

3. Çoklu dizi hizalama

Human beta -----VHLT**PEEKSA**V**TALW**GKVN--**V**DEVGGEAL**GRLLV**VYPWTQ**RRFF**ESFGDLST
Horse beta -----VQLS**GEEKAA**V**LALW**DKVN--**E**EEVGGEAL**GRLLV**VYPWTQ**RRFF**DSEFGDLSN
Human alpha -----VLS**PA**DKTNV**KAAM**GKVG**AHAGEY**GAEAL**ERMFL**SFP**TTKTY**FPHF-DLS-
Horse alpha -----VLS**AA**DKTNV**KAAM**SKVGG**HAGEY**GAEAL**ERMFL**GFP**TTKTY**FPHF-DLS-
Whale myoglobin -----VLS**E**GE**WQLV**L**HVVAK**VEAD**VAGHQ**QDIL**LRLFK**SH**PETLEK**FDRFKHLKT
Lamprey globin PIVDTGS**VAPLSAA**E**TKT**IR**SAAW**APV**YSTY**ETSGVDIL**VK**F**PTSTPAAQ**EFFPKFKGLTT
Lupin globin -----GAL**TESQA**AL**VKSS**WEEFNAN**I**PK**H**THR**FFILV**LEI**APAAK**DLFSFLKGTSE

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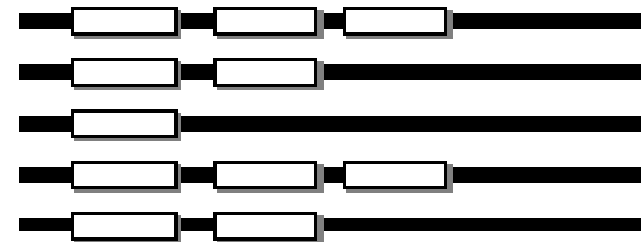
Human beta PDAVMGNPK**VKAH**GK**VLGA**FS**DGLA**HLDN-----L**KGTF**ATL**SELE**CDKLHVD**PENFRL**
Horse beta PGAVMGNPK**VKAH**GK**VLSF**GEGV**HHL**DN-----L**KGTF**AAL**SELE**CDKLHVD**PENFRL**
Human alpha ----HG**SAQ**V**KGH**GK**VADAL**T**NAV**AHVDD----**MPNALS**AL**SDL**HA**HKL**RVD**PVNFKL**
Horse alpha ----HG**SAQ**V**KAH**GK**VGDAL**T**LAV**GHLD-----L**PGALS**NL**SDL**HA**HKL**RVD**PVNFKL**
Whale myoglobin EAEMKASE**DLK**K**HGV**T**VTAL**G**A**IL**KKK**GH-----**HEAEL**K**PLAQ**SH**ATK**HKI**P**IKYLE**F**
Lamprey globin ADQL**KK**S**ADVR**W**HAER**I**INAV**ND**AVAS**MDDT--**EKMS**M**KLRD**LS**GKH**AK**SFQ**VD**PQY**FKV
Lupin globin VP--**QNN**PE**LQA**H**AGK**V**FKL**VY**EAAI**QLQ**V**TG**VVV**T**DATL**K**NLGS**V**HVS**KGVAD-**AHFPV**

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Human beta **LGNVL**V**CVLA**H**HF**GKEFT**PPV**Q**AAYQ**K**VVAG**VANAL**AHKYH**-----
Horse beta **LGNVL**V**VVLA**R**H**FGKDF**TP**EL**QASY**Q**KVVAG**VANAL**AHKYH**-----
Human alpha **L**SH**CLL**V**T**LA**AHL**PAEFT**PAV**HA**SLDK**FL**ASV**ST**VLT**SKYR-----
Horse alpha **L**SH**CLL**S**T**LAV**HLP**ND**FTPAV**HA**SLDK**FL**SSV**ST**VLT**SKYR-----
Whale myoglobin **I**SE**AI**I**H**V**L**HSR**H**PGDFG**ADAQ**G**AMN**KA**LEL**FR**KDIA**AKY**KEL**GY**Q**G
Lamprey globin **L**A**AVI**AD**TVAAG**---D-----**AG**FE**KL**MS**MIC**IL**LS**RAY-----
Lupin globin **V**KE**AIL**K**TI**KE**V**VGAK**W**SEEL**NSA**WT**IAY**DE**LAI**V**IK**KEMNDAA---

