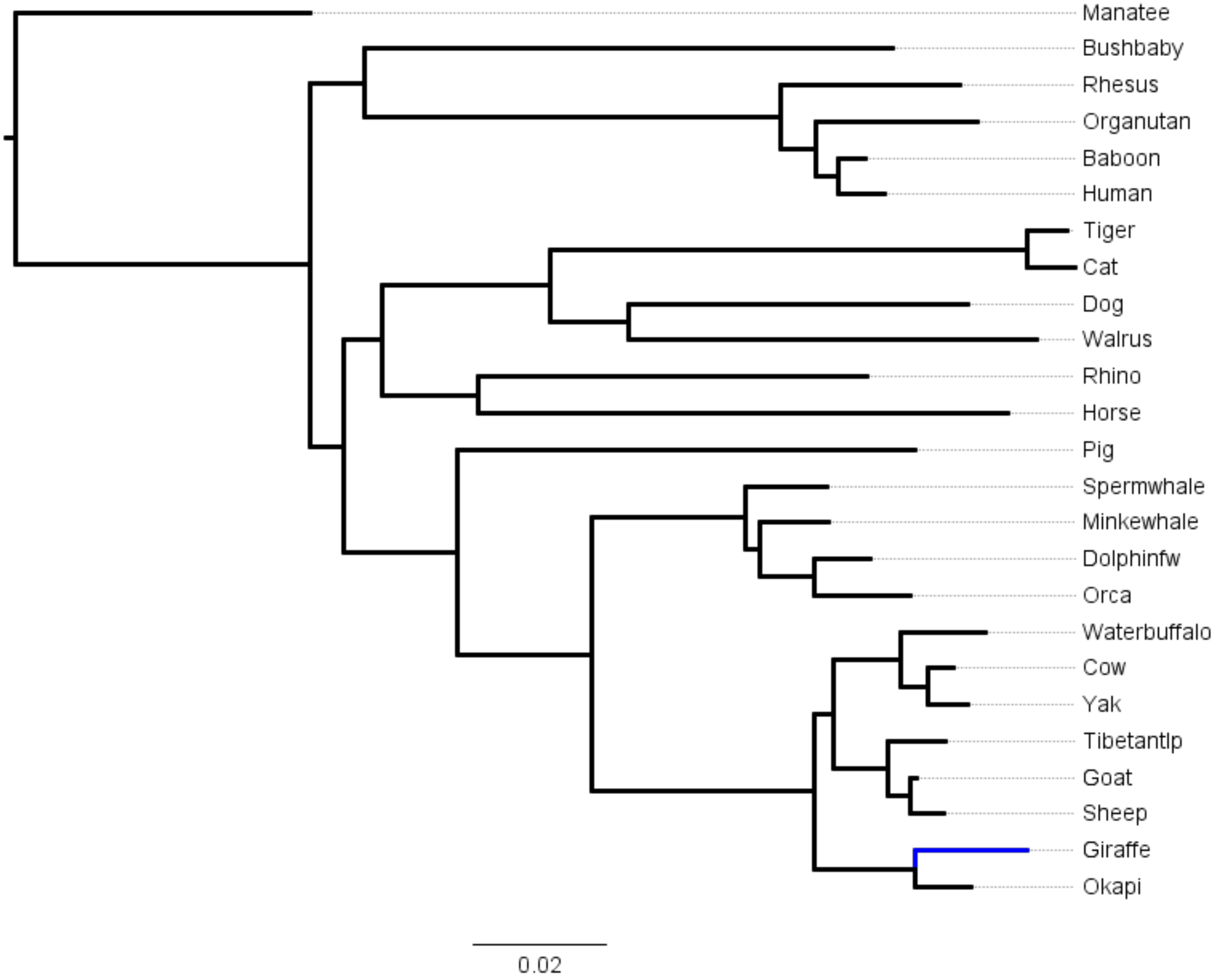

Locus Name: Exonuclease 1 (EXO1)

Locus Name: Nibrin (NBN)

ENSBTAT00000017598   NBN-201 component of MRN complex dsDNA break repair, chromosome integrity
mouse: impaired extraembryonic tissue growth and early embryonic death to growth retardation, lymphoid defects, lymphoma susceptibility, and failure of oogenesis. Null heterozygotes are cancer prone

PP2: (Giraffe) S278V, L490S

Giraffe: P6S UIS, P10L UPS, S277V UPS, H299R UPS, P339R UPS, L351V UIS, D372H UPS, H437P UPS, S463A UPS, Q474E UIS, T487V UPS, C489F UPS, N505T UPS, V516A UPS, N519K UPS, Y524H UPS, A525P UPS, P531A UPS, E572A UPS, I608T UPS, V735I UIS

Protein sequence Alignment of Cow, Giraffe and Okapi NBN

```
Cow          1      MWKLVPAAGPAREPYRLLTGVEYIVGRKNCGILIEDDQSISRNHATLTANFSVTNLSQTD  60
Giraffe      1      .....S...L..................................................  60
Okapi        1      ..................................Q.........................  60

Cow          61     EIPVLTIKDNSKYGTFVNEEKMQNGLSQILKSGDRVTFGVFESKFRVEYEPLVACSSCLD  120
Giraffe      61     ............................................................  120
Okapi        61     ......V.....................................................  120

Cow          121    VSGKTALSHAILQLGGLTVNNWTEECTHLVMVSVKVTIKTICALICGRPIVKPEYFTEFL  180
Giraffe      121    ............................................................  180
Okapi        121    ........................R...................................  180

Cow          181    KAVQSKKQLPEIESFYPPVDEPAIESKNIDLSGRQERKQIFKGKTFVFLNAKQHKKLSAA  240
Giraffe      181    ........P...............GN..................................  240
Okapi        181    ........P...................................................  240

Cow          241    VIFGGGDARLITEENKEDDSFFSAPGTCVVDAGLTDSQTFIPDSQKKWIHSIMDILQRRG  300
Giraffe      241    .................E..................V..L..................H.  300
Okapi        241    ...............................T.......LV.................Q.  300

Cow          301    LRPIPEAEIGLAVLFVTTENYCDPQGQPSTGLKTTTPGPSLSQALPANENLMPNASVNTT  360
Giraffe      301    .............I........................R...........V.........  360
Okapi        301    .............I..................................K....D....A.  360

Cow          361    TYVADTESEQADTCMDLSERPKEIKIFGMEPKCRILSQETSTVKKPHKISSNNNIVSNTL  420
Giraffe      361    A..........H................................................  420
Okapi        361    A...............V...................................S.......  420

Cow          421    VRMKIPNYQLSPTKVPHVNKSRGWPSQHQQTNSIRDYFQPLTSPQKRERDEENQEMSLSK  480
Giraffe      421    ..............F.P.................K.......ATK........E...S..  480
Okapi        421    ..............F...................K......N..K...............  480

Cow          481    SARMETSCSLLEQTQPTTSLIRKNKDEHLSQNVLVEENPDNSYADTNVKPTVKNYANKSL  540
Giraffe      481    .....V.F..S......A.S...T....P.....A.KT....HP..DL.A..........  540
Okapi        481    .....I.............S...I...........GK..........L............  540

Cow          541    FTENLKSKKRKEIDDLAIEDEVLEQLFKDTELELESEVKVQKQEEDINVRKRLRLDKETN  600
Giraffe      541    ...K...N........................A...................P...M...  600
Okapi        541    ...K...E...........E..........................T.....P...I...  600

Cow          601    VTFNDETIPESNKISQENEIKKKCELKKESLWSTKELSNNCELQDGDEMLPKKVLLTEFR  660
Giraffe      601    ..C....T............G...................G..........R........  660
Okapi        601    A...................E...................G.P.................  660

Cow          661    SLVVCNSTSRNASNVNNDYGELKNFKKFKKVTFPGAGKLPHIIGGSDLIAHHARKNTELE  720
Giraffe      661    ....R........S..............................................  720
Okapi        661    .............S..............................................  720

Cow          721    EWLRQEMEVQNQHAKEDSLADDLFRYNPNVKRRR    754
Giraffe      721    ........I.........................    754
Okapi        721    ..................................    754
```

Newick Tree of Mammalian NBN

```
(African_Bush_Elephant:0.0703092, (((((((Gorilla:0.00656225, Humans:0.00142722):0.000893651,
(Bonobo:4.3724e-05, Chimpanzee:0.00794575):0.00717268):0.00826899,
(Northern_White_cheeked_Gibbon:0.00747707, Siamang:0.00453136):0.00596178):0.00471753,
(Wolf_s_Mona_Monkey:0.00776341, Olive_Baboon:0.00693344):0.0197714):0.018193,
Bolivian_Red_Howler:0.0544405):0.0568263, Phillipine_tarsier:0.0885859):0.0246784,
(European_Rabbit:0.116838, (((White_Rhinoceros:0.0799503, Horse:0.0831269):0.00665034,
((Giant_Panda:0.0434426, Dog:0.088366):0.00765649,
Siberian_Tiger:0.0672528):0.0333086):0.00192851, (Bactrian_Camel:0.104846,
(((Bottlenose_Dolphin:0.0231422, Sperm_Whale:0.0277381):0.00210022,
Minke_Whale:0.0160832):0.0276671, (giraffe:0.0393298, ((Tibetan_Antelope:0.0110148,
(Sheep:0.00560167, Goat:0.0037381):0.00645804):0.0117507, (Water_Buffalo:0.00736511,
(Cow:0.00137023,
Wild_Yak:0.00128582):0.0100501):0.0129403):0.00678369):0.0613014):0.015145):0.0124811):0.00567769
):0.0019239):0.0703092);
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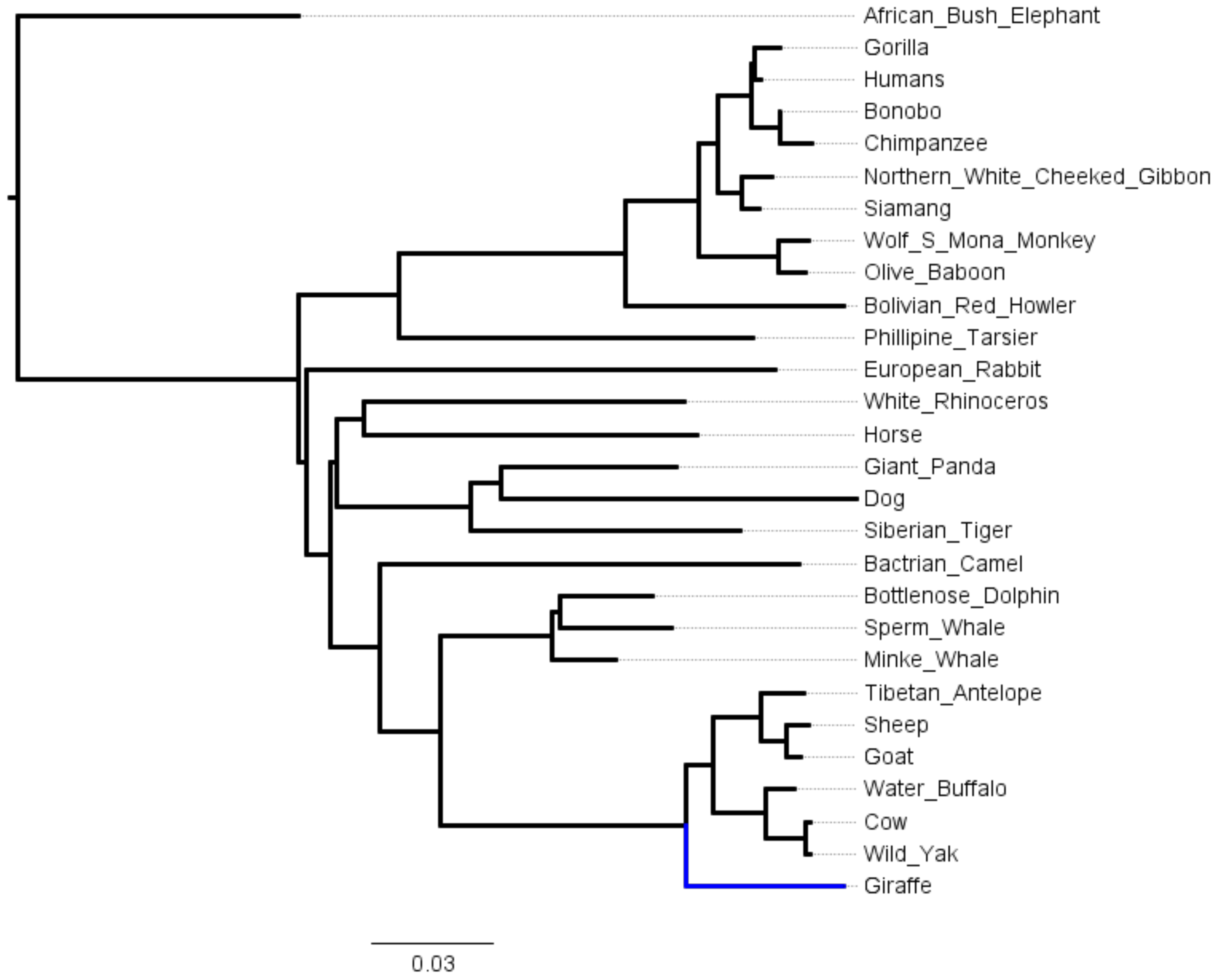

Locus Name: Nibrin (NBN)

Locus Name: Meiotic Recombination 11 Homolog A (MRE11A)

ENSBTAT00000011748 MRE11A-201 component of MRN complex dsDNA break repair, chromosome integrity
mouse: chromosome instability human: Ataxia-telangiectasia-like disorder 1 (ATLD1) [MIMOUSE:604391]: A rare disorder characterized by progressive cerebellar ataxia, dysarthria, abnormal eye movements, and absence of telangiectasia. Hypersensitivity to ionizing radiation.

PP2: All benign
PSG: D647S
Giraffe: N34H UIS, A539D UIS, A564T UPS, A566G UPS, S590L UPS, D647S UIS
Giraffe/Okapi: F660L UPS, M699V UPS

Protein sequence Alignment of Cow, Giraffe and Okapi MRE11A

```
Cow         1     MSPADALDDENTFKILVATDIHLGFMEKDAVRGNDTFVTLDEILRLAQENDVDFILLGGD  60
Giraffe     1     .................................H.....F....................  60
Okapi       1     .......................................F....................  60

Cow         61    LFHENKPSRKTLHTCLELLRKYCMGDRPVQFEILSDQSVNFGFSKFPWVNYQDGNLNISV  120
Giraffe     61    ...........................................................I  120
Okapi       61    ...........................................................I  120

Cow         121   PVFSIHGNHDDPTGADALCALDILSCAGFVNHFGRSMSVEKIDISPVLLQKGSTKIALYG  180
Giraffe     121   ......................V.....................................  180
Okapi       121   ......................V.....................................  180

Cow         181   LGSIPDERLYRMFVNKKVTMLRPKEDENSWFNLFVIHQNRSKHGSTNFIPEQFLDDFIDL  240
giraffe     181   ............................................................  240
okapi       181   ............................................................  240

Cow         241   VIWGHEHECKIAPTKNEQQLFYVSQPGSSVVTSLSPGEAVKKHIGLLRIKGRKMNMQKIP  300
Giraffe     241   ............................................................  300
Okapi       241   ............................................................  300

Cow         301   LRTVRQFFMEDVVLADHPDIFNPDNPKVTQVIQNFCLEKVEEMLENAERERLGNSQQPEK  360
Giraffe     301   .........D.............................................R....  360
Okapi       301   .........D.....G.......................................R....  360

Cow         361   PLIRLRVDYSGGFEPFSVLRFSQKFVDRVANPKDVIHFFRHREQKENTGEEINFGKFISK  420
Giraffe     361   ............................................................  420
Okapi       361   ............................................................  420

Cow         421   PSEGTTLRVEDLVKQYFQTAEKNVQLSLLTERGMGEAVQEFVDKEEKDAIEELVKYQLEK  480
Giraffe     421   ............................................................  480
Okapi       421   ............................................................  480

Cow         481   TQRFLKERHIDALEDKIDEEVRRFRESRQKNTNEEDDEVREAMSRARALRSQSEDAASAL  540
Giraffe     481   ..........................................................D.  540
Okapi       481   ............................................................  540

Cow         541   TAEDLMSIDLAEQMADDSDDSIKAAANKGRGRGRGQRGGRGQNSMSRRGSQRGRAGTSLE  600
Giraffe     541   ......................IT.G..................V....L..........  600
Okapi       541   ......................IM....................V...............  600

Cow         601   ISTQGRGSKATTSTSRNMSIIDAFKSTRQQPSRNVATKNYTEVIEVDESDTEEDVFLTTF  660
Giraffe     601   ..............................................S.......I....L  660
Okapi       601   ......................................................I....L  660

Cow         661   KTDQRGSSTSSSSKPMSQSQITKGVDFESDEEDDDDPFMNLSCLRRNRR    709
Giraffe     661   .....................AR...............V..........    709
Okapi       661   .....................AR...........E...V....V.....    709
```

Newick Tree of Mammalian MRE11A

(rat:0.038408, ((Dog:0.0155616, panda:0.024859):0.0125348, (((Horse:0.0403516, rhino:0.0438057):0.00950569, ((Human:0.00498374, (baboon:0.0011894, rhesus_monkey:0.00307501):0.00212889):0.0252834, bushbaby:0.0362617):0.00368096):0.001105, (((Freshwater_Dolphin:0.00537519, Killer_Whale:0.0103065):0.00456771,

