MEDWIN PUBLISHERS
Committed to create value for Researchers

Physical Science & Biophysics Journal
ISSN: 2641-9165

# Appendix

## Probability of EPR-Generated Hydrogen Bond Arrangements, *keto-amino → enol-imine*, Using Approximate Quantum Methods

Natural selection has designed duplex genomes for the time-dependent populating of initially unoccupied, but energetically accessible, enol and imine proton qubit states as consequences of quantum uncertainty limits, $\Delta x \, \Delta p_x \geq \hbar/2$, operating on metastable amino ($-NH_2$) hydrogen bonding protons [32-37,42-44]. The resulting quantum confinement introduces direct quantum mechanical proton – proton physical interaction in too small of space, Δx, thereby generating probabilities of EPR arrangements, *keto-amino →enol-imine,* which create position and momentum entanglement between separating product protons [10-12,16-19]. Each reduced energy product proton is shared between two indistinguishable sets of electron lone-pairs belonging to enol oxygen and imine nitrogen, and thus, participates in entangled quantum oscillations at $\sim 10^{13}$ $s^{-1}$ between near symmetric energy wells within *intramolecular* decoherence-free subspaces, until "measured by" Grover's-type [20] enzyme quantum processors [16-19,23-25,44-45]. In intervals $\delta t << 10^{-13}$ s, the quantum reader "traps" an entangled oscillating qubit, $H^+$, in a DNA groove [38]. This creates an enzyme – proton entanglement that instantaneously specifies explicit instructions for an entangled enzyme quantum search, $\Delta t' \leq 10^{-14}$ s, to select the correct incoming tautomer for pairing with the ultimately decohered eigenstate, which forms the observable molecular clock substitution, ***ts*** [16,31,35-36,42-44]. Since specification of the molecular clock, ***ts*** or ***td,*** is completed before proton decoherence, $\Delta t' < \tau_D < 10^{-13}$ s, a feedback loop exists between an entangled enzyme quantum processor "measurement" and initiation of duplex genome evolution [16-19].

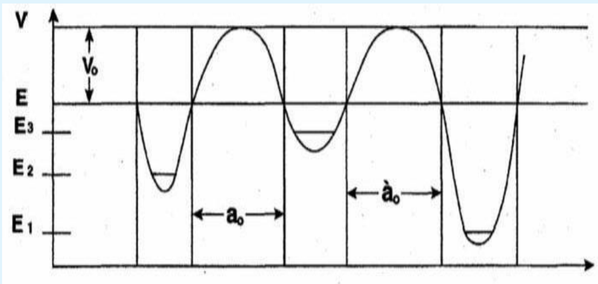
For purposes of discussing metastable keto-amino states populating reduced energy enol and imine, dynamic entangled proton qubit states, G-C → ***G′-C′*** and G-C → ****G-*C***, time- dependence for the reactive five proton system of metastable G-C to populate complementary entangled proton qubit states is modeled in terms of a "composite" proton, in an asymmetric three-well potential, illustrated in Figure 11. An expression is obtained for the quantum mechanical "rate constant" associated with the EPR hydrogen bond arrangement, *keto-amino → enol-imine,* via symmetric and asymmetric channels (Figures 2&3; Tables 1 & 2). This allows development of a polynomial expression for an evolving Darwinian, genomic system to express time-dependent alterations — classical + EPR-generated entanglements — in genetic specificities at DNA base pairs within a particular gene [16-19,39,42-44]. Here the motion of two tunneling-exchange protons, using the symmetric and asymmetric channels (Figures 2&3), is simulated in terms of a composite proton model. Secondary contributions by the 2nd asymmetric pathway (unlabeled) are neglected. At t = 0, the composite proton is replicated into the metastable state $|3>$ at energy $E_3$ which, per data and shown in Figure 11, is separated from the enol- imine ground state, $|1>$, and hybrid state, $|2>$, by approximately equal energy barriers. The relationship $E_1 < E_2 < E_3$ for the ground state, hybrid state and metastable state, respectively, is displayed in Figure 11. Enol-imine product states are designated by a general arrangement state, $|\rho>$, where the energy $E_\rho$ would equal $E_1$ or $E_2$ as appropriate. Time-dependence of an eigenstate, $|\Psi>$, is expressed by $|\Psi> = |\varphi_I> \exp(-i E_i t/\hbar)$, so $|\Psi> = |\varphi_I>$ at t = 0 [33,118-119]. The relationship $|\Psi> = \Sigma_i |i><i|\Psi>$ is used to express an eigenstate $|\Psi>$ in terms of base states $|i>$ and amplitudes Ci as