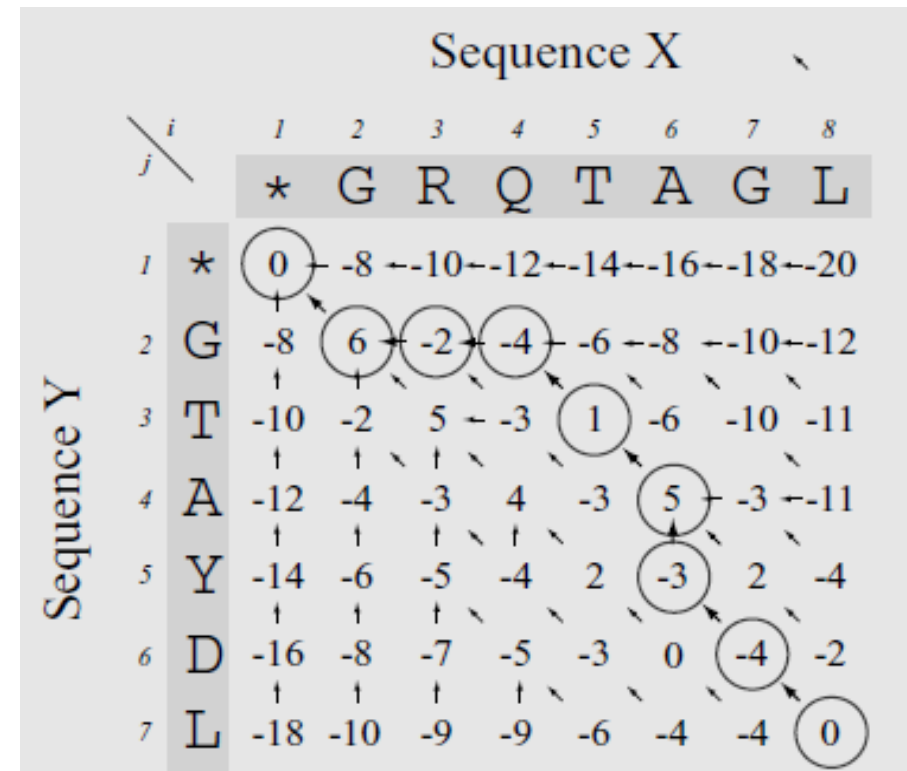
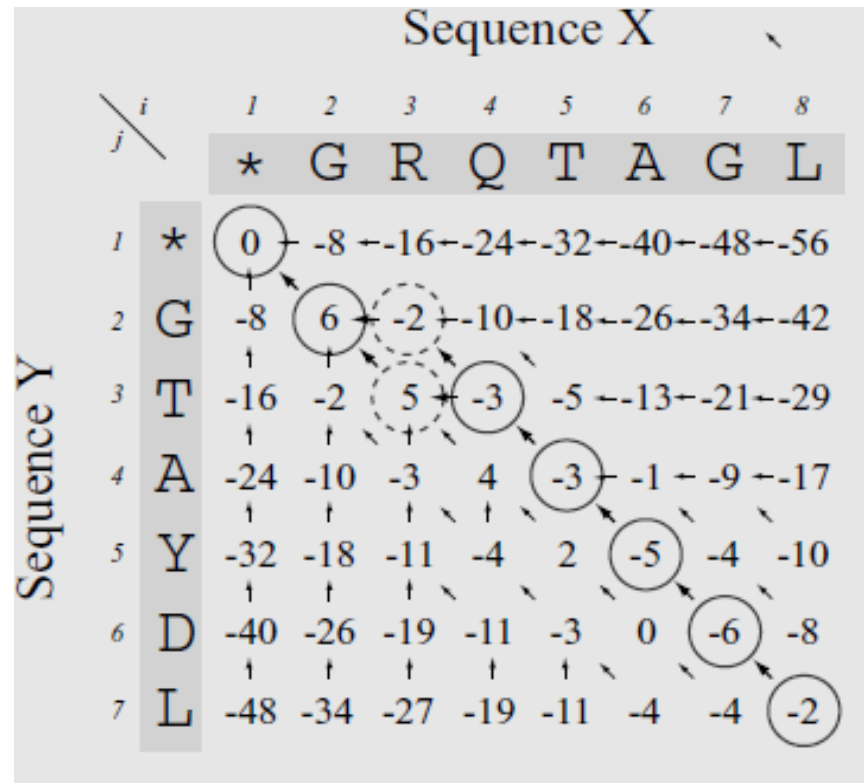