```
Sperm_Whale:0.0170226):0.0262469, (camel:0.0401972, ((Cow:0.0017424, Yak:0):0.00531566,
(Water_Buffalo:0.00877464, ((Gerenuk:0.00202422, (Goat:0.00302343,
Tibetan_Antelope:0.00407389):0.00223722):0.00230315, (Giraffe:0.00787458,
Okapi:0.00490096):0.00594156):0.00393068):0.000720289):0.0270679):0.00240898):0.00592855):0.00170
572):0.038408);
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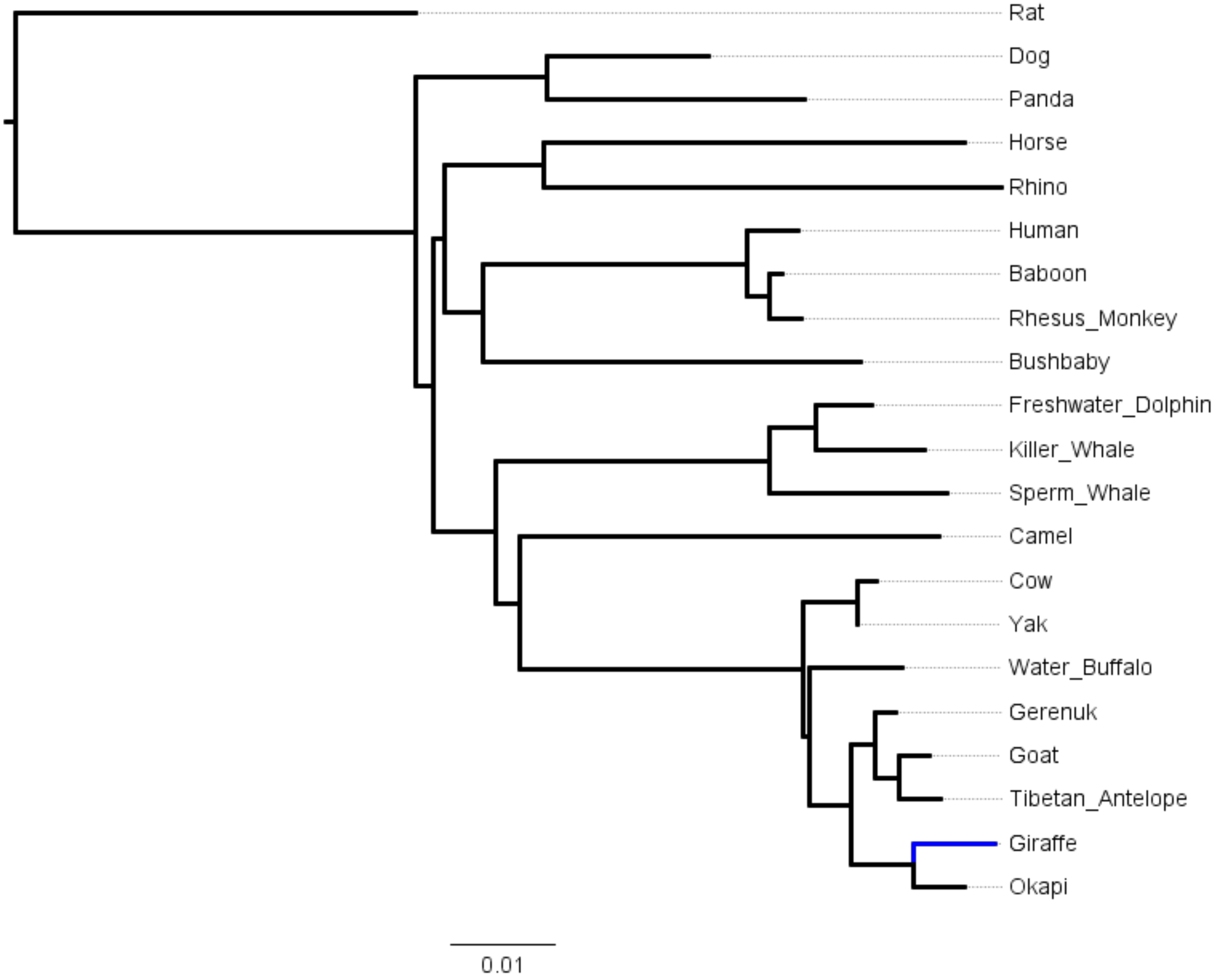


Locus Name: Meiotic Recombination 11 Homolog A (MRE11A)

Locus Name: Nucleic Acid Binding Protein 1, SOSB2, (NABP1)

ENSBTAT00000024821 NABP1-201 component of SOSS complex dsDNA break repair, chromosome integrity
no mutation in m/h described

PP2: (Giraffe) G157C; (Okapi) G157V

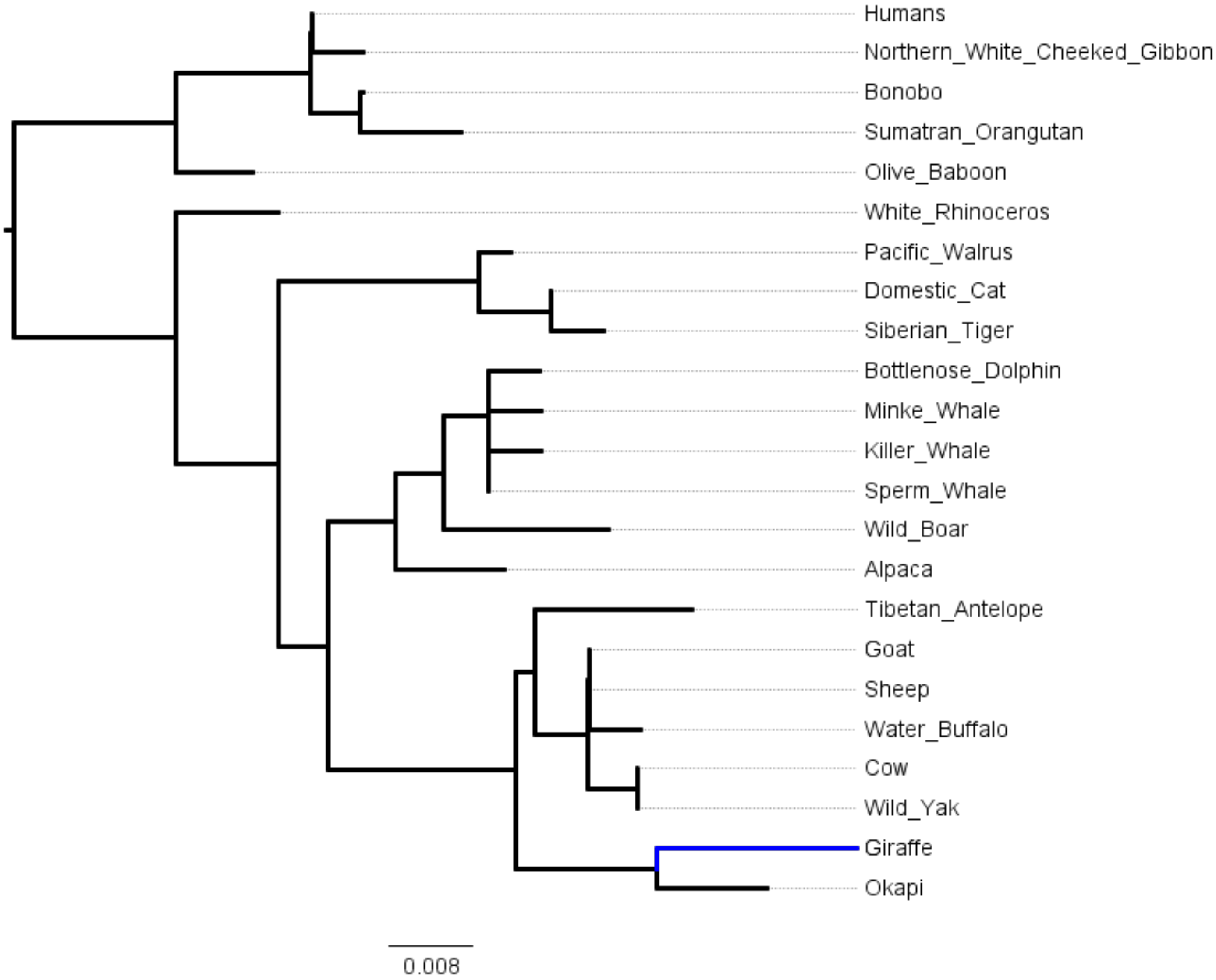
Giraffe: P8F UPS, K15R UIS, S139R UPS, G157C UPS, A185P UIS
Giraffe/Okapi: T192S UIS

Protein sequence Alignment of Cow, Giraffe and Okapi NABP1

```
Cow          1      MNGVRDPPLFIKDIKPGLKNLNVVFIVLEIGRVTKTKDGHEVRSCKVADKTGSITISVWD  60
Giraffe      1      .......F......R.............................................  60
Okapi        1      .....N.L....................................................  60

Cow          61     EIGGLIQPGDIIRLTRGYASMWKGCLTLYTGRGGELQKIGEFCMVYSELPNFSEPNPDYR  120
Giraffe      61     ............................................................  120
Okapi        61     ............................................................  120

Cow          121    GQQNKGAHNEQKNNSMNNSNNVGTGTFGPMGNGVQTGAEARGCQFSYAGRSNGRGPINPQ  180
Giraffe      121    ..................R...........V.....CP.................L....  180
Okapi        121    ..............................V.....VP.................L....  180

Cow          181    LPGTANNQTVMTTISNGRDPRRAFKR    206
Giraffe      181    ....P......S..............    206
Okapi        181    ...........S..............    206
```

Newick Tree of Mammalian NABP1

((((Humans:1.35158e-05, Northern_White_cheeked_Gibbon:0.00490052):0.000173763, (Bonobo:0.000230472, Sumatran_Orangutan:0.00962198):0.0047895):0.0126725, Olive_Baboon:0.00724493):0.0153951, (White_Rhinoceros:0.00969271, ((Pacific_Walrus:0.0029945, (Domestic_Cat:0, Siberian_Tiger:0.00492291):0.00688252):0.0190245, ((((Bottlenose_Dolphin:0.00487486, ((Minke_Whale:0.00492623, Killer_Whale:0.00492623):2.9495e-05, Sperm_Whale:0):5.13674e-05):0.00420664, Wild_Boar:0.015666):0.0046031, Alpaca:0.0103256):0.00635077, ((giraffe:0.018899, okapi:0.0105192):0.0133158, (Tibetan_Antelope:0.0147935, ((Goat:0, (Sheep:4.49295e-05, Water_Buffalo:0.00486911):4.64641e-05):0.000157009, (cow:0, Wild_Yak:1.22161e-05):0.00472713):0.00489268):0.00182553):0.0178111):0.00476268):0.0096721):0.0153951);



Locus Name: Nucleic Acid Binding Protein 1, SOSB2, (NABP1)

Locus Name: Nudix (Nucleoside Diphosphate Linked Moiety X)-Type Motif 15 (NUDT15)

ENSBTAT00000025978 NUDT15-201   8-oxo-dGTP diphosphatase   DNA repair
human: SNP associated with thiopurine-induced early leukopenia

PP2: (Giraffe) G41C,

Giraffe: F38S UPS, G41C UIS, S42G UPS

Protein sequence Alignment of Cow, Giraffe and Okapi NUDT15

```
Cow          1      MTASVEPRGRRPGVGVGVVVTSGRHPRCVLLGKRKGSFGAGSFQLPGGHLEFGETWEECA  60
giraffe      1      .....................................S..CG...S..............  60
okapi        1      ................................R...........................  60

Cow          61     QRETWEEAALHLKNVRFASVVNSFIEKENYHYVTILMKGEVDLTHDSEPKNVEPEKNESW  120
Giraffe      61     ........................V...................................  120
okapi        61     ........................V...................................  120

Cow          121    EWVPWEEFPPLDQLFWGLRCLKEQGYDPFKEDLDHLVGYKGSHLEVNKEIH           171
Giraffe      121    ................A................................T.           171
okapi        121    ................A..................................           171
```

Newick Tree of Mammalian NUDT15

```
(polar_bear:0.054059, (polecat:0.0716555, (((walrus:0.0192266, weddel_seal:0.0164991):0.0390647,
(tiger:0.0104963, cat:0.0655627):0.020215):0.00836249, (dog:0.0476442,
((((flying_fox_bat:0.0308995, rhino:0.0191318):0.00240289, ((((minke_whale:0.0198181,
dolphin:0.0219912):0.00377589, baiji_dolphin:0.029413):0.00875072, camel:0.0323124):0.0104892,
(horse:0.0271261, bushbaby:0.0555545):0.0096214):0.00228131):0.00462611, ((pig:0.0534803,
manatee:0.0699637):0.0149886, ((orangutan:0.0281216, human:0.00915845):0.0089688,
baboon:0.0225089):0.0140251):0.00950781):0.00607612, (giraffe:0.0315998,
(((tibetan_antelope:0.0121413, sheep:0.0115307):0.00753406, okapi:0.00430192):0.00439255,
(cow:0.000458753,
water_buffalo:0.0113064):0.00758047):0.00142054):0.0176639):0.0304707):0.00753779):0.0103838):0.0
54059);
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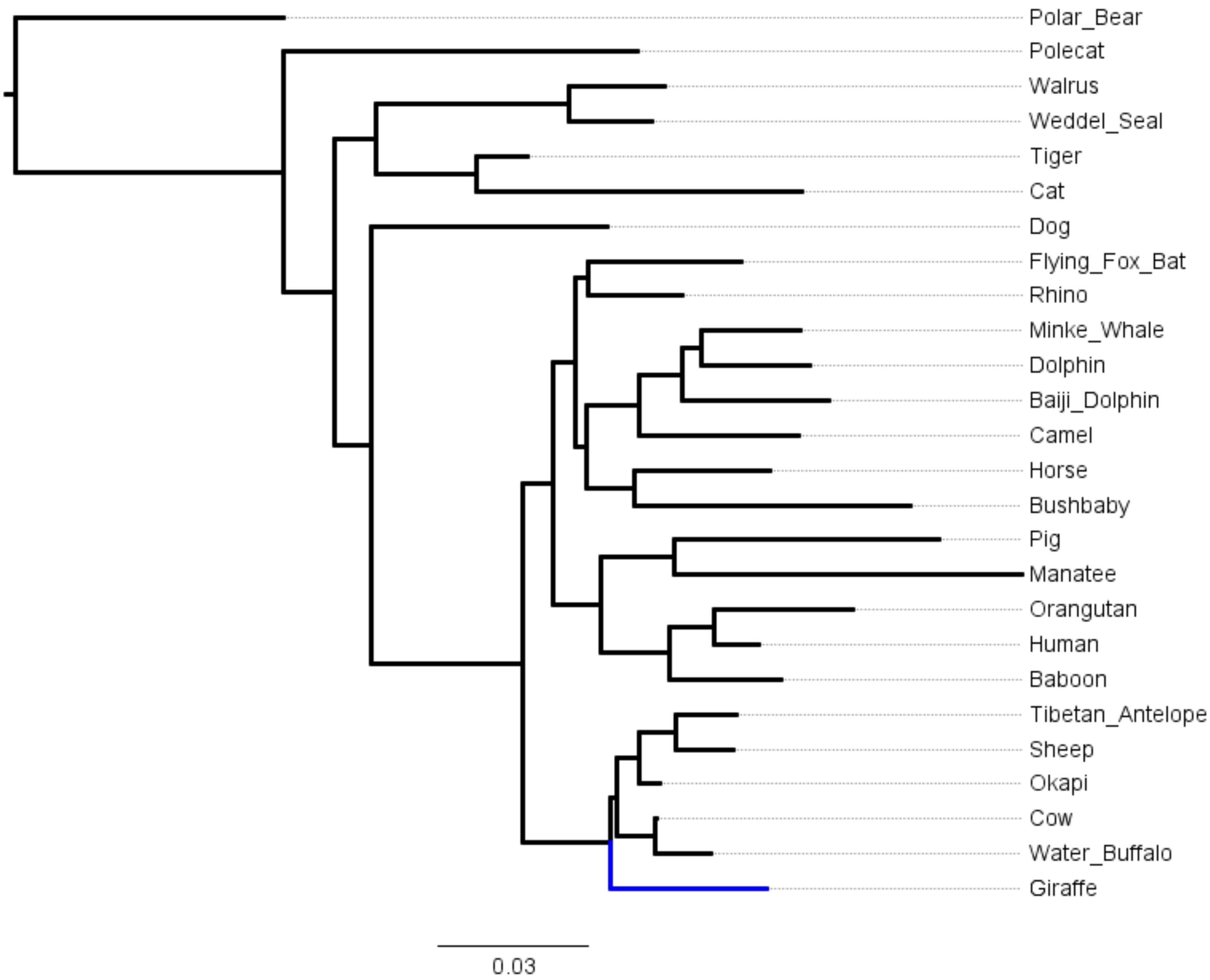


Locus Name: Nudix (Nucleoside Diphosphate Linked Moiety X)-Type Motif 15 (NUDT15)

Locus Name: SAC3 domain containing 1 (SAC3D1)

ENSBTAT00000002904 SAC3D1-201   SAC3 domain containing protein   centrosome duplication and mitotic progression
mouse: null allele had increased numbers of myeloid and erythroid progenitor cells. Mice homozygote for a null allele had these features plus mild spleen and thymus hyperplasia, an increased T cell proliferative response, and enhanced IgM secretion by B cells to IL-5.

PP2: (Giraffe) P36S, D46H

Giraffe: P36S UPS, D46H UIS, E85D UIS, GQ 269-270 deletion UIS
Giraffe/Okapi: T90N UPS, A228S UPS, G302E UIS

Protein sequence Alignment of Cow, Giraffe and Okapi SAC3D1

```
Cow         1      MPGYELPVGTCLDMCPAAERAQREKERRLHRFEVVPGCRRDRPRADPQRAVKEYSRPAAG  60
Giraffe     1      ..................................AS..PG.....H..............  60
Okapi       1      ..................................A....G....................  60

Cow         61     KNRPPPSQLRPPSVLLATVRYLASEVAERTDASCAEVASFVADRLRAVRLDLALQTASDV  120
Giraffe     61     .I......................D....N.........................S....  120
Okapi       61     .I...........................N.........................S....  120

Cow         121    ETALVLESALAVLLAVVARLGPNATHGPVDPMLLQAQVQESFGSLRRCYALGAGPHPRQA  180
Giraffe     121    .......A....................................................  180
Okapi       121    .A.....A....................................................  180

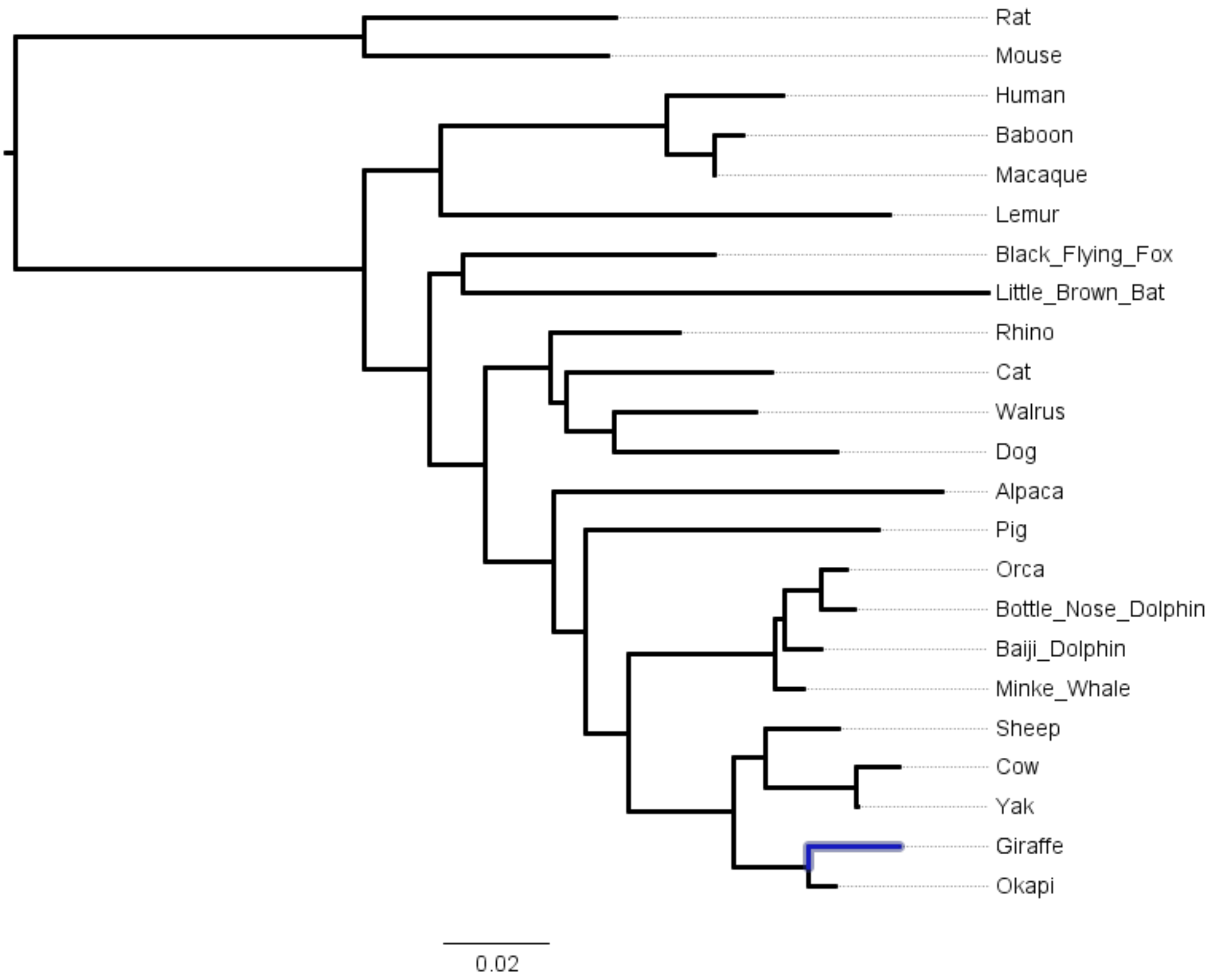
Cow         181    TFQGLFLLYNLGSVEALHEILRLPAALRSCPALRTALAVDSAFREGNAARLFRLLRTLPY  240
Giraffe     181    ...................V.Q............A............S........M...  240
Okapi       181    ...................V.Q............A.....F......S............  240