$$|\Psi> = |1><1|\Psi> + |2><2|\Psi> = |1>C_1 + |2>C_2 \quad (23)$$

where base states satisfy $<i|j> = \delta_{ij}$. The eigenstate is normalized, $<\Psi|\Psi> = 1$, and an eigenstate and eigenvalue E are related to the Hamiltonian matrix, $\Sigma_{ij} <i|H|j>$, by $\Sigma_j <i|H|j><j|\Psi> = E <i|\Psi>$, which can be rewritten as

$$\Sigma_j (H_{ij} - E^k \delta_{ij}) C^k_j = 0 \quad (24)$$

for an expression to solve for amplitudes, $\{C^k_j |\ i=1,2; j=1,2\}$. A nonzero solution to Equation (24) is available if the determinant of $\Sigma_j (H_{ij} - E\,\delta_{ij}) = 0$.




(Figure 11: Asymmetric three-well potential to simulate metastable keto-amino protons populating accessible enol-imine states in terms of a "composite" proton originating in the metastable E3 energy well at $t = 0$ where $E_1 < E_2 < E_3$).

A two-level Hamiltonian that will allow a composite proton to tunnel from the metastable state $|3>$ at energy $E_3$, to an arrangement state $|\rho>$ at energy $E_\rho$, can be written as

$$H = \begin{pmatrix} E_3 & -\alpha_\rho \\ -\alpha_\rho & E_\rho \end{pmatrix} \begin{pmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{pmatrix} \quad (25)$$

where $\alpha_\rho$ is the quantum mechanical coupling between states $|3>$ and $|\rho>$. The resulting upper and lower eigenvalues, $E_{A\rho}$ and $E_{B\rho}$, are found as

$$E_{A\rho} = \xi_\rho + \gamma_\rho \quad (26)$$

and

$$E_{B\rho} = \xi_\rho - \gamma_\rho \quad (27)$$

where $\xi_\rho = (E_3 + E_\rho)/2$, $\gamma_\rho = [(E_3 - E_\rho)^2/4 + \alpha_\rho^2]^{½}$ and $\rho = 1, 2$ for the symmetric and asymmetric channels, respectively. The time-dependent wave function $|\Psi(t)>$ of the composite proton in the asymmetric three well potential can be expressed in terms of the corresponding eigenstates as

$$|\Psi(t)> = |\Psi_{A1}> \exp(-i E_{A1} t/\hbar) + |\Psi_{A2}> \exp(-i E_{A2} t/\hbar) + |\Psi_{B1}> \exp(-i E_{B1} t/\hbar) + |\Psi_{B2}> \exp(-i E_{B2} t/\hbar), \quad (28)$$

which can be expressed in terms of physical base states $|3>$, $|2>$, $|1>$ as [120]

$$|\Psi(t)> = \exp(-i\xi_1 t/\hbar)\{|3> \exp(-i\gamma_1 t/\hbar) + |1'> \exp[-i(\gamma_1 t/\hbar + \delta)]\}$$
$$+ \exp(-i\xi_1 t/\hbar)\{|3> \exp(+i\gamma_1 t/\hbar) + |1'> \exp[+i(\gamma_1 t/\hbar + \delta)]\}$$
$$+ \exp(-i\xi_2 t/\hbar)\{|3> \exp(-i\gamma_2 t/\hbar) + |2'> \exp[-i(\gamma_2 t/\hbar + \delta)]\}$$
$$+ \exp(-i\xi_2 t/\hbar)\{|3> \exp(+i\gamma_2 t/\hbar) + |2'> \exp[+i(\gamma_2 t/\hbar + \delta)]\}. \quad (29)$$

This can be written more succinctly as

$$|\Psi(t)> = (0.5)^{½} \exp(-i\xi_1 = t/\hbar)\{|3> \cos(\gamma_1 t/\hbar) + |1'> \sin(\gamma_1 t/\hbar)\}$$
$$+ (0.5)^{½} \exp(-i\xi_2 t/\hbar)\{|3> \cos(\gamma_2 t/\hbar) + |2'> \sin(\gamma_2 t/\hbar)\} \quad (30)$$

where $|1> = |1'> e^{i\delta}$, $|2> = |2'> e^{i\delta}$ and $\delta$ of the arbitrary phase factor ei $\delta$ is $-\pi/2$ and the relation $\cos(\theta - \pi/2) = \sin(\theta)$ is used. Data show that ***ts*** rates are approximately equal for transversions and transitions; so, quantum mechanical "rate constants" for EPR arrangements, *keto-amino* → *enol-imine* via symmetric and asymmetric channels, are approximately equal (Figure 11). Since the lifetimes, $\tau$, for $37^0$C keto-amino G-C protons are, $\tau \geq 3{,}000$ years, the wave function expression in Equation (30) is applicable in the interval, $0 < t < 3{,}000$ years[35-36,118-119].