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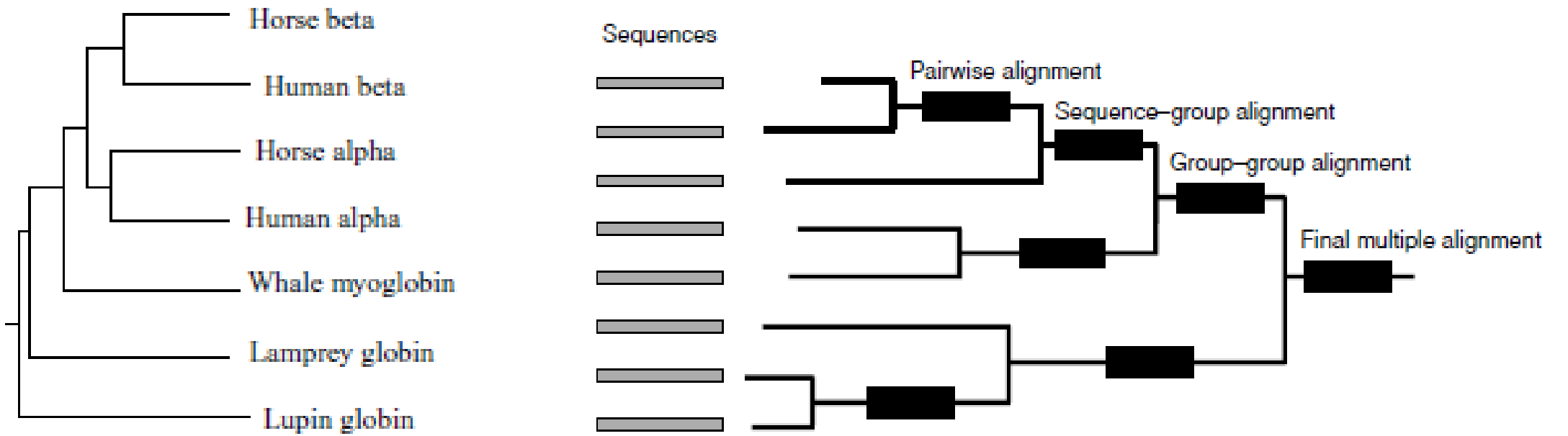
(a)