Cow         241    LQSCAVQCHVGRARRGALARLARALSTPGQTLPLGFMVHLLALDGPNEARDLCQAHGLPL  300
Giraffe     241    ............................--................K.............  298
Okapi       241    ..............................................K.............  300

Cow         301    DGQERVVFLRGRYTEEGLPPAGTCQILVGNKLGGRTLEDVAMAEEEDEAVDRPTTEV    358
Giraffe     299    .E.......................V..............V.............P.A    356
Okapi       301    .E.........C.............V..............V....-........P.A    355
```

Newick Tree of Mammalian SAC3D1

((rat:0.0481168, mouse:0.0464892):0.0668792, (((human:0.0222544, (baboon:0.00562448, macaque:0):0.00904964):0.0431507, lemur:0.0859029):0.0146379, ((black_flying_fox:0.0479258, little_brown_bat:0.100247):0.00646711, ((rhino:0.0247291, (cat:0.039166, (walrus:0.0270068, dog:0.0424409):0.00919329):0.00319157):0.0123405, (alpaca:0.074389, (pig:0.0561884, ((((orca:0.0048984, bottle_nose_dolphin:0.00633791):0.00712948, baiji_dolphin:0.00700041):0.00168236, minke_whale:0.00535034):0.0279719, ((giraffe:0.0173528, okapi:0.00531299):0.0142441, (sheep:0.0140873, (cow:0.00822133, yak:0.000217642):0.0173079):0.00614948):0.0199847):0.00830785):0.00618363):0.0129237):0.0107031):0.0124859):0.0668792);



Locus Name: SAC3 domain containing 1 (SAC3D1)

Locus Name: HAUS augmin-like complex, subunit 2 (HAUS2, CEP27)

ENSBTAT00000045340 CEP27-201   centrosomal protein 27   centrosome assembly, cytokinesis
no mutation in m/h described

PP2: (Giraffe) E59K; (Giraffe/Okapi) R110K, N186D

Giraffe: E59K UIS, S83T UPS, A234I UPS
Giraffe/Okapi: R110K UIS, N186D UIS, K213T UIS
Okapi: V140I UIS, E182K UIS, L213V UPS

Protein sequence Alignment of Cow, Giraffe and Okapi HAUS2

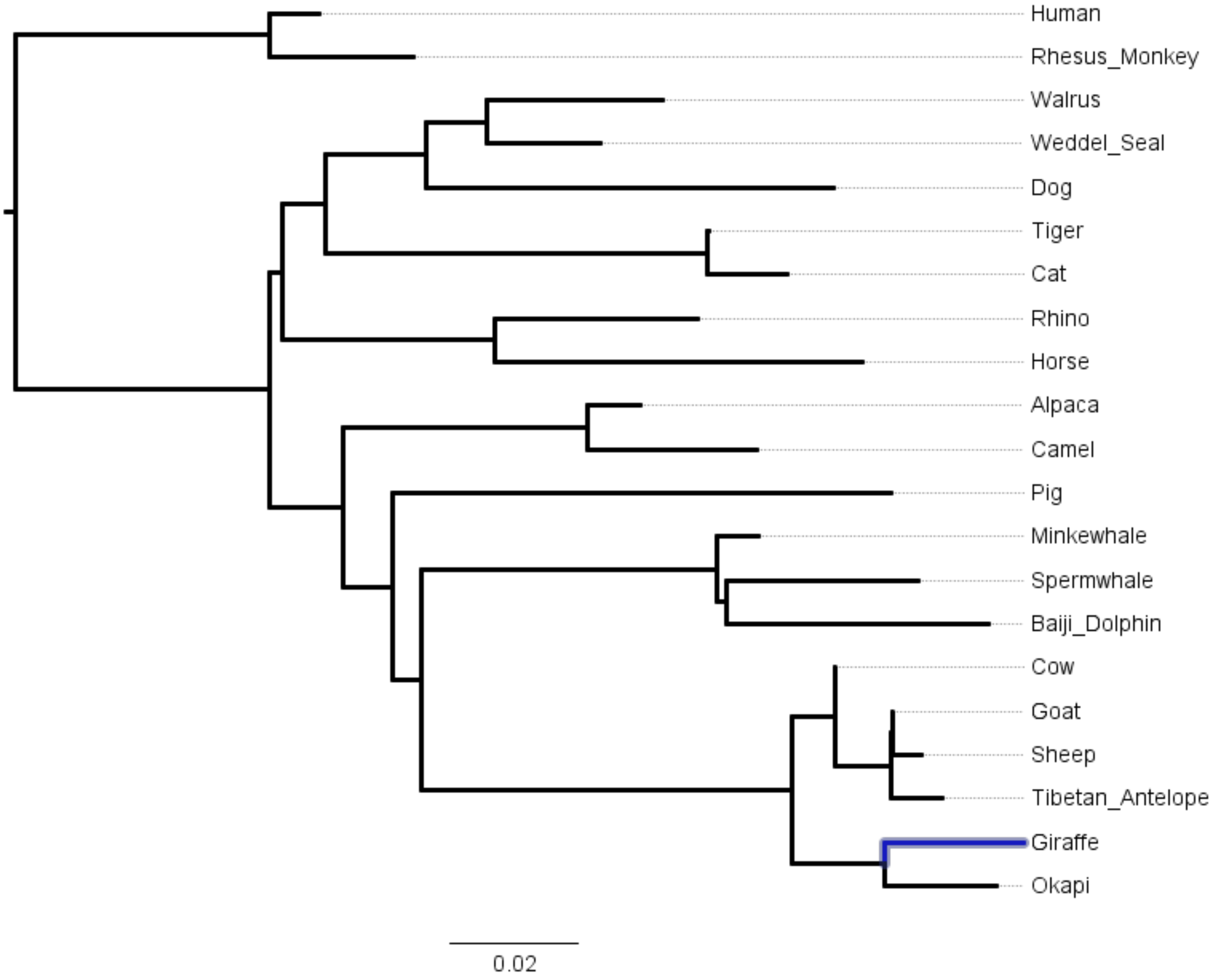
```
Cow          1      MAAANPWDPATAPNAAGLLLGHFITSELVTEEMLNISKKSTSCFVNFSRLQQITDIQAEI  60
Giraffe      1      ..T.S...................Q.................................K.  60
Okapi        1      ........................Q...................................  60

Cow          61     YQKNLEIELLSLEKDAADVVHPSFLAQKCHSLQSMNNHLEAVLKEKRSLRQRLLKPMCQG  120
Giraffe      61     ......................T..........................K..........  120
Okapi        61     .................................................K..........  120

Cow          121    NLPIEAVYHRYMVHLLELAVTFIERLEDHLETIRNIPHLDADLKKMSTALAKMDILVTET  180
Giraffe      121    ............................................................  180
Okapi        121    ...................I........................................  180

Cow          181    EELAENILKWREQQKEVSSYIPKILAEKNSLHKHDVIVPPLPLTSKVNVQTINAK       235
Giraffe      181    .....D..........................T..A.................I.       235
Okapi        181    .K...D............F.............T..A......V............       235
```

Newick Tree of Mammalian HAUS2
((human:0.00781634, rhesus_monkey:0.0224282):0.0395964, (((((walrus:0.0273919,
weddel_seal:0.0177438):0.00942989, dog:0.0634805):0.0157581, (tiger:0.000307832,
cat:0.0125407):0.059509):0.00673875, (rhino:0.0316379, horse:0.0574269):0.033083):0.00201224,
((alpaca:0.0081809, camel:0.0264615):0.0381112, (pig:0.077705, ((minkewhale:0.00665894,
(spermwhale:0.0297894, baiji_dolphin:0.0407829):0.00156408):0.0460076, ((cow:0, ((goat:0,
sheep:0.00431966):0.000442935, tibetan_antelope:0.00812269):0.00862458):0.00663573,
(giraffe:0.0215924,
okapi:0.0174681):0.0142901):0.0578789):0.00438738):0.00787604):0.0114256):0.0395964);



Locus Name: HAUS augmin-like complex, subunit 2 (HAUS2, CEP27)

Locus Name: RCC1 Domain Containing 1 (**RCCD1)**

ENSBTAT00000024803 RCCD1-201 histone demethylase complex chromosome segregation
no mutation in m/h described

PP2: (Giraffe) P157R; (Giraffe/Okapi) R5C, A177T, A283S

Giraffe: E3K UPS, E122Q UPS, H123S UPS, P157R UIS, P200S UPS, A214V UIS
Giraffe/Okapi: R5C UPS, G124V UPS, A177T UPS, T257S UPS, S275P UPS, S298T UPS

Protein sequence Alignment of Cow, Giraffe and Okapi RCCD1

```
Cow          1      MDEERRGTWFGFGFCGFGQALGSGLGRQVHSPEPLRTPGGSLGVCRVSASWSYTAFVTRG  60
Giraffe      1      ..K.C.....................................D.................  60
Okapi        1      ....C.....................................D.................  60

Cow          61     GRVQLSGAAGGTADGCTDAWASEELLVLLRAGPGAGAELQAWAPGSAMRGDPLWSQAVQE  120
Giraffe      61     ...........A.G.................................L..E.........  120
Okapi        61     ...........A.G.......................K.........L..E.........  120

Cow          121    AEHGPSRDETQAGLLPLLPCARAYVSPRPPFYRPLAPTLRARRLELGAEHALLLDAAGQV  180
Giraffe      121    .QSV.......V.P......................R...................T...  180
Okapi        121    ..RV.........P..........................V...............T...  180

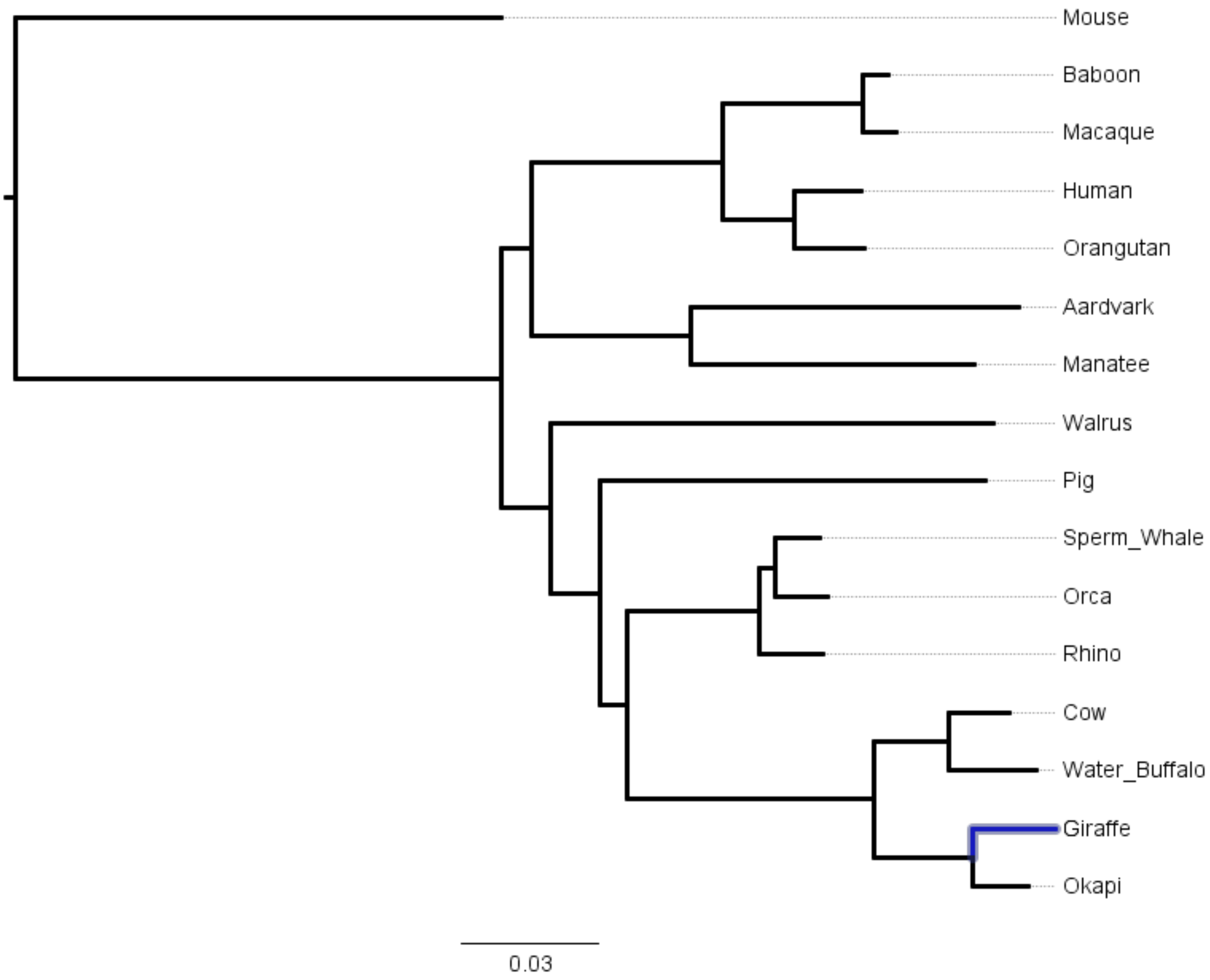
Cow          181    FSWGAGRHGQLGHGTLEAEPEPRLLEALQGLRMAEVAAGGWHSVCLSETGDIYIWGWNES  240
Giraffe      181    ...................S...........P.V..........................  240
Okapi        181    ...............................P............................  240

Cow          241    GQLALPTKSLAEDGKTTAGEASGLEEDGSEVKRGSAGEDGAPAPFIAVQPFPALLDLSPG  300
Giraffe      241    ................S.......D....Q...VPG......S..............T..  300
Okapi        241    ................S.......D....Q...VPG......S..............T..  300

Cow          301    SEAVKVSCGSRHTAVLTRTGELYTWGWGKYGQLGHKDTTTLDRPCRVEYFVDKQLQVRTV  360
Giraffe      301    ............................................................  360
Okapi        301    ...I........................................................  360

Cow          361    SCGPWNTYVYAVEKEKS                                            377
Giraffe      361    .................                                            377
Okapi        361    ...............--                                            375
```

Newick Tree of Mammalian RCCD1
(mouse:0.105706, ((((baboon:0.00581647, macaque:0.00757101):0.0303074, (human:0.0144056, orangutan:0.0152905):0.0155866):0.0415576, (aardvark:0.0712829, manatee:0.0615056):0.0347084):0.00671051, (walrus:0.0965316, (pig:0.0838172, (((sperm_whale:0.00979843, orca:0.0114241):0.0036096, rhino:0.0138793):0.0287441, ((giraffe:0.0176997, okapi:0.0119964):0.0215354, (cow:0.0132835, water_buffalo:0.01907):0.016207):0.0539794):0.0056637):0.0108573):0.0107874):0.105706);



Locus Name: RCC1 Domain Containing 1 (**RCCD1)**

Locus Name: HAUS Augmin-Like Complex, Subunit 6 (HAUS6)

ENSBTAT00000031479 HAUS6-201 mitotic spindle assembly centrosome integrity cytokinesis
human: GWAS study mapped pulmonary tuberculosis susceptibility to 8 loci including HAUS6

PP2: (Giraffe) A53T, C699R, L882G; (Giraffe/Okapi) G26Y, L127T, A194T, K342G, S854H; (Okapi) L127T, P500Q, L840Q, S899Y
PSG: L882G
Giraffe: A52T UIS, N240S UPS, D686G UIS, C700R UIS, L882G UPS
Giraffe/Okapi: C26Y UPS, I127T UPS, A194T UIS, F799S UIS, S854H UPS, R297S UPS

Protein sequence Alignment of Cow, Giraffe and Okapi HAUS6

```
Cow          1      MSSAWVTSFEKARLWMYLQALGFEPCLATIACGNTVSHTQFGVNMFDKLNRDAFHIVSYF  60
Giraffe      1      .........................Y.............H............T.......  60
Okapi        1      .........................Y.............H....................  60

Cow          61     LFQTLDKSLTKEVFKHCWPPFDQKRDVEFRKLFCEWLKKISAECGSSFPQVVGSLFLFPV  120
Giraffe      61     .........................E......C...........................  120
Okapi        61     ................................C...........................  120

Cow          121    GPKFIHIMYHFARFVAVKYIKTHSKNSSIRFTETFNVKPQDLHICLARCLVARNRFLQVL  180
Giraffe      121    ......T.....................................................  180
Okapi        121    ......T.....................................................  180

Cow          181    QREDCVTRKYQENAQLSVKQVRNLRSECMGLENQIKKMEPCDDQSNIQEKIQKVRSLWTN  240
Giraffe      181    .............T.................Q..M........................S  240
Okapi        181    .............T.................Q...........................S  240

Cow          241    VNETLMFLEKEREVVSSVLSLDNNYTLDGTDIAINIPSLLLDKIEKQMCQLHTGNIYEAG  300
Giraffe      241    ..............................N.....................I.......  300
Okapi        241    ..............................N.....................I.......  300

Cow          301    KLNILTVFWLLNEVLKVMKCECCQTDQARLTIDLHFLEKETRFQKERLSDLKHMRYKITE  360
Giraffe      301    ...................Y..................R..G..R...............  360
Okapi        301    ...................Y..................R..G..R...............  360

Cow          361    ALKTIRHSIVEKQEEWHKKWKEFLGLSPFSIIKGSTPAVDLLPPMSPLSFDPASEEAYAR  420
Giraffe      361    D........I.......................S..........................  420
Okapi        361    D........I.......................R..........................  420

Cow          421    SILLQYPASLPVTPKQHIQENNCRRASDTLETKSDPPNSPASFPLQPVPPLGGDIVTLLE  480
Giraffe      421    .............................V......A......L......S.........  480
Okapi        421    .............................V......A......L......S.........  480

Cow          481    KDTKLVTLREKNETVPKKTPEFNVENSSSSNIVKNTDSSACGGSLPAKKSNPFQKEQDHL  540
Giraffe      481    .E...I................K..D......A............A..............  540
Okapi        481    .N...I..........T..Q..K..D......A............S..............  540

Cow          541    VEEVARAVLSNSPQLSEEKEVKLEELIDSLISNPFLTRSQIPRTPENLISEIRSSWRKAV  600
Giraffe      541    .................G................................D.........  600
Okapi        541    .................G................................D.........  600

Cow          601    DTEDNRSTEPIQVDTERREELPESLPVVHNQKEFSMASFLSAATVSNSSHSHLPEEKVVS  660
Giraffe      601    EI..............H.............................D.............  660
Okapi        601    EI..............H.............................D..........L..  660