At $t = 0$, the composite proton was in the metastable state $|3>$ at energy $E_3$. The probability, $P_1(t)$, that the proton is in the ground state $|1>$, at a later time t, is given by

$$P_1(t) = |<1'|\Psi(t)>|^2 = 0.5 \sin^2(\gamma_1 t/\hbar) \quad (31)$$

which is the contribution by the asymmetric channel. The probability that the proton is in metastable state $|3>$ at time t is given by

$$P_2(t) = |<2'|\Psi(t)>|^2 = 0.5 \sin^2(\gamma_2 t/\hbar) \quad (32)$$

which is the contribution by the asymmetric channel. The probability that the proton is in metastable state $|3>$ at time t is given by

$$P_3(t) = |<3|\Psi(t)>|2 = 0.5[\cos^2(\gamma_1 t/\hbar) + \cos^2(\gamma_2 t/\hbar)] \quad (33)$$

which is the sum of contributions for protons existing state $|3>$ by the symmetric and asymmetric channels.

The sum of Equations (31 to 33), given by

$$\sum_{i=1}^{3} P_i(t) = (0.5)\left[sin^2\left({r_1 t}/{\hbar}\right) + cos^2\left({r_1 t}/{\hbar}\right)\right] + (0.5)\left[sin^2\left({r_2 t}/{\hbar}\right) + cos^2\left({r_2 t}/{\hbar}\right)\right] = 1, \quad (34)$$

is consistent with the requirement that the composite proton be confined to its set of base states, $|3>$, $|2>$, $|1>$. The time derivative of $P\rho(t)$, Equations (31 & 32), can be expressed as

$$dP_\rho/dt = (\gamma_\rho/\hbar)\sin(\gamma_\rho t/\hbar)\cos(\gamma_\rho t/\hbar) \quad (35)$$

where $P_\rho(t)$ represents either P1(t) or P2(t) and the 0.5 normalization factor is omitted. A Taylor series expansion of Equation (35) is given by

$$dP_\rho/dt \approx (\gamma_\rho/\hbar)^2 t - 4/3(\gamma_\rho/\hbar)^4 t^3 + 4/15(\gamma_\rho/\hbar)^6 t^5 + \ldots \quad (36)$$

where the first three terms are given. The experimental lifetime of metastable keto-amino G-C protons is the order of ~3,000 years, which is large compared to human lifetimes of, say, ~100 years. For times t << 3,000 years (e.g., t ≤ 100 years), one could employ a small t approximation to express the probability of metastable protons populating enol and imine states $|1>$ or $|2>$ as

$$P\rho(t) = ½(\gamma_\rho/\hbar)^2 t^2, \quad (37)$$

indicating *nonlinear* time dependence. Nonlinearity of Eq (37) is consistent with *exponential* increases observed in base substitutions, ***ts***, and deletions, ***td***, as a function of age in *nonmitotic* human mtDNA [121]. Equation (37) provides the approximate quantum entanglement term for "biological noise" in Eq (17), and expresses observable quantum contributions in the Darwinian EPR-entanglement polynomial, $\Sigma_j\beta_j t^4$ in Eq (22). For times t ≤ 100 y, this approximation accounts for the time-dependent generation of quantum informational content embodied within entangled proton qubits populating decoherence-free subspaces of ***G′-C′***, ****G-*C*** and ****A-*T*** sites in duplex genomic systems [16-19,23-25,35-36,44]. Subsequent enzyme – proton entanglement processing of entangled proton qubits introduces entanglement originated "*stochastic*" mutations, ***ts*** and ***td***, which are expressed in terms of $\Sigma_j\beta_j t^4$ in the Darwinian polynomial, Eq (22). Curiously, incidence of age-related (10 to 80 y) human cancer [77] exhibits an empirical ~ $t^4$ time-dependence (Figure 7), implying phenotypic expression of age-related cancer is a consequence of the quantum entanglement algorithm, yielding decohered products, ***ts*** and ***td.*** Based on observation and the model, Eq (22), the EPR-generated quantum entanglement algorithm introduces single nucleotide polymorphisms, ***SNPs***, which are expressed as cancer causing "driver" mutations *after* CNGS, *s* (1 ≥ *s* ≥ 0.97), have been populated by entangled proton qubits to an "unsafe" threshold, i.e., to s ≈ 0.97 + ε [16-19,42,77-80,87-88]. In this case, classical "ball-and-rod" Newtonian mechanisms do *not* contribute to "driver" mutation spectra for age-related incidence of cancer exhibited in (Figure 7) [48,55,67,89].