(b)

accgtacc--gtaccgt
accgtaccccgtaaccgt
accgtac--gtaccgt
accgtacac-gtaccgt

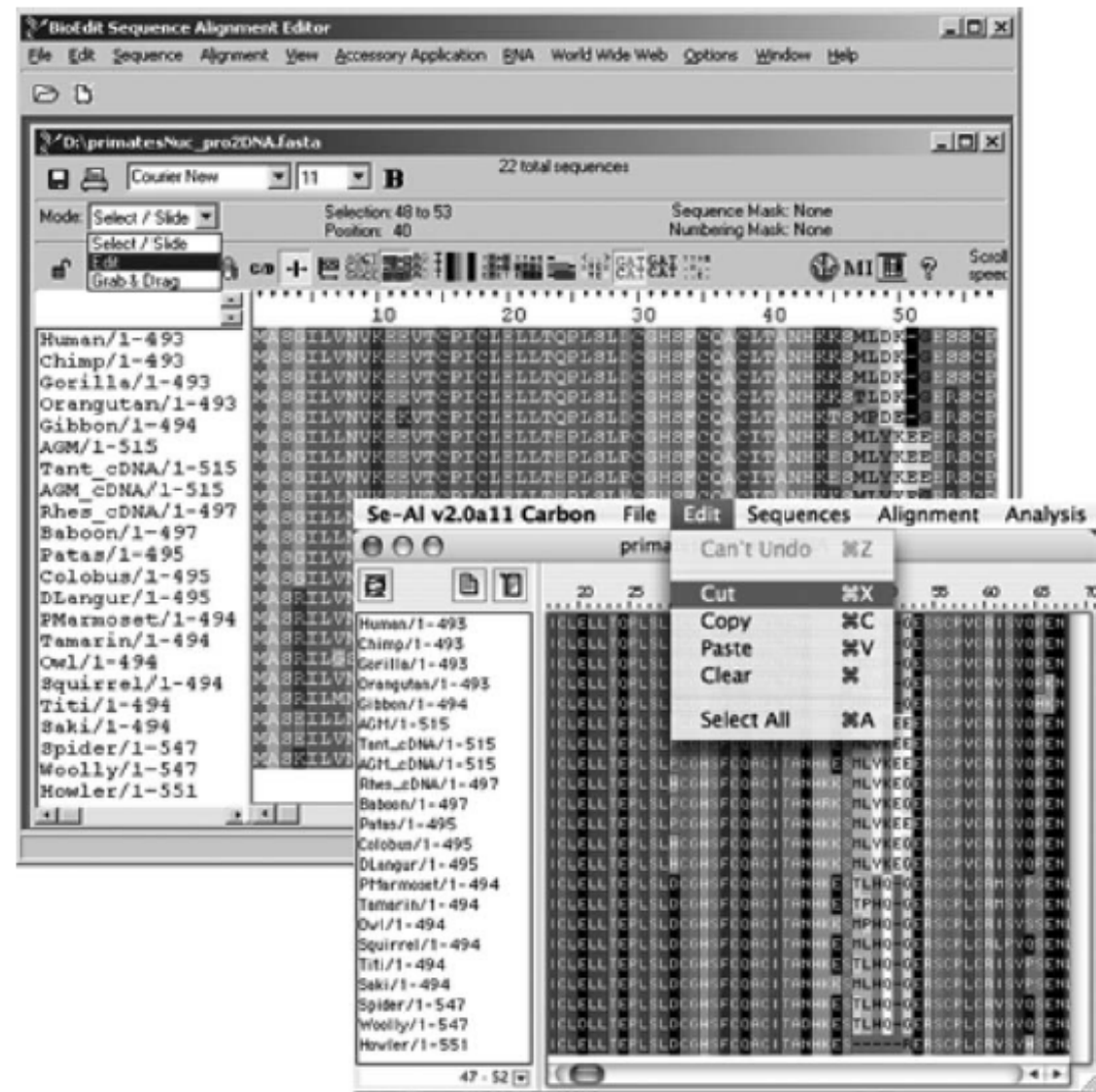




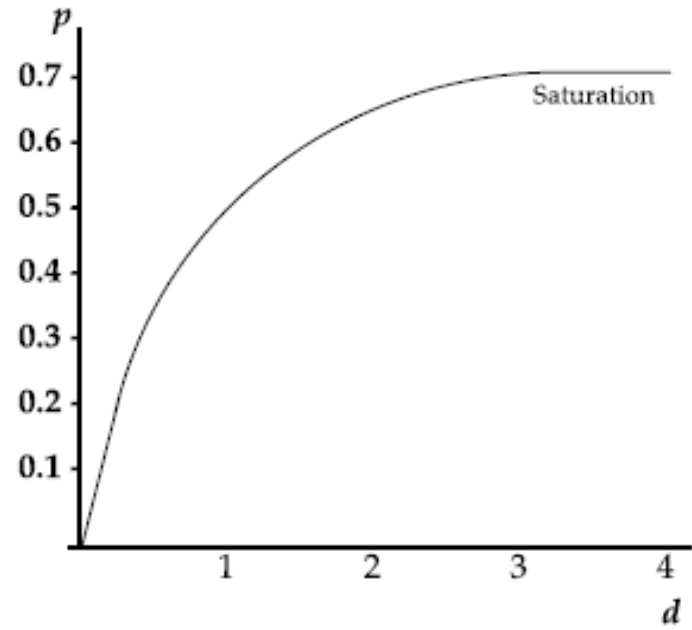
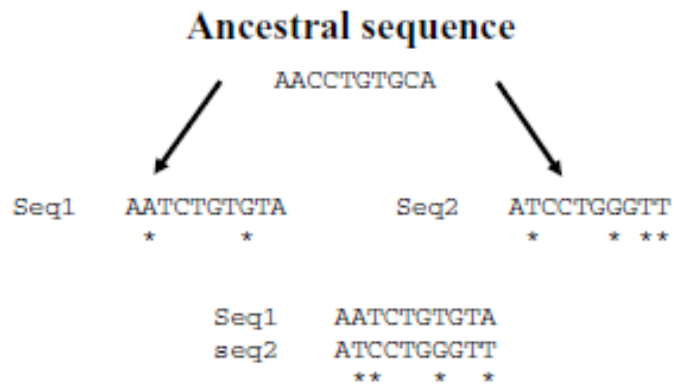
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Human      M..SMLDK-GE..PE-G..PKPQIIYGARGTRYQTFV-----N..QPDAMCNI
Chimp      M..SMLDK-GE..PE-G..PKPQIIYGARGTRYQTFM-----N..QPDAMCNI
Gorilla    M..SMLDK-GE..PE-G..PKPQIIYGAGGTRYQTFM-----N..QPDATCNI
Orangutan  M..STLDK-GE..PE-G..PEPQIIYGAGGTTYQTFV-----N..QPDAMYNI
Gibbon     M..SMPDE-GE..PEEG..PEPQIIYGAQGTISQTFV-----N..QPDAMYNI
AGM        M..SMLYKEEE..PEEG..QNPQIMYQAPGSSPGLTNFNFYCTGVLGQSITSRKLTN..QPDATYNI
Tant_cDNA  M..SMLYKEEE..PEEG..QNPQIMYQAPGSSPGLTNFNFYCTGVLGQSITSRKLTN..QPDATYNI
AGM_cDNA   M..SMLYKEEE..PEEG..RNPQIMYQSPGSLPGLTNFNSYCTGVPVGSQSITSGKLTN..QPDATYNI
Rhes_cDNA  M..SMLYKEGE..PEEG..RNPQIMYQAPGTLPTFPS-----LTN..QSDAMYNI