Cow          661    DCLECVPQKPVVTTCIGEPTTQNPSDLLNKDIICMQDLDCTTLQNKLLETSQIETFSPAV  720
Giraffe      661    .........................G.............R...........H........  720
Okapi        661    ....................................N.......................  720

Cow          721    GNRRNVLGSSEEDNIKISDQSKASYKDFSMYNSMLWNCFQVSSEISSSFKDGDFGILHET  780
Giraffe      721    .........................E....HK...........G................  780
Okapi        721    .........................E....HK...........G................  780

Cow          781    LPEVGHISLISPSSTEATFNLEPNSPMHSGIFTEDVVGEKQTTPESDFNLQATCSGYEAL  840
Giraffe      781    ..................SK...................R....................  840
Okapi        781    ..................SK.......R...........R...................Q  840
```

```
Cow          841   KKSPSKQREEIYLSNPEILERHKPELSLTPQKMQTDDMLNFLGIHDLHIDYTKPSSRMSL  900
Giraffe      841   ...L.........H.........L.S.....N.........G..............S...  900
Okapi        841   ...L.ER......H.........L...F...N.........................S.Y.  900

Cow          901   GERKRSLSPLIKFSPVEQRLKTTIPCSLGELLSNLTEEEILNKSLDAEVSPSDSTR      956
Giraffe      901   ..........................N.....P......L.S.....K.....L..      956
Okapi        901   ..........................N.....P..............K.....L..      956
```

Newick Tree of Mammalian HAUS6

```
((human:0.0194397, (macaque:0.00812563, baboon:0.00662755):0.019272):0.0570848,
(((rhino:0.0623698, horse:0.0890501):0.0140823, ((cat:0.00924832, tiger:0.0194657):0.0663829,
((walrus:0.0260784, panda:0.0356352):0.017548, dog:0.0656536):0.0180032):0.0426137):0.00404989,
((camel:0.00742002, alpaca:0.0119366):0.0560334, (pig:0.0853386, ((minke_whale:0.0149833,
(baiji_dolphin:0.0186215, orca:0.0206927):0.00512539):0.034174, (((tibetan_antelope:0.0165858,
(goat:0.00656066, sheep:0.0054682):0.00551236):0.0137305, ((yak:0.00210216,
cow:0.00209073):0.00634826, water_buffalo:0.0132339):0.0181573):0.00730959, (giraffe:0.0121769,
okapi:0.0121782):0.0157611):0.105023):0.0106529):0.00214122):0.0141138):0.0570848);
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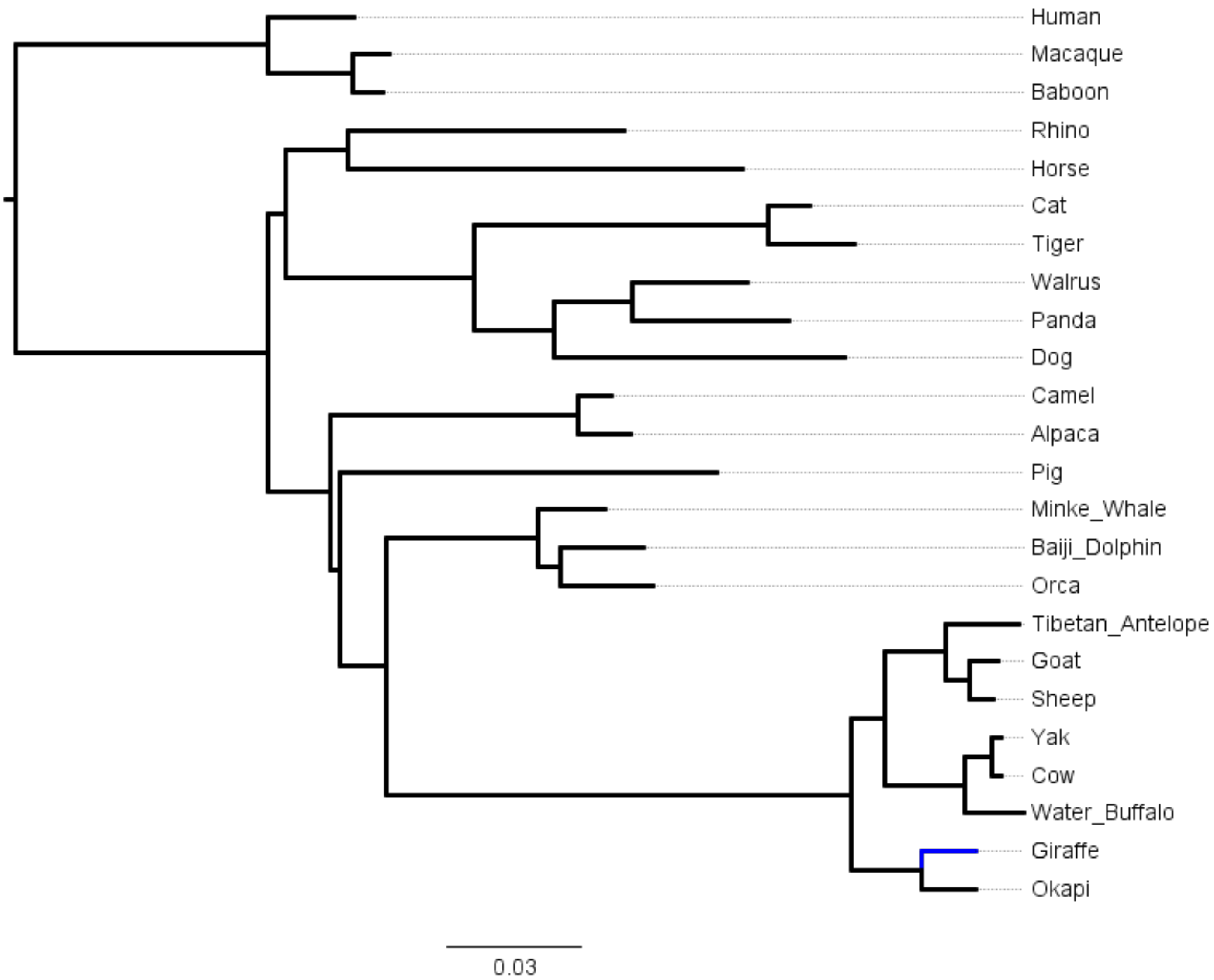


Locus Name: HAUS Augmin-Like Complex, Subunit 6 (HAUS6)

Locus Name: Rho GTPase Activating Protein 15 (**ARHGAP15A)**

ENSBTAT00000061453 ARHGAP15-201 Rho GTPase-activating protein   trypanosome resistance
mouse: reduced leukocyte numbers and abnormally shaped macrophage. Chemotactic responses of macrophage are normal while neutrophile chemoattraction and bacterial pagocytosis are increased.

PP2: (Giraffe) L14R, I177T

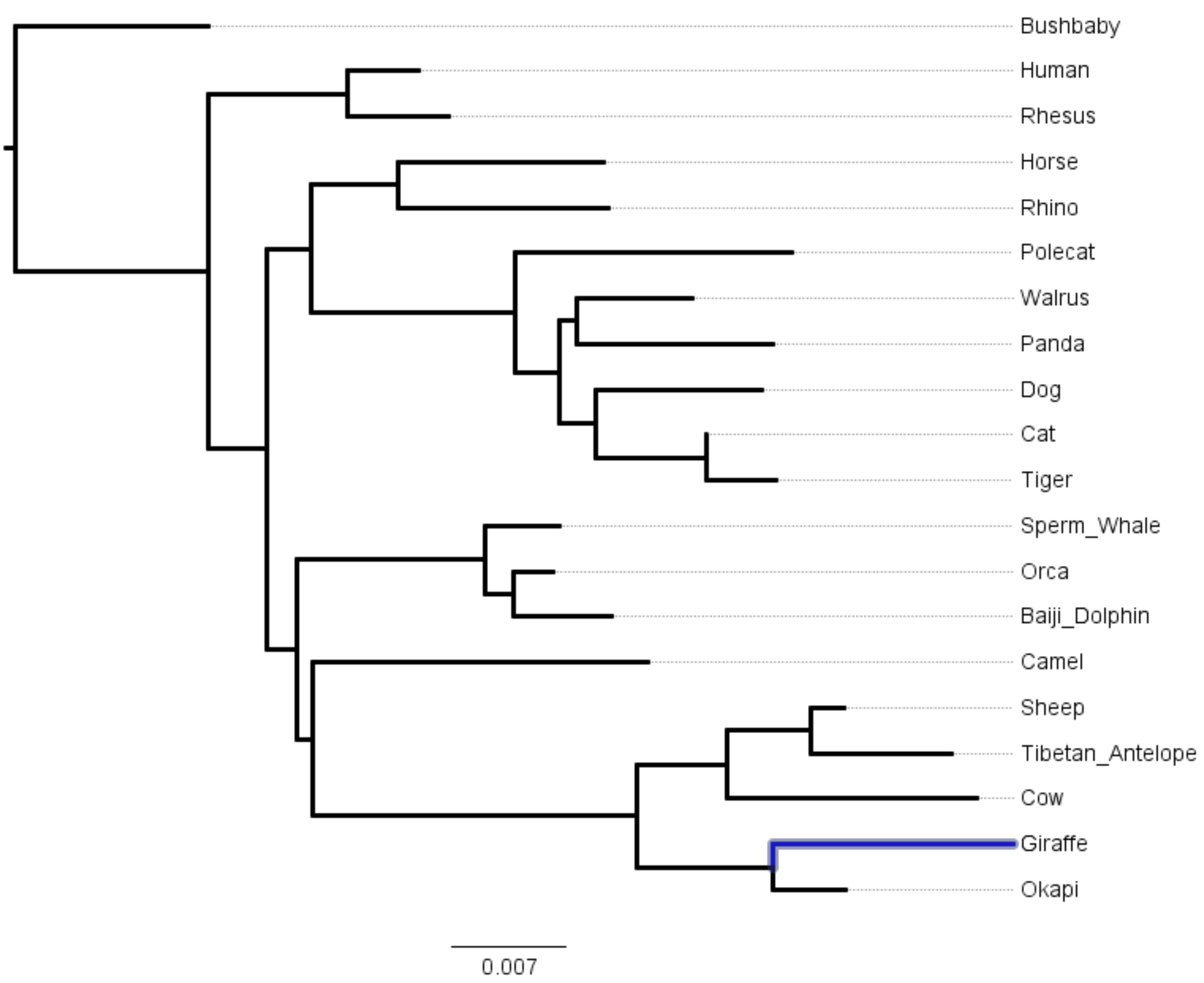
Giraffe: Q122P UIS, I177T UIS

Protein sequence Alignment of Cow, Giraffe and Okapi ARHGAP15A

```
Cow          1      MQKSTNSDIPVETLNPTRQGTGAVQMRIKNANSHHDRLSQSKSMILTEVGKVTEPISRHR  60
Giraffe      1      ........T....R.................................DA...........  60
Okapi        1      ........T......................................D.......V....  60

Cow          61     RNHSQHILKDVIPPLEQLMVEKEGYLQKAKIADGGKKLRKNWTTSWIVLSSRKIEFYKES  120
Giraffe      61     ......V...................................S.......N.........  120
Okapi        61     ......V...................................S.......N.........  120

Cow          121    KQQALSNMKTGNKPESVDLCGAHIEWAKEKSSRKNVFQITTLSGNEFLLQSDIDFIILDW  180
Giraffe      121    .P.......A..............................................T.E.  180
Okapi        121    .........A..................................................  180

Cow          181    FHAIKNAIDRLPKDPSSHSRNLELFKIQRSSSTELLSHYDSDTKEQKPEHRKSLMFRLHH  240
Giraffe      181    ..........................................V.................  240
Okapi        181    ..........................................I.................  240

Cow          241    SASDTSDKNRVKSRLKKFITRRPSLKTLQEKGLIKDQIFGSHLHTLCEREKSTVPRFVKQ  300
Giraffe      241    ..................................................N.........  300
Okapi        241    ..................................................N.........  300

Cow          301    CIEAVEKRGLDVDGIYRVSGNLATIQKLRFIVNQEEKLNLDDSQWEDIHVVTGALKMFFR  360
Giraffe      301    ............................................................  360
Okapi        301    ............................................................  360

Cow          361    DLPEPLFPYSFFEQFVEAIKKQDNNTRIEAIKSLVQKLPPPNRDTMKVLFGHLTKIVARA  420
Giraffe      361    ........................S...................................  420
Okapi        361    ........................S.................................K.  420

Cow          421    SKNLMSTHSLGIVFGPTLLRAEDESGNMAVHMVYQNQIAELMLSAYDQIFS           471
Giraffe      421    .Q.....Q................T...................E..K...           471
Okapi        421    .Q.....Q..............N.T...................E..K...           471
```

Newick Tree of Mammalian ARHGAP15A

(bushbaby:0.0118693, ((human:0.0043642, rhesus:0.0062181):0.00859842, (((((giraffe:0.0147509, okapi:0.00450219):0.00839461, ((sheep:0.00200696, tibetan_antelope:0.00868854):0.00515523, cow:0.0153501):0.00557623):0.0198966, camel:0.0205926):0.000958678, (sperm_whale:0.00458877, (orca:0.00240179, baiji_dolphin:0.00605502):0.00176742):0.0115323):0.00185767, ((horse:0.0126713, rhino:0.0129193):0.00529789, (polecat:0.0170393, ((walrus:0.00708325, panda:0.0120471):0.00103587, (dog:0.0102075, (cat:0, tiger:0.0042562):0.00681543):0.00219187):0.00279409):0.0124646):0.00276319):0.00361606):0.0118693);



Locus Name: Rho GTPase Activating Protein 15 (**ARHGAP15A)**

Locus Name: Lactoperoxidase (LPO)

ENSBTAT00000016986 LPO-201   lactoperoxidase   antibacterial in milk
GWAS study in cattle maps susceptibility to bronchial respiratory disease

PP2: (Giraffe) A155T, T179S, Y289C, A373V, G651W, H675Y; (Giraffe/Okapi) S302P, E355V

Giraffe: V14M UPS, S118F UIS, G651W UIS, H675Y UPS
Giraffe/Okapi: S302P UIS, E355V UIS, L367V UPS

Protein sequence Alignment of Cow, Giraffe and Okapi LPO

```
Cow          1      MWVCLQLPVFLASVTLFEVAASDTIAQAASTTTISDAVSKVKIQVNKAFLDSRTRLKTTL  60
Giraffe      1      .....H.......M..........N...T...............................  60
Okapi        1      .....H..................N...T...............................  60

Cow          61     SSEAPTTQQLSEYFKHAKGRTRTAIRNGQVWEESLKRLRRDTTLTNVTDPSLDLTALSWE  120
Giraffe      61     .......R.......Q.........................................F..  120
Okapi        61     .......R.......Q..................F....L....................  120

Cow          121    VGCGAPVPLVKCDENSPYRTITGDCNNRRSPALGAANRALARWLPAEYEDGLALPFGWTQ  180
Giraffe      121    ..................................T.................S.....S.  180
Okapi        121    ..............S.....................................S.......  180

Cow          181    RKTRNGFRVPLAREVSNKIVGYLDEEGVLDQNRSLLFMQWGQIVDHDLDFAPETELGSNE  240
Giraffe      181    .......................N..................V...............S.  240
Okapi        181    .......................N..................V...............S.  240

Cow          241    HSKTQCEEYCIQGDNCFPIMFPKNDPKLKTQGKCMPFFRAGFVCPTPPYQSLAREQINAV  300
Giraffe      241    ...A....H.......................................C...........  300
Okapi        241    ...A....H..........T........................................  300

Cow          301    TSFLDASLVYGSEPSLASRLRNLSSPLGLMAVNQEAWDHGLAYLPFNNKKPSPCEFINTT  360
Giraffe      301    .P............................................D.......V.....  360
Okapi        301    .P............................................D.......V.....  360

Cow          361    ARVPCFLAGDFRASEQILLATAHTLLLREHNRLARELKKLNPHWNGEKLYQEARKILGAF  420
Giraffe      361    .Q....V...S.V.......AS............K.........D...............  420
Okapi        361    .Q....V...S.V........S............K.........D...............  420

Cow          421    IQIITFRDYLPIVLGSEMQKWIPPYQGYNNSVDPRISNVFTFAFRFGHMEVPSTVSRLDE  480
Giraffe      421    ................................................L...........  480
Okapi        421    ................................................L...........  480

Cow          481    NYQPWGPEAELPLHTLFFNTWRIIKDGGIDPLVRGLLAKKSKLMNQDKMVTSELRNKLFQ  540
Giraffe      481    .........................E.................LY...............  540
Okapi        481    .........................E.................LY...............  540

Cow          541    PTHKIHGFDLAAINLQRCRDHGMPGYNSWRGFCGLSQPKTLKGLQTVLKNKILAKKLMDL  600
Giraffe      541    .............................................A...........L..  600
Okapi        541    .............................................A...........L..  600

Cow          601    YKTPDNIDIWIGGNAEPMVERGRVGPLLACLLGRQFQQIRDGDRFWWENPGVFTEKQRDS  660
Giraffe      601    ............A.................I...................W.........  660
Okapi        601    ............A............S....I......R......................  660

Cow          661    LQKVSFSRLICDNTHITKVPLHAFQANNYPHDFVDCSTVDKLDLSPWASREN         713
Giraffe      661    .........V....Y................G.....AI..............         713
Okapi        661    .........V...............V.....G.....AI..............         713
```

Newick Tree of Mammalian LPO

(aardvark:0.0501076, (((((crab_eating_macaque:0, baboon:0.00289749):0.00857466, human:0.00988003):0.00028666, orangutan:0.0096434):0.0465617, (lemur:0.0860017, naked_mole_rat:0.0947617):0.00580509):0.00668931, ((black_flying_fox:0.0723435, ((horse:0.0378994, rhino:0.0442298):0.0218112, ((panda:0.0339126, (walrus:0.0203033, Weddell_seal:0.0227582):0.0181913):0.00301572, dog:0.0646278):0.0260308):0.00307433):0.00465552, ((camel:0.00280621, dromedary_camel:0.00850957):0.0698379, (((minke_whale:0.0194947, ((bottle_nose_dolphin:0.00185447, orca:0.00236792):0.0107734, baiji_dolphin:0.0134454):0.0115035):0.00532388, sperm_whale:0.0334334):0.0374344,

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((giraffe:0.0118233, okapi:0.00944058):0.0211749, (((sheep:0.00660276,
goat:0.0146914):0.00438947, tibetan_antelope:0.0112999):0.00949666, (cow:0.0051338,
water_buffalo:0.0104369):0.0122571):0.0126386):0.05275):0.00898427):0.0147262):0.00703359):0.0501
076);
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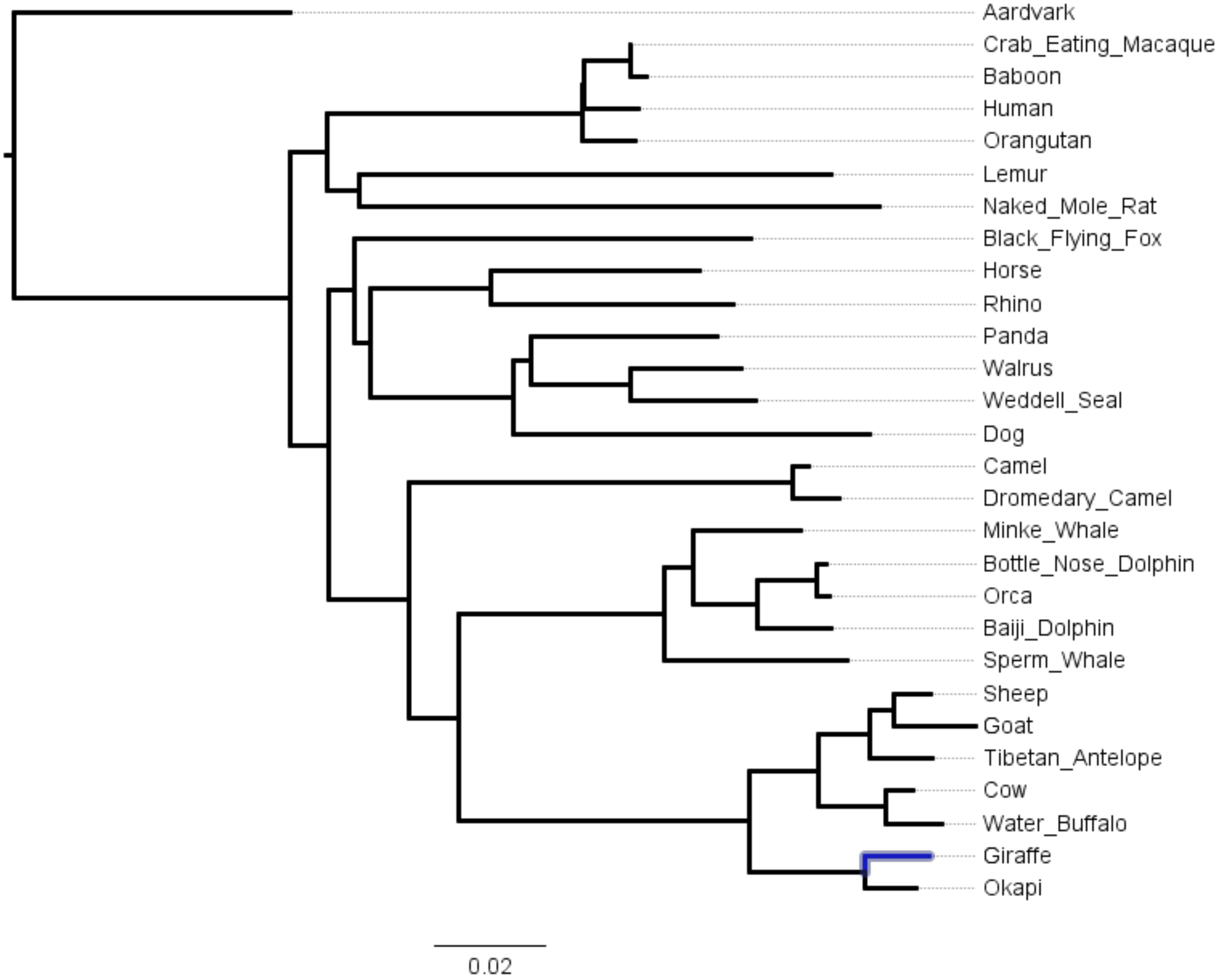


Locus Name: Lactoperoxidase (LPO)

Locus Name: Semaphorin 7A (SEMA7A)

ENSBTAT00000015210 SEMA7A-201 semaphorin 7A cell migration, adhesion, immune response
mouse: impaired development of olfactory tract

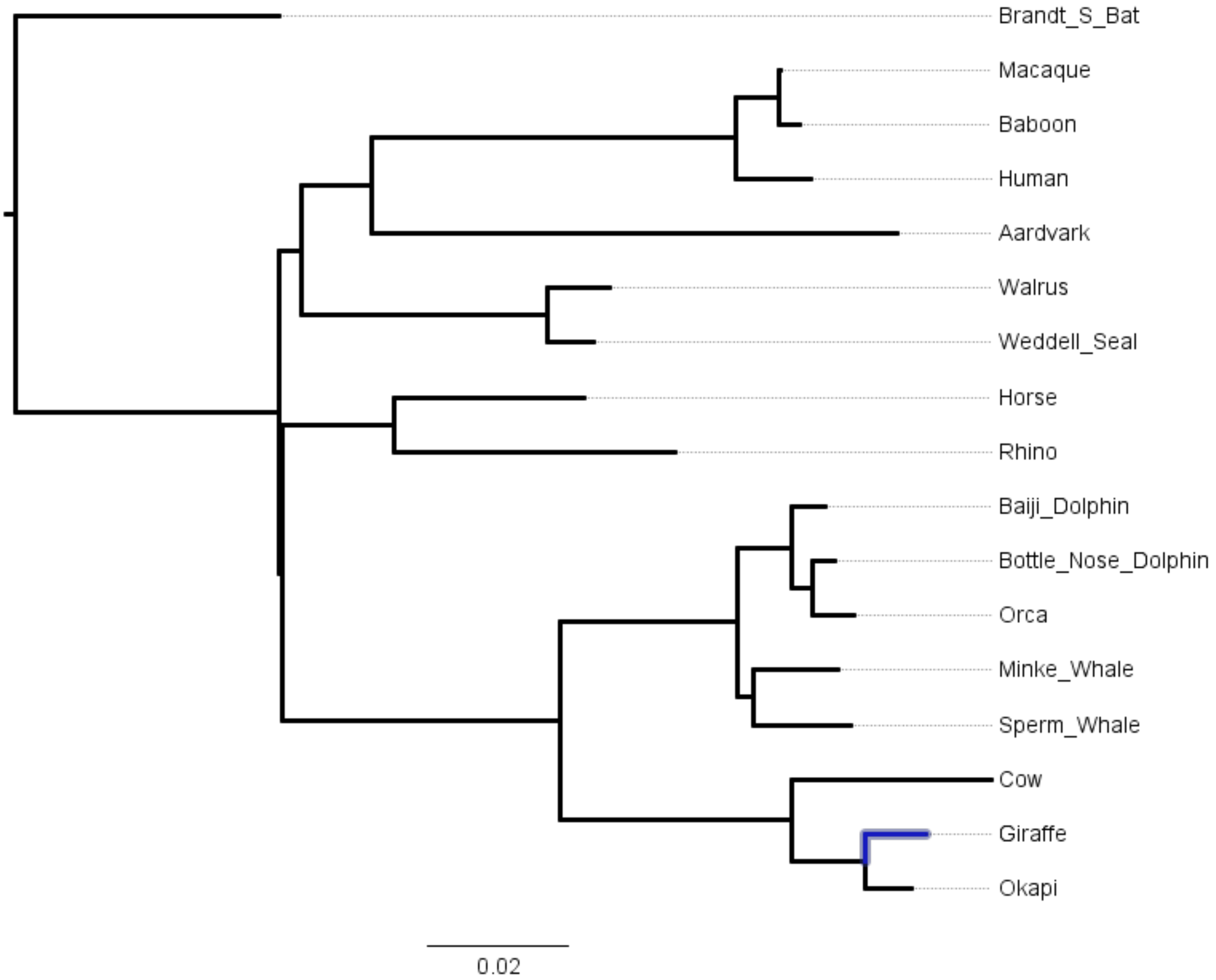
PSG: (Giraffe) R107H|CGC/CAC
PP2: All benign

Giraffe: T428A UIS, TL656-657RV UISs
Giraffe/Okapi: R24W UPS, V95A UPS, W300R UIS, Q423H UIS

Protein sequence Alignment of Cow, Giraffe and Okapi SEMA7A

```
Cow          1      MTPPPSRCTALGAPRARVSSSLARSRFPLWLLLQLVWTAAASQGHSKSGPRISAVWKGRA  60
Giraffe      1      ....................P..W.G...R...............P............H.  60
Okapi        1      ....................P..W.G...R...............P..........T.H.  60

Cow          61     GQDHVDFGSTEPHTVLFHEPGSSSVWVGGRNRIYVFAFSKGRNASVRTVNIGSTKGSCRD  120
Giraffe      61     ..............................S.V.A.D........MH.............  120
Okapi        61     ................S..Q..........S.V.A.D........M..............  120

Cow          121    KQDCGNYITLLEKQNEGLLACGTNARRPSCWILVNDSVEFLGERKGYAPFSPDENSLVLF  180
Giraffe      121    ....E................................AV.....................  180
Okapi        121    ....E................................AV.....................  180

Cow          181    DGDEVYSTIRKQEYNGKIPRFRRIKGEIELYTSDTVMQNPQFIKATIVHQDQAYDDKIYY  240
Giraffe      181    ............................................................  240
Okapi        181    ............................................................  240

Cow          241    FFREDNPDKNPEAPLNVSRVAQLCRGDQGGESSLSVSKWNTFLKAMLVCSDATTNKNFNR  300
Giraffe      241    ....................................................A......W  300
Okapi        241    ....................................................A......W  300

Cow          301    LQDVFLLPDPNGQWKDTRVYGVFSNPWNYSAVCVYSLGDIDKVFCTSSLKGYHSSLPNPR  360
Giraffe      301    ............................................................  360
Okapi        301    ............................................................  360

Cow          361    PGKCLPDRQPIPTETFQVADSHPEVVQRVEPMGPLKAPLFHSKYHYQKVVVHRMHASNGE  420
Giraffe      361    ....................................T.......................  420
Okapi        361    ....................................T.......................  420

Cow          421    TFHVLYLTTDKGTIHKVLEPGEWEHGLVFNILEIQPFRRAAAIQAMSLDADRRKLYVNSQ  480
Giraffe      421    .......A.........V...KR.....................................  480
Okapi        421    .................V....R.....................................  480

Cow          481    WEVSQVPLDLCELYTGGCHGCLMARDPYCGWYQDRCVSIYSSQEPVLQSISPVDPHKGCP  540
Giraffe      481    ............V.............................H.......N..E......  540
Okapi        481    ............V.............................H.......N..E......  540

Cow          541    NPKPEQAPLQKVSLAQNSRYYLSCPMESRHATYSWRHENSVEQSCEPGHQSPNCILFIEN  600
Giraffe      541    ............................................................  600
Okapi        541    ............................................................  600

Cow          601    LTDLHYGHYYCEAQEDSYLREAQHWELLREDSAMTSQLLGHACTLATSLWLGVLPTLILG  660
Giraffe      601    ...............G...............R........R..............RV...  660
Okapi        601    ...............G..F............R............................  660

Cow          661    LLVH                                                          664
Giraffe      661    ....                                                          664
Okapi        661    ....                                                          664
```

Newick Tree of Mammalian SEMA7A
(Brandt_s_bat:0.0374918, (((((macaque:0.000115098, baboon:0.0029015):0.00606498,
human:0.0106665):0.051877, aardvark:0.0746724):0.00991221, (walrus:0.0086756,
Weddell_seal:0.00652284):0.0350117):0.00327992, ((horse:0.0270289, rhino:0.0400769):0.0157669,
(((baiji_dolphin:0.00469115, (bottle_nose_dolphin:0.00324284,
orca:0.00584826):0.00290453):0.00779418, (minke_whale:0.0120336,
sperm_whale:0.0139448):0.00222698):0.0252228, (cow:0.0282195, (giraffe:0.00857852,
okapi:0.00659686):0.0104437):0.033028):0.0393207):0.000607242):0.0374918);



Locus Name: Semaphorin 7A (SEMA7A)

Locus Name: V-Rel Avian Reticuloendotheliosis Viral Oncogene Homolog(REL)

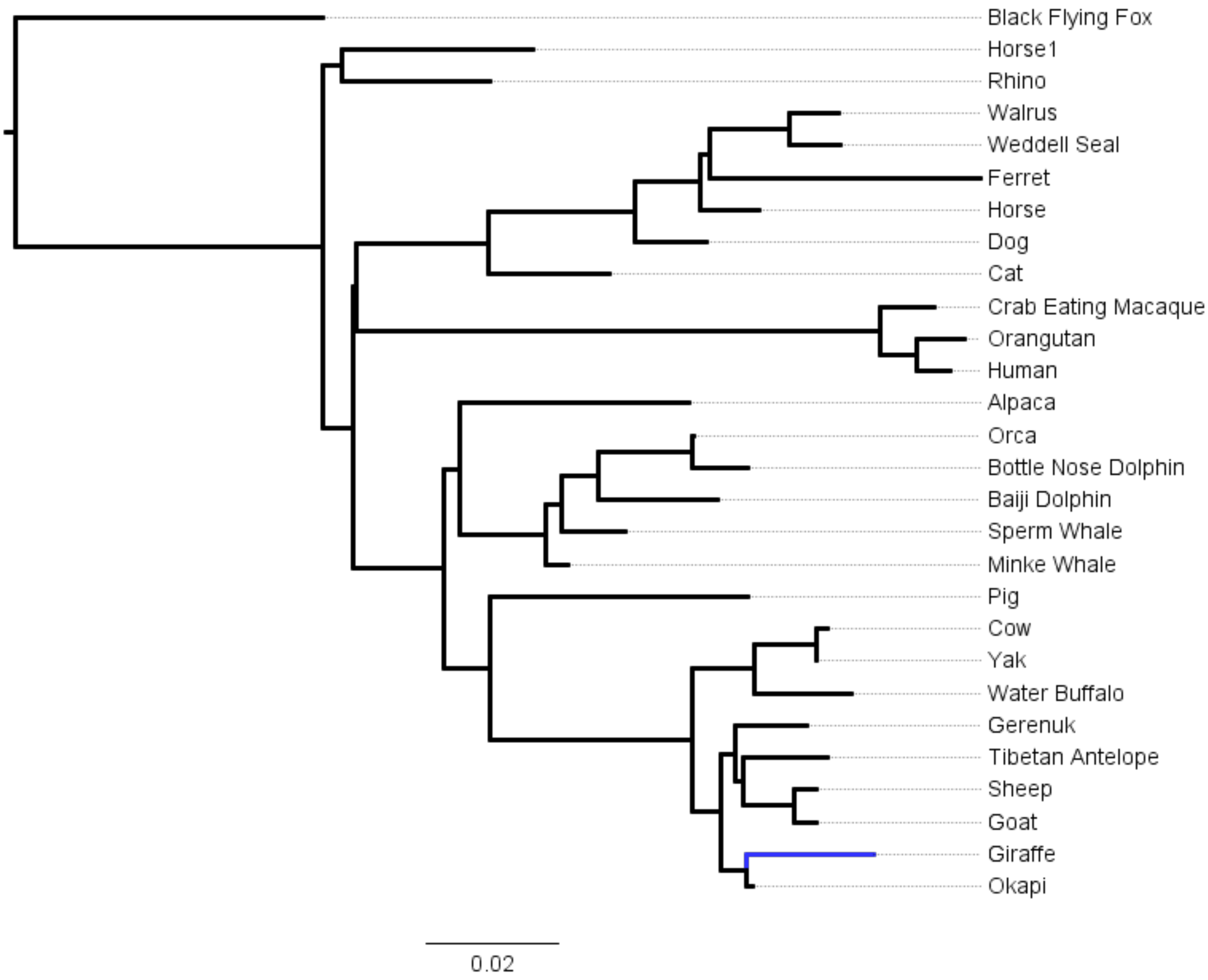
ENSBTAT00000020447 REL-201   v-rel oncogene   lymphocyte and ketatinocyes growth and development
mouse: defects in lymphocyte proliferation, humoral immunity, cytokine production

PSG: Q305E
PP2: Q574P
Giraffe: L163F UIS, A291T UIS, Q301Y UPS, Q305E UIS, P319S UPS, H390P UPS, S472N UIS, Q574P UIS

Protein sequence Alignment of Cow, Giraffe and Okapi REL

```
Cow          1      MASGGFNPCIEIIEQPRQRGMRFRYKCEGRSAGSIPGEHSTDNNRTYPSIQILNYYGKGK  60
Giraffe      1      ............................................................  60
Okapi        1      ............................................................  60

Cow          61     VRITLVTKNDPYKPHPHDLVGKDCRDGYYEAEFGQERRPLFFQNLGIRCVKKKEVKDAVI  120
Giraffe      61     ........................................................E.I.  120
Okapi        61     ........................................................E.I.  120

Cow          121    SRVRAGINPFNVPEQQLLDIEDCDLNVVRLCFQVFLPDEHGNLTTALPPVVSNPIYDNRA  180
Giraffe      121    ..I.......................................F..T..............  180
Okapi        121    ..I..........................................T..............  180

Cow          181    PNTAELRICRVNKNCGSVKGGDEIFLLCDKVQKDDIEVRFVLNDWEAKGVFSQADVHRQV  240
Giraffe      181    ...........................................E................  240
Okapi        181    ...........................................E................  240

Cow          241    AIVFKTPPYCKAIIEPVTVKMQLRRPSDQEVSESMDFRYLPDEKDTYGNKAKKQKTTLLF  300
Giraffe      241    .............T....................................T.........  300
Okapi        241    .............T..............................................  300

Cow          301    HKLWQDCGVNFPERPRPSPLGPTGEGRFIKKEPNLFSHGAVLPETSRPVSSQAESYYSSS  360
Giraffe      301    Y...E.............S.........................................  360
Okapi        301    Q...........................................................  360

Cow          361    ASISSTLSHPASAMLPMGTQSSSGWSSVAHPTSRSVNTNSLSSFSTGTLSSNSQVIPPFL  420
Giraffe      361    .............................P...H........G..............S..  420
Okapi        361    .............I.............I..............G.................  420

Cow          421    EMSDLNVSNACIYNNTNDIGRMEASSVSPADLYSISDASMLPNCPVNMITPSNDSMRETD  480
Giraffe      421    ......A..........................G.................N........  480
Okapi        421    ......A..........................G..........................  480

Cow          481    NPRLVSMNLENPSCNSVLDPRDLRQLHQMSPSSMSTVTSSSTTAYVAQSEAFEGSDFNCA  540
Giraffe      481    ..........S...................S.............F...............  540
Okapi        481    ..........S...................S.............F...............  540

Cow          541    DNSMINEAGPSNSTNANSHGFGPNSQYSGIGAMQNEQLSDSFAFEFFKV            589
Giraffe      541    ............G......S..Q..........P........P....Q.            589
Okapi        541    ............G......S..Q...................P....Q.            589
```

Newick Tree of Mammalian REL



Locus Name: V-Rel Avian Reticuloendotheliosis Viral Oncogene Homolog(REL)

Axis inhibition protein 1 (AXIN2)

ENSBTAT00000042542 AXIN2-201   negative regulator of Wnt signaling   embryonic somitogenesis and skeletal development
mouse: premature fusion of cranial sutures, enhanced expansion of osteoprogenitors, accelerated ossification, increased osteoblast proliferation and differentiation