Baboon     M..SMLYKEGE..PEEG..RNPQITYQAPGTLPTFPS-----LTN..QPDAMYNI
Patas      M..SMLYKEEE..PEEG..RNPQIMYWAQGKLPQSLK-----N..QPDAMYDV
Colobus    M..SMLYKEGE..PEEG..PNPQIMYRAQGTLPQSLK-----N..QPDAMYNI
DLangur    M..SMLYKEGE..PEEG..Q-VPI-HQPLV-----K..KCNAKWNV
Tamarin    M..STPHQ-GE..PEEG..Q-FQI-HQPSV-----K..KCNAKWNV
Owl        M..SMPHQ-GE..PEEG..Q-KRI-YQPFL-----K..KRTASCSV
Squirrel   M..SMLHQ-GE..PEER..Q-KPI-RHLLV-----K..KCTANQSV
Titi       M..STLHQ-GE..PEEG..Q-EWI-HQSSG-----R..KCAANRNG
Saki       M..SMLHQ-GE..PEEG..Q-ERI-HQSPG-----K..KCTANRNG
Spider     M..STLHQ-GE..PEEG..Q-EQI-HQPSV-----K..KCTAN--V
Woolly     M..STLHQ-GE..PEEG..Q-QQR-HRPSV-----K..KCTAN--V
Howler     M..S-----RE..PEEG..Q-EQIHHPSP-----E..KCIQN--F
|         |         |         |         |         |         |         |         |
1         47        52        88        91        325        463        402        409