Confirmed 5aa del in MA1, Reticulated and Rothschild

PP2: (Giraffe/Okapi) K486P, F679C

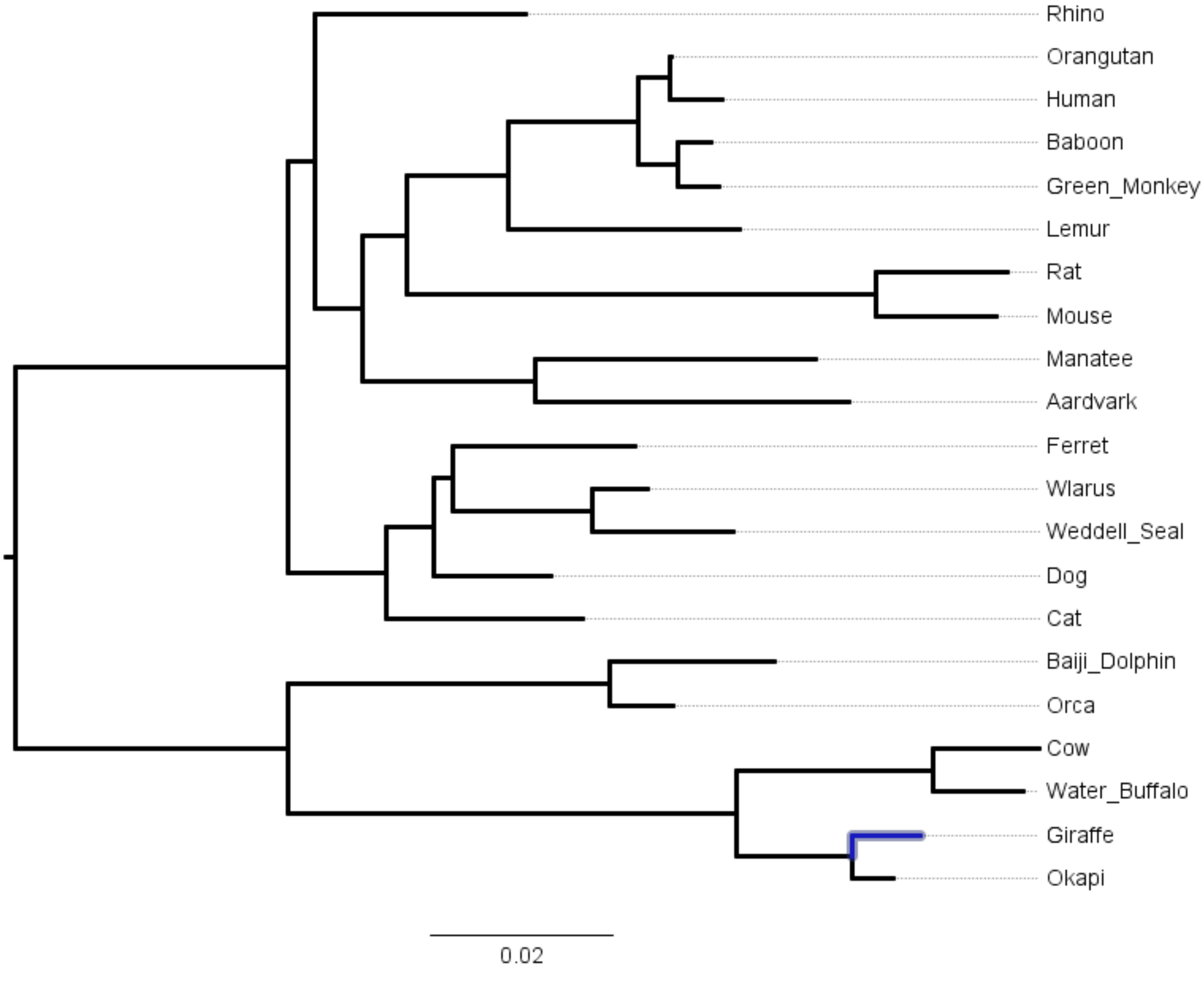
Giraffe: VPRLP 7-11 deletion UIS, Q165H UIS, S428C UIS, P489A UIS, A645P UPS
Giraffe/Okapi: I302M UIS, M312L UIS, M605V UPS

Protein sequence Alignment of Cow, Giraffe and Okapi AXIN2

```
Cow          1      MSSAVLVPRLPDPSSSFREDAPRPPVPGEEGETPPCQPGVGKGPAAKASPVSPSARRNEG  60
Giraffe      1      ......-----.........................P...........P...S.......  55
Okapi        1      .....................................L..........P...S.......  60

Cow          61     GLGEPEGRASPDSPLTRWTKSLHSLLGDQDGAYLFRTFLEREKCVDTLDFWFACNGFRQM  120
Giraffe      56     ............................................................  115
Okapi        61     ............................................................  120

Cow          121    NLKDAKTLRVAKAIYKRYIENNSIVSKQLKPATKTYIRDSIKKQQIDSVMFDQAQTEVQA  180
Giraffe      116    ............................................H...............  175
Okapi        121    ............................................................  180

Cow          181    VMEENAYQTFLTSDICLQYVGSGGENPAYLSQGGLGSLRLVCGYLPTLNEEEEWTCADFK  240
Giraffe      176    ........M......Y.E..R........V.H............................  235
Okapi        181    ........M......Y.E..R........V.H............................  240

Cow          241    CKLPPTVVGLSSKTLRATASARAMDTIESGYRSFRRSDPVNPYHVGSGYVFAPAASANDS  300
Giraffe      236    ......................................................T.....  295
Okapi        241    ......................................................T.....  300

Cow          301    EISSDALTDDSMSMTDSSVDGVPPYRVGSKKQLQREMHRSVKANGQVSLPHFPRTHRLPK  360
Giraffe      296    .M.........L................................................  355
Okapi        301    .M.........L................................................  360

Cow          361    EMTPVEPAAFAAELIARLEKLKLELETRHSLEERLQQIQEDEEKEGVELAPGSREAGPAP  420
Giraffe      356    ........T.............................R.......S.............  415
Okapi        361    ........T.............................R.......S........V....  420

Cow          421    HALCLLPSSSYEEDPQTILDDHLSRVLKTPGCQSPGVGRYSPRARSPDHHHRHHLQSHRA  480
Giraffe      416    .P.....C................................................A...  475
Okapi        421    .P......................................................A...  480

Cow          481    LPPPGGPLPAVAVPASCSLLGARGFVSRQATKHIHHHYIHHHAGPRTRDEAEAEAAPRAR  540
Giraffe      476    ........APA.I................T...V..............E...........  535
Okapi        481    ........SPA.L................T...V..............E...........  540

Cow          541    CPCPVPGGADYSCCAKCKSHPGVPEPPGAAQLGWTRSSVPTSSRGGAPARRSTAPAREAG  600
Giraffe      536    ..........................A.............LG......T...A.......  604
Okapi        541    ..........................A.............XG..........A.......  608

Cow          601    APGGMGSLQPPGEEGDRTQVVWQWVLESERPGKPKPHSAQSTKRAYPTESARTSPAERAG  660
Giraffe      605    ....V............A....................T.....P.......A.......  664
Okapi        609    P...V............A....................T.............A.......  668

Cow          661    RHHLWGGSTGHPRAVPRAHPACTQDSSVPPLTPPNTLAQLEEACRRLAEVSKPPKQRCCA  720
Giraffe      665    ..............T.......A...A.................................  724
Okapi        669    ..............T.......A...A.................................  728

Cow          721    AGQQRDRSHPGPGMPGTTPFSSPSPASEDHKEPKKLAGMHALQASELVVTYFFCGEEIPY  780
Giraffe      725    ..........AL.Q...A....................V.....................  784
Okapi        729    ..........AL.Q...A....................V.....................  788
```

```
Cow          781   RRMLKAQSLTLGHFKEQLSKKGNYRYYFKKASDEFACGAVFEEVWDDEVVLPMYEGRILG  840
Giraffe      785   ............................................................  844
Okapi        789   ............................................................  848

Cow          841   KVERID                                                        846
Giraffe      845   ......                                                        850
Okapi        849   ......                                                        854
```

Newick Tree of Mammalian AXIN2
(((rhino:0.0231316, (((((orangutan:0.000135022, human:0.00581387):0.00350805, (baboon:0.00373345, green_monkey:0.00460499):0.0042932):0.0142304, lemur:0.0253743):0.0111668, (rat:0.0145529, mouse:0.0132807):0.0515446):0.00502125, (manatee:0.0308067, aardvark:0.0344936):0.0191671):0.00514728):0.00296164, (((ferret:0.0200918, (wlarus:0.00611816, Weddell_seal:0.015519):0.0153809):0.00212345, dog:0.0129166):0.00523803, cat:0.0216697):0.0107635):0.03006, ((baiji_dolphin:0.0181628, orca:0.00697578):0.0354123, ((cow:0.0115613, water_buffalo:0.00994656):0.0216675, (giraffe:0.00736486, okapi:0.00449796):0.0127801):0.0493753):0.03006);



Axis inhibition protein 1 (AXIN2)

Locus Name: Peripherin PRPH2

ENSBTAT00000007836 PRPH2-201   perpherin-2 visual function
m common cause of retinitis pigmentosa, human: retinal degeneration

PSG: P10Q

Giraffe: P10Q UIS

Protein sequence Alignment of Cow, Giraffe and Okapi PRPH2

```
Cow         1      MALLKVKFDQKKRVKLAQGLWLMNWFSVLAGIIIFGLGLFLKIELRKRSDVMNNSESHFV  60
Giraffe     1      .........P.......................................E..........  60
Okapi       1      .................................................E..........  60

Cow         61     PNSLIGVGVLSCVFNSLAGKICYDALDPAKYAKWKPWLKPYLAVCVLFNVVLFLVALCCF  120
Giraffe     61     ..................................................T.........  120
Okapi       61     ........M.........................................T.........  120

Cow         121    LLRGSLESTLAHGLKNGMKFYRDTDTPGRCFMKKTIDMLQIEFKCCGNNGFRDWFEIQWI  180
Giraffe     121    ............................................................  180
Okapi       121    ............................................................  180

Cow         181    SNRYLDFSSKEVKDRIKSNVDGRYLVDGVPFSCCNPNSPRPCIQYQLTNNSAHYSYDHQT  240
Giraffe     181    ............................................................  240
Okapi       181    ............................................................  240

Cow         241    EELNLWLRGCRAALLSYYSNLMNTTGAVTLLVWLFEVTITVGLRYLHTALEGMANPEDPE  300
Giraffe     241    ...............N........I...............I...................  300
Okapi       241    ...............N........I...................................  300

Cow         301    CESEGWLLEKSVPETWKAFLESVKKLGKGNQVEAEGEDAGQAPAAG               347
Giraffe     301    ............................S..................               347
Okapi       301    ............................S..................               347
```

Newick Tree of Mammalian PRPH2

```
((((Human:0.00588561, Northern_White-Cheeked_Gibbon:0):0.000738324,
Orangutan:0.00507583):0.00517584, (Baboon:0.0018958, (Angola_Colobus:0.0030238,
Drill:0.0086045):0.00100277):0.00214564):0.0214713, (((Vampire_Bat:0,
Black_Flying_Fox:0.00301012):0.0299616, ((((Dog:0.0115878, (((Weddell_Seal:0.00282626,
Walrus:0.00297089):0.00615544, (Polar_Bear:0.00927793, Panda:0.0111622):0.00708484):0.0021069,
Ferret:0.015548):0.00158817):0.00829999, (Tiger:0.00497386,
Cat:0.00665444):0.0202934):0.00184041, (((White_Rhino:0.0162639, Horse:0.013068):0.00991163,
Hedgehog:0.039621):0.00142509, (Mouse:0.0121093,
Deer_Mouse:0.0112857):0.0267635):0.00278664):0.00161864, (Aardvark:0.0242448,
(Elephant:0.0166021, Manatee:0.0217036):0.00396617):0.0119554):0.00254992):0.00461297,
((Alpaca:0.000514034, (Camel:0, Bactrian_Camelus:0.00296152):0.00820715):0.0264655,
((Sperm_Whale:0.00617751, (Minke_Whale:0.00976298, ((Orca:0.00273464, Bottle-
nose_dolphin:0.000159718):0.00675668, Baji_Dolphin:0.00782157):0.00192789):0.0010987):0.00927823,
((Cow:0.00123748, (Yak:0.00116035, Water_Buffalo:0.0046368):0.00166535):0.00163245,
((Gerenuk:0.00436983, (Musimon_Sheep:0, Tibetan_Antelope:0.00291997):0.00143578):0.00357245,
(Giraffe:0.00518775,
Okapi:0.00352069):0.00962686):0.00127879):0.0245697):0.00432251):0.0106901):0.0214713);
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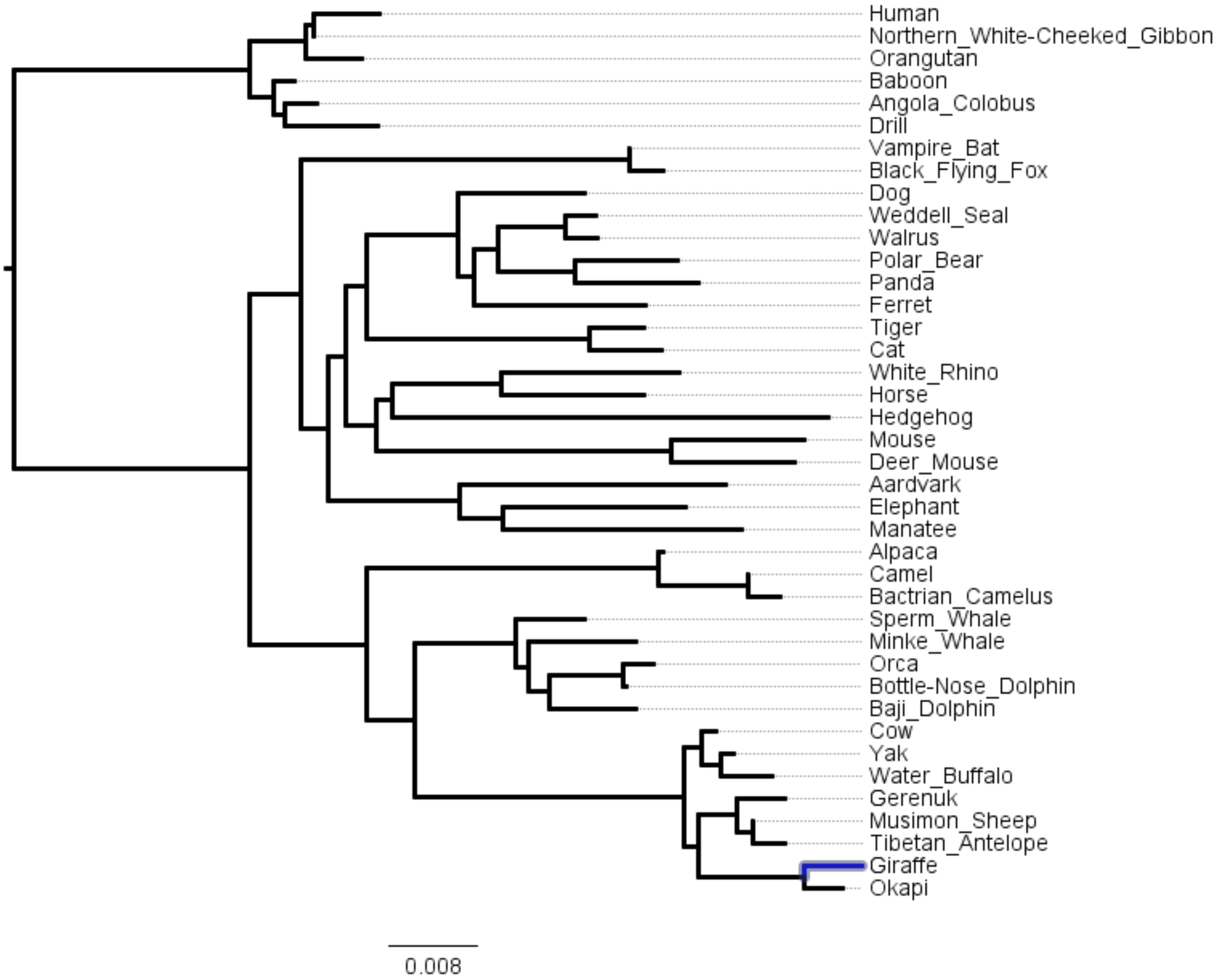

Locus Name: Peripherin PRPH2

Locus Name: NF-X1-type zinc finger protein (NFXL1)

ENSBTAT00000061348 NFXL1-201   NF-X1-type   skeletal growth
mouse: reduced body length and short tibia

PP2: None
PSG: T616M

Giraffe: P441A UIS, PT615-616LM UIS with M(TS)UPS

Protein sequence Alignment of Cow, Giraffe and Okapi NFXL1

```
Water Buffalo 1      MEASWRQVAGGRGRARGRGTAAPSSGNGVHLRGAGGGREKGSVGAAGPGLSPGGAATPAA  60
Giraffe       1      ..................A.....................................I...  60
Okapi         1      ..................A.G.......................................  60

Water Buffalo 61     AGSSARRCPAGSEAPQTSVAGELMSQKKFEEIKKANQAAAKKIVEEHFSSSSEEEGDEDF  120
Giraffe       61     ....G..S..R............I....................................  120
Okapi         61     ....G..S...............I....................................  120

Water Buffalo 121    EGKRGKIVANTFITYTTQTDGDVRELERTKQYVNEAFQAGAMTCLICIASVKRNQAVWSC  180
Giraffe       121    ............T...............................................  180
Okapi         121    ............T...............................................  180

Water Buffalo 181    SGCFCIFHMPCIQKWAKDSQFLVSSLTDDDFGKRDYPWPCPKCRFEYKRSDTPSRYYCYC  240
Giraffe       181    ............................................................  240
Okapi         181    ............................................................  240

Water Buffalo 241    GKVEDPPLDPWLVPHSCGQVCERDFKPSCGHKCLLLCHPGPCPPCPKMVTTTCYCKKAKP  300
Giraffe       241    ...........................P................................  300
Okapi         241    ...........................P................................  300

Water Buffalo 301    IPRRCSAKEWSCQLPCGRKLLCGQHKCENPCHAGSCPPCPRVSRQKCVCGKRVAERSCAS  360
Giraffe       301    ................................S...................A.......  360
Okapi         301    ....................................................A.......  360

Water Buffalo 361    PLWHCDQVCGKTLPCGNHTCEQVCHVGACGDCPRSGKRFCPCQKSKFSLPCTEDVPTCGD  420
Giraffe       361    ............................................................  420
Okapi         361    ............................................................  420

Water Buffalo 421    SCDKVLECGIHRCSQRCHRGPCETCRQEVEKHCRCGKHTKRMPCHKPYLCETKCVKMRDC  480
Giraffe       421    ....................A.......................................  480
Okapi         421    ............................................................  480

Water Buffalo 481    QKHQCRRKCCPGNCPPCDQNCGRTLGCRNHKCPSVCHRGSCYPCPETVDVKCNCGNTKVT  540
Giraffe       481    ............................................................  540
Okapi         481    ....................................................S.......  540

Water Buffalo 541    VPCGRERTTRPPKCKEQCSRPPTCHHTSQEKHRCHFGSCPPCHQPCQKVLEKCGHLCPAP  600
Giraffe       541    ............................................................  600
Okapi         541    ............................................................  600

Water Buffalo 601    CHDQALIKQTGRHQPTGPWEQPSEPAFIQTALPCPPCQVPIPMECLGKHEVSPLPCHAVG  660
Giraffe       601    ..............LM............................................  660
Okapi         601    ..............L.............................................  660

Water Buffalo 661    PYSCKRACGRTLTCQNHTCMKECHKVTETDSCTDKKKAGPECLHCEEGCSKSRPSGCPHP  720
Giraffe       661    ......V.....N...............................................  720
Okapi         661    ......V.....N............................................T..  720

Water Buffalo 721    CVLPCHPGECPPCVQMLRIKCHCKITSLYVECRKITTADVNEKNLLSCCKNQCPKELPCG  780
Giraffe       721    .......................................I....................  780
Okapi         721    .......................................I....................  780

Water Buffalo 781    HRCKEMCHPGECPFNCNQKVKLRCPCKRIKKEVQCNKVRENQISIECDTTCKEMKQKASE  840
Giraffe       781    .......................................................R....  840
Okapi         781    .......................................................R....  840
```

```
Water Buffalo 841    LKEAEAKAALEEEKRRQQAELEAFENRLKGRRKKNRKRDEVAVELTLWQKYKYYLFPLCA  900
Giraffe       841    ............................................................  900
Okapi         841    ............................................................  900

Water Buffalo 901    IVVVVFAWYIANAVD                                               915
Giraffe       901    V..........L...                                               915
Okapi         901    ...........L...                                               915
```

Newick Tree of Mammalian NFXL1

```
(((Northern_White-Cheeked_Gibbon:0.00359942, (Human:0.00856959,
Orangutan:0.00803366):0.000796594):0.00387898, (Drill:0.00255115,
Mouse:0.00184931):0.0100495):0.0147522, ((((Polar_Bear:0.00890291, (Walrus:0.00830195,
Weddell_Seal:0.0104325):0.0060435):0.00490846, (Tiger:0.0036526,
Cat:0.00291921):0.0186251):0.00768872, (White_Rhino:0.0203383,
Horse:0.017495):0.00639622):0.00200009, ((((Baji_Dolphin:0.00819689,
'Orca]':0.00609741):0.00184553, (Minke_Whale:0.00741933,
Sperm_Whale:0.00909252):0.000375473):0.0136695, Alpaca:0.0245246):0.00224885,
((giraffe:0.0060733, okapi:0.00381162):0.00758221, ((gerenuk:0.00506027,
Musimon_Sheep:0.00592907):0.000498578, (cow:0.00199488,
Water_Buffalo:0.00348461):0.00280918):0.00297043):0.013462):0.00267698):0.0147522);
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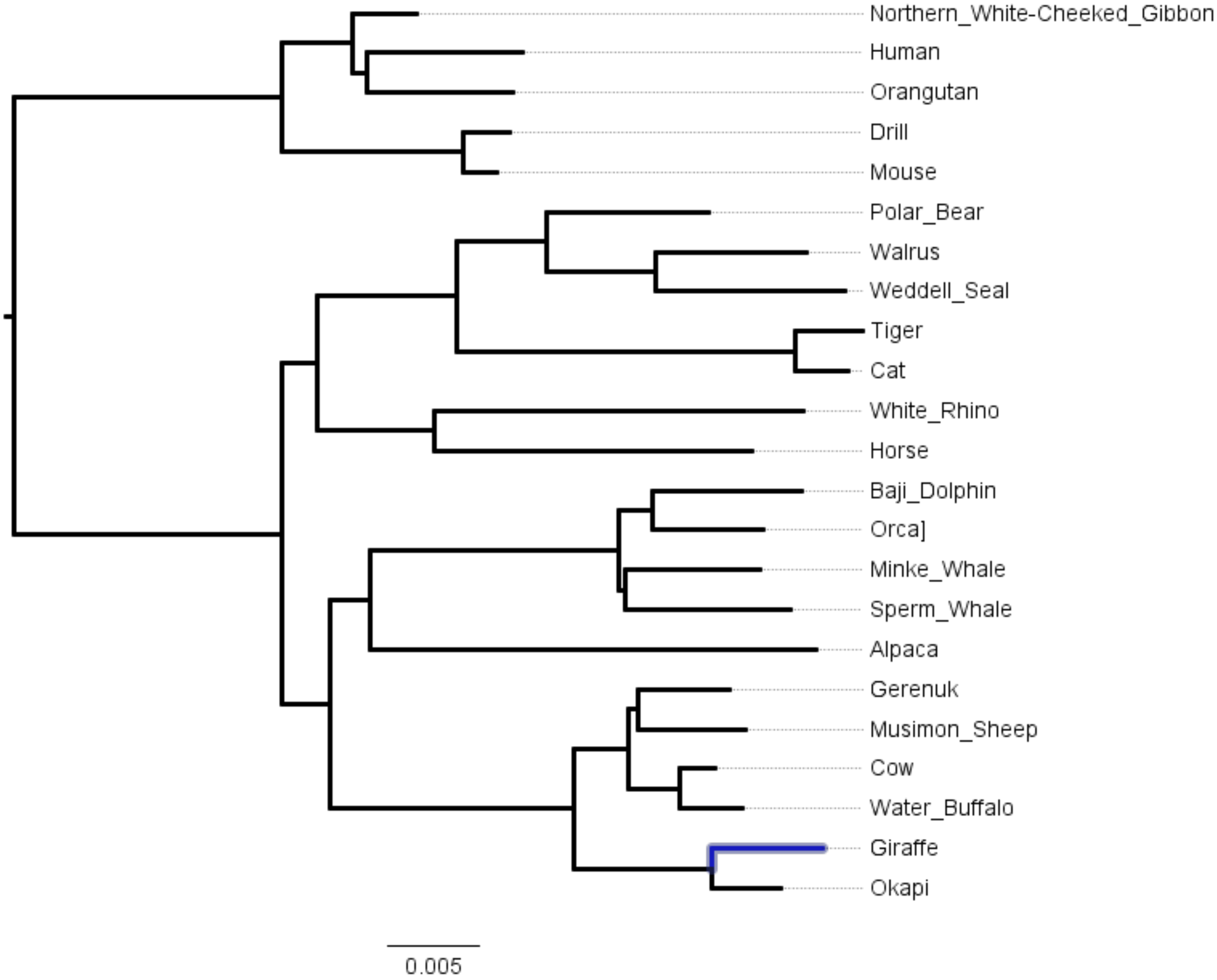

Locus Name: NF-X1-type zinc finger protein (NFXL1)

Supplementary Table 1 Gene Annotations of giraffe and okapi

We used gene annotations for assemblies of the cow and dog genomes to identify putative coding regions for giraffe and okapi, as follows. We downloaded gene models for the cow assembly called bosTau4 from Ensembl (www.ensembl.org). The union of all intervals annotated as coding, as well as 150 bp flanks, were used to extract sequence from the bosTau4 assembly, forming the mapping target. Giraffe reads were mapped to the target using lastz (www.bx.psu.edu/miller_lab/dist/README.lastz-1.02.00/README.lastz-1.02.00a.html) Mapping required an alignment with at least 60% of the read length as matched bases, and at least 3 matches better than the second best alignment. Lastz scoring was as follows.

Nucleotide substitutions:

	A	C	G	T
A	11	-33	-20	-39
C	-33	16	-30	-20
G	-20	-30	16	-33
T	-39	-20	-33	11

gap_open_penalty = 40, gap_extend_penalty = 4, hsp_threshold = 300, x_drop = 80 and y_drop = 80. The analogous process was used to align reads to the dog canFam3 assembly. To allow for the additional evolutionary distance between giraffe and the assembly, we used the following, less stringent lastz scores.

Nucleotide substitutions:

	A	C	G	T
A	11	-22	-10	-28
C	-22	15	-20	-10
G	-10	-20	15	-22
T	-28	-10	-22	11

gap_open_penalty = 30, gap_extend_penalty = 3, hsp_threshold = 300, x_drop = 60 andy_drop = 60. The okapi reads were processed just as for giraffe.

Supplementary Table 2 Genome Assemblies of giraffe and okapi

Summary of genome assemblies of giraffe and okapi

	Giraffa camelopardalis tippelskirchi		*Okapia johnstoni*	
Assembly size (Gb)	2,92		3,28	
GC-content %	41,5		42,3	
Number of scaffolds	2051673		3721563	
Total size of scaffolds (nt)	2923614156		3279649410	
Longest scaffold (nt)	5618088		2167669	
Number of scaffolds > 500 nt	121921	5,90%	191750	5,20%
Number of scaffolds > 1K nt	60763	3,00%	106272	2,90%
Number of scaffolds > 10K nt	13235	0,60%	27730	0,70%
Number of scaffolds > 100K nt	5782	0,30%	7270	0,20%
Number of scaffolds > 1M nt	342	0,00%	62	0,00%
N50 scaffold length (nt)	339613		104593	
L50 scaffold count	2088		6933	
scaffold %A	28,39		27,74	
scaffold %C	20,17		20,3	
scaffold %G	20,06		20,21	
scaffold %T	28,08		27,41	
scaffold %N	3,29		4,33	
Percentage of assembly in scaffolded contigs	82,80%		69,90%	
Ave. length of breaks (20 or more Ns) between contigs	1170		1620	
Number of contigs	2133680		3808993	
Number of contigs in scaffolds	101091		124674	
Number of contigs not in scaffolds	2032589		3684319	
Total size of contigs (nt)	2827601364		3137992281	
Longest contig (nt)	540046		592595	
Number of contigs > 500 nt	187457	8,80%	251065	6,60%
Number of contigs > 1K nt	121879	5,70%	159155	4,20%
Number of contigs > 10K nt	50330	2,40%	54534	1,40%
Number of contigs > 100K nt	4159	0,20%	3359	0,10%
Number of contigs > 1M nt	0	0,00%	0	0,00%
N50 contig length (Kb)	47286		33770	
L50 contig count	16327		22986	

Mapping reads to genome assemblies of giraffe and okapi

	Giraffa camelopardalis tippelskirchi			*Okapia johnstoni*		
	PE	MP	Adaptor-clipped MP	PE	MP	Adaptor-clipped MP
Number of reads	570222616	156989988	134919530	541205364	134600726	117136186
Coverage (resp. mapped coverage)	29.26x (28.44x)	8.05x (6.44x)	6.63x (5.67x)	24.75x (23.65x)	6.16x (4.98x)	5.08x (4.40x)
Number of mapped reads (out of total)	563495089 (98.82%)	155254040 (98.89%)	134692225 (99.83%)	537760172 (99.36%)	132951488 (98.77%)	116902286 (99.80%)
Percentage of PCR duplicate reads*	N/A	43,00%	N/A	N/A	64,00%	N/A
Insert size average (bp)	527.4	4610.1	4630,4	541.9	4271	4274,8
Insert size standard deviation (bp)	132.4	3623	3623,7	157.2	3584.4	3591,3
Number of reads in pairs that map to the same scaffold	518811698	110023320	107539588	447699474	81993204	80146978
Number of reads in pairs that map to the same scaffold in PE orientation**	518139122 (99.87%)	44469980 (40.42%)	43154754 (40.13%)	445077876 (99.41%)	34908928 (42.58%)	34157932 (42.62%)
Number of reads in pairs mapping to the same scaffold in MP orientation**	672576 (0.13%)	65553340 (59.58%)	64384834 (59.87%)	2621598 (0.59%)	47084276 (57.42%)	45989046 (57.38%)
Mismatch rate (over all mapped bases)	1.11%	0.26%	0.16%	0.63%	0.44%	0.30%

Prepared MP libraries are MP that have been processed by the NextClip software, then given to the assembler instead of the original MP contamination in MP libraries.

Coverage is the total number of bases in the reads, divided by the genome size. Mapped coverage is the number of mapped bases, divided

*as detected by NextClip software ** out of all reads mapping to the same scaffold

Supplementary Table 3 Pathway (KEGG) and Biological Functions (GO) analysis genes enriched for dN and dN/dS

KEGG dN giraffe enriched	
dN giraffe-cattle > 1.5X okapi-cattle	
N=649 transcripts	
	p-value
bta00020=Citrate cycle	0.0046
bta05010=Alzheimer's disease	0.0048
bta05012=Parkinson's disease	0.0061
bta04260=Cardiac muscle contraction	0.011
bta04728=Dopaminergic synapse	0.015
bta05016=Huntington's disease	0.018
bta00190=Oxidative phosphorylation	0.019
bta04724=Glutamatergic synapse	0.024
bta05014=Amyotrophic lateral sclerosis	0.028
bta03015=mRNA surveillance pathway	0.03
bta04730=Long-term depression	0.032
bta04962=Vasopressin-reg. water reabsorp.	0.034
bta00562=Inositol phosphate metabolism	0.037
bta04070=Phosphatidylinositol signaling	0.044
bta04727=GABAergic synapse	0.049
bta04360=Axon guidance	0.05

GO dN giraffe enriched	
dN giraffe-cattle > 1.5X okapi-cattle	
N=649 transcripts enriched	
	p-value
response to hormone stimulus	0.00029
ossification	0.00063
tricarboxylic acid cycle	0.00093
trophectodermal cell differentiation	0.0021
negative regulation of cell migration	0.0022
response to cytokine stimulus	0.0035
mitochondrial inner membrane	0.0048
protein homodimerization activity	0.0049
regulation of transcription	0.0051
protein transporter activity	0.0072
cellular membrane organization	0.0076
transcription factor binding	0.008
gap junction	0.015
positive regulation of cell differentiation	0.015
double-stranded DNA binding	0.02
negative reg. of osteoblast differentiation	0.02
ATP synthesis coupled proton transport	0.021
male gonad development	0.025
ribosome biogenesis	0.025
ER-Golgi intermediate compartment	0.026
metanephros development	0.026
Wnt receptor signaling pathway	0.026
protein domain specific binding	0.029
catalytic step 2 spliceosome	0.031
embryonic skeletal system morphogenesis	0.036
histone deacetylase binding	0.036
ligand-dependent nuclear receptor activity	0.04
positive regulation of cell proliferation	0.042

KEGG dN/dS giraffe enriched	
dN giraffe-cattle > dN okapi-cattle	
N=1,002 transcripts enriched	
	p-value
bta04060=Cytokine-cytokine receptor interaction	0.00011
bta05012=Parkinson's disease	0.0041
bta00190=Oxidative phosphorylation	0.0049
bta00630=Glyoxylate and dicarboxylate metabolism	0.006
bta05014=Amyotrophic lateral sclerosis (ALS)	0.018
bta05010=Alzheimer's disease	0.027
bta00740=Riboflavin metabolism	0.029
bta04740=Olfactory transduction	0.034
bta04640=Hematopoietic cell lineage	0.034
bta01100=Metabolic pathways	0.034
bta05016=Huntington's disease	0.037
bta04630=Jak-STAT signaling pathway	0.047

GO dN/dS giraffe enriched	
dN giraffe-cattle > dN okapi-cattle	
N=1,002 transcripts enriched	
	p-value
extracellular region	2.10E-09
cytokine activity	0.00001
chemokine activity	0.000072
immune response	0.00017
mitochondrion	0.00078
hormone activity	0.0011
WW domain binding	0.0018
mitochondrial inner membrane	0.0028
electron transport chain	0.004
ATPase binding	0.0048
organic anion transport	0.0048
positive regulation of Ras protein signal transduction	0.0048
enzyme activator activity	0.0054
chemotaxis	0.0059
growth factor activity	0.006
mitochondrial respiratory chain complex I	0.0071
mitochondrial membrane	0.0077
respiratory chain	0.013
NADH dehydrogenase (ubiquinone) activity	0.014
chaperone binding	0.014
leukotriene biosynthetic process	0.014
ribonucleoprotein complex	0.021
cysteine-type endopeptidase inhibitor activity	0.031
glutathione transferase activity	0.031
mitochondrial matrix	0.032
tRNA processing	0.036
peptidase inhibitor activity	0.038
cytochrome-c oxidase activity	0.042
G-protein coupled receptor protein signaling pathway	0.042
cysteine-type endopeptidase activity	0.045
positive regulation of peptidyl-tyrosine phosphorylation	0.05

Supplementary Table 4   Genes exhibiting positive selection in giraffe and okapi

giraffe: over (+) under (-) representation

Biological Process		P value
lysosomal transport	+	0.023
natural killer cell activation	+	0.023
immune response	+	0.029
angiogenesis	+	0.033
protein ADP-ribosylation	+	0.035
blood circulation	+	0.037
response to pheromone	+	0.046
nervous system development	-	0.046
protein phosphorylation	-	0.052
cellular defense response	+	0.055
neuronal action potential propagation	+	0.057
sex determination	+	0.057
protein metabolic process	-	0.075
mRNA transcription	+	0.089
cell-matrix adhesion	+	0.091
mRNA processing	-	0.101
response to stimulus	+	0.108
mitochondrion organization	+	0.111
mitochondrial transport	+	0.111
macrophage activation	+	0.12
cellular protein modification process	-	0.127
mRNA splicing via spliceosome	-	0.147
anion transport	+	0.148
immune system process	+	0.149
B cell mediated immunity	+	0.164
ectoderm development	-	0.171
cell communication	-	0.171
antigen processing and presentation	+	0.2
protein transport	-	0.209
lipid metabolic process	+	0.212
RNA catabolic process	+	0.218

okapi: over (+) under (-) representation

Biological Process		P value
nervous system development	-	0.03
protein methylation	+	0.063
sensory perception of taste	+	0.075
phosphate-containing compound metabolic proce	+	0.087
cellular amino acid metabolic process	-	0.095
sensory perception of pain	+	0.098
sensory perception of chemical stimulus	+	0.098
cell adhesion	+	0.106
biological adhesion	+	0.106
mitochondrion organization	+	0.121
mitochondrial transport	+	0.121
steroid metabolic process	+	0.123
ectoderm development	-	0.124
muscle organ development	-	0.125
cholesterol metabolic process	+	0.128
localization	-	0.129
glycolysis	+	0.133
system development	-	0.135
transport	-	0.151
cell-cell signaling	-	0.156
protein metabolic process	+	0.156
regulation of liquid surface tension	+	0.166
transcription DNA-dependent	-	0.173
antigen processing and presentation	+	0.176
Unclassified	+	0.178
transcription from RNA polymerase II promoter	-	0.179
exocytosis	+	0.18
proteolysis	+	0.185
protein acetylation	+	0.187
developmental process	-	0.189
blood circulation	+	0.191

Supplementary Table 5 Genes exhibiting multiple signs of adaptation (MSA) in giraffe

Gene[1]	Protein Function	Stage Tissue/Organ/Function	Protein Divergence[2]	Substitutions at Fixed Sites[3]		Polyphen2 PRD[4]	PSG[5]
			branch length	number	p-value	number	
HOXB3	homeobox transcription factor	segmental identity, anterior axial skeleton, angiogenesis	G-mammals	G-2US; GO-3US	n.s.	GO-1PRD	n.s.
HOXB13	homeobox transcription factor	segmental identity, posterior axial skeleton, angiogenesis	GO-mammals	GO-5US, 4aadel	n.s.	GO-3PRD	n.s.
CDX4	homeobox transcription factor	segmental identity, posterior axial skeleton, heart develop.	GO-cetartiodactyls	G-2US, GO-1US	n.s.	G-1PRD, GO-1PRD	n.s.
NOTO	homeobox transcription factor	embryonic somitogenesis,	G-mammals	G-2US, GO-2US	n.s.	G-2PRD, GO-2PRD	n.s.
JAG1	Notch ligand	vertebrae development, cardivascular, eye, kidney	G-mammals	G-2US, GO-6US	n.s.	GO-1PRD	n.s.
DLL3	Notch ligand	embryonic somitogenesis	GO-cetartiodactyls	G-1US, GO-4US	n.s.	GO-3PRD	n.s.
NOTCH4	notch pathway	mesoderm development, angiogenesis, neurogenesis	G-mammals	G-8US, O?	n.s.	G-3PRD, GO-1PRD	n.s.
FGFRL1	decoy FGF receptor	cranofacial, axial & appendic. skeleton, heart, kidney	G-cetartiodactyls	G-7US; GO-1US	4.00E-06	G-3PRD	7 P< 0.09
FOLR1	folate receptor	embryogenesis, folate homeostasis	G-cetartiodactyls	G-3US	n.s.	G-2PRD	5*
PDCD2L	transcriptional repressor	programmed cell death	G-pecorans	G-3US; GO-1US	n.s.	G-2PRD	n.s.
MYC	transcription factor	cell proliferation, growth control, oncogene	GO-mammals	G-3US, GO-2US	n.s.	G-1PRD, GO-3PRD	n.s.
E2F5	transcription factor	cell proliferation, growth control, brain	G-mammals	G-4US, GO-1US	0.00011	GO-2PRD	n.s.
E2F4	transcription factor	cell proliferation, growth control, cranofacial, erythroid	G-pecorans	G-2US, GO-1US	n.s.	G-1 PRD	n.s.
ETS2	ETS transcription factor	somitogenesis, heart development	G-mammals	GO-1US	n.s.	n.s.	n.s.
TGFB1	secreted growth factor	growth control, bone growth, heart	G-cetartiodactyls	G-1US	n.s.	n.s.	5*
ALDH16A1	aldehyde dehydrogenase	eye development	GO-mammals	G-3US	n.s.	G-3PRD, GO-1PRD	n.s.
FHL5	Four-half lim domains	testis, heart, brain	G-pecorans	G-2US, GO-1US	n.s.	G-1 PRD	2*
ITGA10	integrin alpha 10	heart, muscle articular cartilage	G-mammals	G-2US, GO-2US	n.s.	G-1 PRD	n.s.
ECM1	extracellular matrix protein	endochondral bone formation and angiogenesis	G-cetartiodactyls	G-1US, GO-2US	n.s.	G-3PRD, GO-2PRD	n.s.
TTYH2	chloride channel	growth control, development	G-cetartiodactyls	G-2US, GO-1US	n.s.	G-1PRD, GO-1PRD	1*
CREBBP	CBP histone acetylase	angiogenesis, skeletal growth, regulates Hox protein activity	G-mammals	G-3US, GO-US	n.s.	G-3PRD	n.s.
PTGES2	prostaglandin E synthase	heart, brain regulates smooth muscle contraction	G-pecorans	G-1US	n.s.	G-1 PRD	n.s.
IFT74	intraflagellar transport protein	ciliogenesis kidney, heart, lung	G-pecorans	G-2US, GO-2US	n.s.	G-1 PRD	n.s.
ABHD2	abhydroloase	smooth muscle cell migration	G-cetartiodactyls	G-1US	n.s.	G-1PRD	n.s.