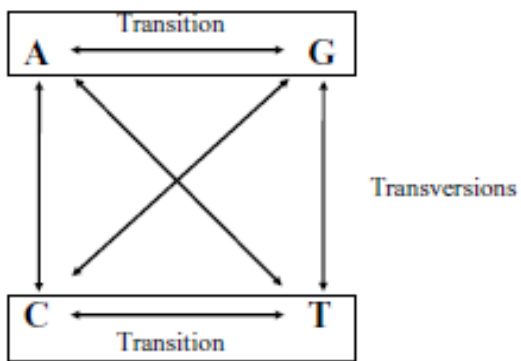
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4. Genetik uzaklıklar ve nükleotid substitüsyon modelleri



$$Q = \begin{pmatrix} \text{A} & \text{C} & \text{G} & \text{T} \\ \begin{matrix} -\mu(a\pi_C + b\pi_G + c\pi_T) \\ g\mu\pi_A \\ h\mu\pi_A \\ j\mu\pi_A \end{matrix} & \begin{matrix} a\mu\pi_C \\ -\mu(g\pi_A + d\pi_G + e\pi_T) \\ i\mu\pi_C \\ k\mu\pi_C \end{matrix} & \begin{matrix} b\mu\pi_G \\ d\mu\pi_G \\ -\mu(h\pi_A + j\pi_C + f\pi_T) \\ l\mu\pi_G \end{matrix} & \begin{matrix} c\mu\pi_T \\ e\mu\pi_T \\ f\mu\pi_T \\ -\mu(i\pi_A + k\pi_C + l\pi_G) \end{matrix} \end{pmatrix}$$



$$Q = \begin{pmatrix} \mathbf{A} & \mathbf{C} & \mathbf{G} & \mathbf{T} \\ -\mu(a\pi_C + b\pi_G + c\pi_T) & a\mu\pi_C & b\mu\pi_G & c\mu\pi_T \\ a\mu\pi_A & -\mu(a\pi_A + d\pi_G + e\pi_T) & d\mu\pi_G & e\mu\pi_T \\ b\mu\pi_A & d\mu\pi_C & -\mu(b\pi_A + d\pi_C + f\pi_T) & f\mu\pi_T \\ c\mu\pi_A & e\mu\pi_C & f\mu\pi_G & -\mu(c\pi_A + e\pi_C + f\pi_G) \end{pmatrix}$$

$$R_{ij}^{HKY} = \kappa \quad \text{for Ts}$$

$$R_{ij}^{HKY} = 1 \quad \text{for Tv}$$

$$R_{ij}^{TN} = \kappa \left(\frac{2\gamma}{\gamma + 1} \right) \quad \text{for Ts}_Y$$

$$R_{ij}^{TN} = \kappa \left(\frac{2}{\gamma + 1} \right) \quad \text{for Ts}_R$$

$$R_{ij}^{TN} = 1 \quad \text{for Tv}$$

$$\rho = \frac{\pi_R \pi_Y [\pi_R \pi_Y \tau - (\pi_A \pi_G + \pi_C \pi_T)]}{(\pi_A \pi_G \pi_Y + \pi_C \pi_T \pi_R)}$$

$$\kappa = 1 + \frac{1}{2}\rho \left(\frac{1}{\pi_R} + \frac{1}{\pi_Y} \right)$$

$$\gamma = \frac{\pi_Y + \rho}{\pi_Y} \frac{\pi_R}{\pi_R + \rho}$$

Model

Free parameters in the Q-matrix