ENG	endgolin	regulation of angiogenesis	unremarkable	G-1US	n.s.	G-1PRD, GO-5PRD	n.s.
SEMA3E	semaphorin 3E	regulates angiogenesis and neuronal synaptogenesis in eye	G-cetartiodactyls	G-1US, GO-3US	n.s.	G-1 PRD	n.s.
JARID2	modulates histone methyltransferase	heart and nervous system development	GO-mammals	GO-4US	n.s.	GO-3PRD	n.s.
CYP27B1	25-hydroxyvitamin D-1 alpha hydroxylase	bone development and calicium metabolism	unremarkable	G-1US, GO-1US	n.s.	n.s.	1*
NFXL1	NF-X1-type	skeletal growth	G-cetartiodactyls	G-2US	n.s.	n.s.	1*
AXIN2	negative regulator of Wnt signaling	embryonic somitogenesis and skeletal development	unremarkable	G-2US & 5aadel, GO-2US	n.s.	GO-2PRD	n.s.
RCAN3	inhibits calcineurin A, binds troponin	heart, brain, skeletal muscle, kidney, language SNP humans	G-mammals	G-7US	3.70E-06	G-3PRD	n.s.
BORG1	rho GTPase inhibit CDC42	heart	G-mammals	G-1US	0.00216	n.s.	6 $P<0.09$
UTS2B	urotensin 2, vasoconstrictor	regulates blood pressure in the brain	Giraffe>okapi	G-1US	n.s.	G-2PRD, GO-1PRD	n.s.
ADRA1A	adrenergic receptor	regulation of blood pressure	unremarkable	G-1US	n.s.	G-1PRD	1*
ADRA2B	adrenergic receptor	regulation of vasoconstriction	GS-mammals	G-3US, GO-1US	0.00203	n.s.	n.s.
ACE	angiotensin I converting enzyme	regulation of blood pressure	unremarkable	G-3US, GO-1US	n.s.	G-2PRD, GO-1PRD	n.s.
SSTR2	somatostatin receptor	behavior, eye, pancreas	G-mammals	G-2US, GO-1US	0.00836	n.s.	n.s.
FSCN1	fascin, organizes filamentous actin	nervous system, eye	G-mammals	G-4US	n.s.	G-2PRD	n.s.
NF2	merlin regulator of hippo pathway	auditory functions	G-mammals	G-4US	n.s.	n.s.	n.s.
CHRNA10	neuronal acetylcholine receptor	auditory functions, pain reception	G-pecorans	G-2US	n.s.	G-1PRD	n.s.
SLIT2	secreted axon guidance replusive protein	axonal guidance in the nervous system	G-cetartiodactyls	G-2US, GO-1US	n.s.	n.s.	n.s.
SEMA3A	semaphorin 3A	axonal guidance	GO-cetartiodactyls	G-2US, GO-3US	n.s.	G-1PRD	n.s.
MOXD1	monooxygenase dopamine β-hydroxylase	dopamine metabolism	unremarkable	G-1US, GO-1US	n.s.	n.s.	1*
PRPH2	perpherin-2	visual function	G-mammals	G-1US	n.s.	n.s.	1*
ALDH5A1	succinic semialdehyde dehydrogenase	brain, clearance of GABA and hydroxybutryic acid	G-cetartiodactyls	G-1US	n.s.	G-2PRD	n.s.
MTHFD1	C-1-tetrahdrofolate synthase	folate metabolism	G-mammals	G-5US, GO-1US	n.s.	G-1PRD	n.s.
SLC17A1	phosphate-sodium cotransporter	kidney	G-mammals	G-1US, GO-1US	n.s.	G-1PRD, GO-5PRD	n.s.
HIBADH	3-hydroxyisobutyrate dehydrogenase	mitochondrial, amino acid degradation	G-cetartiodactyls	G-1US	n.s.	G-1PRD	n.s.
MCT1	monocarboxylate transporter	rumen epithelium, transport volatile fatty acids, butyrate	G-mammals	G-3US, GO-1US	0.045	G-1PRD	n.s.

ACSM3	acyl-CoA synthetase medium-chain	mitochondrial	G-cetartiodactyls	G-1US, GO-4US	n.s.	n.s.	n.s.
ACADS	acyl-CoA dehydrogenase short chain	mitochondrial	GO-mammals	G-1US, GO-3US	n.s.	n.s.	n.s.
NDUFB8	NADH dehydrogenase-ubiquinone subunit	mitochondria electron transport	G-cetartiodactyls	G-2US	n.s.	G-1PRD, GO-1PRD	n.s.
SDHB	succinate dehydrogenase ubiquinone complex II	mitochondria electron transport and citric acid cycle	G-mammals	G-2US	n.s.	GO-1PRD	n.s.
PRR19	proline rich protein 19	secreted tannin binding protein	G-cetartiodactyls	G-1US	n.s.	G-2PRD	1*
MRP10	ribosomal L10 protein	mitochondrial protein synthesis	unremarkable	G-1US	n.s.	G-1PRD	1*
MDC1	meditator DNA damage checkpoint	dsDNA break repair, scaffold	G-mammals	G-6US, GO-3US 264aadel	n.s.	G-13PRD, GO-15PRD	n.s.
EXO1	exonuclease 1	DNA mismatch repair, essential for meiosis	G-cetartiodactyls	G-7US, GO-3US	n.s.	G-1PRD	n.s.
Nibrin	component of MRN complex	dsDNA break repair, chromosome integrity	G-cetartiodactyls	G-4US	n.s.	G-2PRD	n.s.
MRE11	component of MRN complex	dsDNA break repair, chromosome integrity	G-cetartiodactyls	G-3US	n.s.	n.s.	1*
SOSB2	component of SOSS complex	dsDNA break repair, chromosome integrity	G-mammals	G-2US, GO-1US	0.02544	G-1PRD, GO-1PRD	n.s.
NUDT15	8-oxo-dGTP diphosphatase	DNA repair	G-pecorans	G-2US	n.s.	G-2PRD	n.s.
SAC3D1	SAC3 domain containing protein	centrosome duplication and mitotic progression	unremarkable	G-3US, GO-1US	n.s.	G-2PRD	n.s.
HAUS2	centrosomal protein 27	centrosome assembly, cytokinesis	G-mammals	G-1US, GO-3US	n.s.	G-1PRD, GO-1PRD	n.s.
RCCD1	histone demethylase complex	chromosome segregation	G-mammals	G-2US	n.s.	G-1PRD, GO-3PRD	n.s.
HAUS6	mitotic spindle assembly	centrosome integrity cytokinesis	Pecorans>>mammals	G-5US, GO-6US	n.s.	G-3PRD, GO-5PRD	1*
ARHGAP15	Rho GTPase-activating protein	trypanosome resistance	G-mammals	G-2US	n.s.	n.s.	n.s.
LPO	lactoperoxidase	antibacterial in milk	unremarkable	G-2US, GO-2US	n.s.	G-6PRD, GO-2PRD	n.s.
SEMA7A	semaphorin 7A	cell migration, adhesion, immune response	unremarkable	G-3US, GO-2US	n.s.	n.s.	1*
REL	v-rel oncogene	lymphocyte and ketatinocyes growth and development	G-cetartiodactyls	G-6US	0.00127	G-1PRD, GO-1PRD	1*
PACRGL	E3 ubiquitin protein ligase parkin-like	unknown substrate expressed in brain	G-cetartiodactyls	G-2US, GO-1US	n.s.	G-1PRD	n.s.

Abbreviations: G=giraffe, O=okapi, GO= giraffe and okapi, m=mouse, h=human, US=unique substitution at a fixed site in other mammals, PRD=probably damaging polyphen 2 score, PSG=positively selected genes using branch-site test

SNP=single nucleotide polymorphism, GWAS=genome wide association study, n.s.=not statistically significant

[1] Homologous cattle transcript identification is listed in Supplementary Figure 1.

[2] Protein divergence is the relative branch length of giraffe (G) compared to other species on the phylogenetic protein tree. For example "G-mammals" means that giraffe has the longest branch length among all mammals compared. See Supplementary Figure 1 for gene trees. Phylogenetic tree analysis was by PhyML likelihood-based tree-searching algorithm and n=100 bootstrapping.

[3] Unique substitutions at fixed sites refers to amino acid substitutions in giraffe and/or okapi that at sites that are otherwise fixed for another amino acid in all other mammals compared. number of US sites = the number of US positions in the specific protein. p-value for US = are proteins that display an a larger number of unique amino acid substitutions at fixed sites than expected as compared to other mammals.

[4] Polyphen2 PRD = amino acid substitutions in giraffe and/or okapi that are predicted to be "probably damaging" or probably alter function-structure of the protein

[5] PSG = positive selected sites as determined by branch-site test. PSG test was performed using the coding sequences giraffe and okapi and all mammalian species of high quality in the public databases of NCBI and Ensembl. The number of positively selected sites and overall statistical significance are given.

Supplementary Table 6 Survey of major developmental genes for evidence of significant changes in giraffe compared to other eutherians

Gene Cluster/Pathway	Gene	Survey results based on amino acid sequence divergence and attributes of amino acid substitutions
Homeobox Genes	HoxA1	Unremarkable
Homeobox Genes	HoxA2	Unremarkable
Homeobox Genes	HoxA3	Unremarkable
Homeobox Genes	HoxA4	Unremarkable
Homeobox Genes	HoxA5	Conserved (with okapi and cow)
Homeobox Genes	HoxA6	Conserved (with okapi and cow)
Homeobox Genes	HoxA7	Unremarkable
Homeobox Genes	HoxA9	Unremarkable
Homeobox Genes	HoxA10	Unremarkable
Homeobox Genes	HoxA11	Unremarkable
Homeobox Genes	HoxA13	Unremarkable
Homeobox Genes	Even-skipped	Unremarkable
Homeobox Genes	HoxB1	Unremarkable
Homeobox Genes	HoxB2	Unremarkable
Homeobox Genes	HoxB3	Remarkable
Homeobox Genes	HoxB4	Unremarkable
Homeobox Genes	HoxB5	Unremarkable
Homeobox Genes	HoxB6	Conserved (with okapi and cow)
Homeobox Genes	HoxB7	Unremarkable
Homeobox Genes	HoxB8	Conserved (with okapi and cow)
Homeobox Genes	HoxB9	Conserved (with okapi and cow)
Homeobox Genes	HoxB13	Remarkable
Homeobox Genes	HoxC4	Unremarkable
Homeobox Genes	HoxC5	Conserved (with okapi and cow)
Homeobox Genes	HoxC6	Conserved (with okapi and cow)
Homeobox Genes	HoxC8	Conserved (with okapi and cow)
Homeobox Genes	HoxC9	Conserved (with okapi and cow)
Homeobox Genes	HoxC10	Unremarkable
Homeobox Genes	HoxC11	Unremarkable
Homeobox Genes	HoxC12	Unremarkable
Homeobox Genes	HoxC13	Unremarkable
Homeobox Genes	HoxD1	Unremarkable
Homeobox Genes	HoxD3	Unremarkable
Homeobox Genes	HoxD4	Unremarkable
Homeobox Genes	HoxD8	Unremarkable
Homeobox Genes	HoxD9	Remarkable
Homeobox Genes	HoxD10	Unremarkable
Homeobox Genes	HoxD11	Unremarkable
Homeobox Genes	HoxD12	Unremarkable
Homeobox Genes	HoxD13	Unremarkable
Homeobox Genes	Even-skipped 2	Unremarkable

Homeobox Genes	CDX1	Unremarkable
Homeobox Genes	CDX2	Unremarkable
Homeobox Genes	CDX4	Remarkable
Homeobox Genes	Meox1	Unremarkable
Homeobox Genes	Meox2	Unremarkable
Homeobox Genes	TBX18	Unremarkable
Homeobox Genes	PBX1	Conserved (with okapi and cow)
Homeobox Genes	MEIS1	Conserved (with okapi and cow)
Homeobox Genes	NKX3-2	Unremarkable
Homeobox Genes	NKX3-1	Unremarkable
Homeobox Genes	LDB1	Conserved (with okapi and cow)
Homeobox Genes	SHOX2	Remarkable
Homeobox Genes	CREBBP	Remarkable
Homeobox Genes	IRX6	Unremarkable
Homeobox Genes	NOTO	Remarkable
Homeobox Genes	PRRX1	Unremarkable
TGFß Pathway		
TGFß Pathway	BMP4	Unremarkable
TGFß Pathway	BMP5	Unremarkable
TGFß Pathway	TGFB1	Remarkable
TGFß Pathway	TGFBR2	Unremarkable
TGFß Pathway	GDF8	Unremarkable
FGF Pathway		
FGF Pathway	FGF8	Conserved (with okapi and cow)
FGF Pathway	FGF19	Unremarkable
FGF Pathway	FGFR2	Unremarkable
FGF Pathway	FGFR3	Unremarkable
FGF Pathway	FGFR4	Unremarkable
FGF Pathway	FGF4	Unremarkable
FGF Pathway	FGF3	Unremarkable
FGF Pathway	FGFR1	Unremarkable
FGF Pathway	FGFRL1	Remarkable
FGF Pathway	TCF15	Unremarkable
FGF Pathway	FGF21	Unremarkable
FGF Pathway	FGF1	Unremarkable
FGF Pathway	DUSP6	Unremarkable
FGF Pathway	FRS2	Unremarkable
FGF Pathway	GRB2	Conserved (with okapi and cow)
FGF Pathway	SOS1	Conserved (with okapi and cow)
FGF Pathway	BCL2L11	Unremarkable
FGF Pathway	EFNA1	Unremarkable
FGF Pathway	EPHB3	Unremarkable
FGF Pathway	HSPG2	Unremarkable
FGF Pathway	SHH	Unremarkable
FGF Pathway	PTPN11	Unremarkable
FGF Pathway	GAB1	Unremarkable
FGF Pathway	RAS	Unremarkable
FGF Pathway	RAF1	Unremarkable

FGF Pathway	FGF2	Unremarkable
FGF Pathway	Sprouty2	Unremarkable
FGF Pathway	Perlecan	Unremarkable
WNT Signalling Pathway		
WNT Signalling Pathway	WNT3A	Unremarkable
WNT Signalling Pathway	MYC	Remarkable
WNT Signalling Pathway	Rock1	Unremarkable
WNT Signalling Pathway	ZIC1	Unremarkable
WNT Signalling Pathway	VDR	Unremarkable
WNT Signalling Pathway	AXIN2	Remarkable
WNT Signalling Pathway	FZD7	Unremarkable - missing sequence
WNT Signalling Pathway	FZD5	Unremarkable - missing sequence
WNT Signalling Pathway	CDC73	Conserved (with okapi and cow)
WNT Signalling Pathway	PHLDA1	Sequencing missing in giraffe and okapi
WNT Signalling Pathway	DVL2	Unremarkable
WNT Signalling Pathway	HDAC9	Unremarkable - missing sequence
WNT Signalling Pathway	DACT1	Unremarkable - missing sequence
WNT Signalling Pathway	TNFRSF19	Unremarkable - missing sequence
WNT Signalling Pathway	FZD3	Unremarkable
WNT Signalling Pathway	HAS2	Conserved (with okapi and cow)
WNT Signalling Pathway	PPP2R1A	Unremarkable
WNT Signalling Pathway	APC	Unremarkable
WNT Signalling Pathway	SMAD4	Unremarkable
WNT Signalling Pathway	LRP5	Unremarkable
WNT Signalling Pathway	DKK1	Unremarkable
WNT Signalling Pathway	FRZB	Unremarkable
WNT Signalling Pathway	TCF15	Unremarkable
WNT Signalling Pathway	FZD1	Unremarkable
WNT Signalling Pathway	CtBP1	Unremarkable
WNT Signalling Pathway	FZD9	Unremarkable
WNT Signalling Pathway	FZD4	Unremarkable
WNT Signalling Pathway	SMARCA5	Unremarkable
WNT Signalling Pathway	CER1	Unremarkable
WNT Signalling Pathway	DVL1	Unremarkable
WNT Signalling Pathway	GSK3A	Unremarkable
WNT Signalling Pathway	GSK3B	Unremarkable
WNT Signalling Pathway	SP5	Conserved (with okapi and cow)
Notch Pathway		
Notch Pathway	DTX3L	Unremarkable
Notch Pathway	MESP2	Unremarkable
Notch Pathway	LFNG	Unremarkable
Notch Pathway	MFNG	Unremarkable
Notch Pathway	DLL1	Unremarkable
Notch Pathway	DLL3	Remarkable
Notch Pathway	JAG1	Remarkable
Notch Pathway	DLL4	Unremarkable
Notch Pathway	APH1B	Unremarkable
Notch Pathway	HES7	Unremarkable

Notch Pathway	Ripply2	Unremarkable
Notch Pathway	PSN1	Unremarkable
Notch Pathway	PSN2	Unremarkable
Notch Pathway	Notch1	Unremarkable
Notch Pathway	Notch4	Remarkable
Notch Pathway	Notch2	Unremarkable
Notch Pathway	DLK1	Unremarkable
Notch Pathway	DLK2	Unremarkable
Notch Pathway	NUMBL1	Unremarkable
Notch Pathway	HES7	Unremarkable
Notch Pathway	HEY2	Unremarkable
Notch Pathway	PSEN1	Unremarkable
Notch Pathway	HES1	Unremarkable
Notch Pathway	MESP2	Unremarkable
Notch Pathway	NKD1	Unremarkable
Notch Pathway	RTF1	Unremarkable
Notch Pathway	NRARP	Conserved (with okapi and cow)
Hedgehog Pathway		
Hedgehog Pathway	CDX2	Unremarkable
Hedgehog Pathway	SHH	Unremarkable
Hedgehog Pathway	GLI3	Unremarkable
Hedgehog Pathway	SMO	Unremarkable
Hedgehog Pathway	TRPS1	Unremarkable
Hedgehog Pathway	IHH	Unremarkable
Hedgehog Pathway		
Others		
Others	Sox9	Unremarkable