Box 1. Protonic induction and hydraulic action of a water soliton (Fig.1 A,B; Movie.1,2)

Definitions	Relations	Laws and Values
A. H_2O-H^+- the high-energy source of H^+: ΔE_1 – free energy of H_2O-H^+ in water. $Ek(H^+)$, $M(H^+)$, $V(H^+)$, - kinetic energy, mass, and velocity of H^+. ΔE_2 –heat of evaporation-condensation. ΔE_3 –heat of acid-base neutralization. ΔE_4 – the free energy of ATP hydrolysis ΔE_5 – the enthalpy of ATP hydrolysis in closed cycles of muscle contraction. λ – de-Broglie wavelength of H^+.	$[H_2O\text{-}H^+]/[H_2O] = EXP\{-\Delta E_1/kT\}$ $Ek(H^+) = \Delta E_1$ $V(H^+) = (2*Ek(H^+)/M(H^+))^{1/2}$ $\Delta E_1 = \Delta E_2 = \Delta E_3 = \Delta E_4 = \Delta E_5 = \Delta E$ $\lambda = h / ((M(H^+)*V(H^+))$	The Maxwell - Boltzmann relation. $\Delta E_1 = - kT*\ln[10^{-7}/ 55.6] = 20*kT$ (at 290°K, $kT=0.4*10^{-13}$ ergs) $V(H^+) = 10^6$ cm/sec = 10 km/sec $\Delta E = 0.8*10^{-12}$ ergs = 0.5proton*volt = = 11.5 kcal/mole = 48kJoule/mole $\lambda = 0.4*10^{-8}$ cm
B. Dimer's spin (s) and precession (p): Ed – the binding energy between dimers Es, Ls, Is – the dimer spin kinetic energy, angular momentum and moment of inertia. R(H1), R(H2)– spinning radiuses of the dimer two pairs of bound protons. Mp, Mw – proton and water molecule mass. Ld, Dd, Nd – the length, width and volume of dimer occupation in liquid water, assuming 2 lengthwise and 4 anti-parallel neighbors. Dw – effective diameter of a water molecule Dwp, Vwp, Ewp – the water molecule precession diameter, velocity and energy. fdp, Ldp, Edp – the dimer's precession frequency, angular momentum, and energy fmw, Emw - microwave frequency and energy. All values are related to the higher state of dimer precession.	$-Ed = \Delta E = 2*Es$ $Es = Ls^2/(2*Is)$ $R(H1) = 2*R(H2)$ $Is = 2*Mp*(R(H1)^2+R(H2)^2) = 10*Mp* R(H2)^2$ $Ls = (2*Is*Es)^{1/2} = (20*Mp* R(H2)^2*Es)^{1/2}$ $Mp = 1/A\#$ gr, $Mw = 18/A\#$ gr ($A\# = 6.022*10^{23}$ - Avogadro's #) $Nd = Ld*(Dd)^2 = 2*18/A\#\ cm^3$ $Dwp = Dd - Dw$ $Mw = 18/A\#$ gr $Ldp = 2*Mw*Vwp*Dwp/2 = \hbar$ $Vwp = \hbar/(Mw*Dwp)$, $Ewp = ½*Mw*Vwp^2$ $Edp = 2*Ewp$, $Edp = Emw = h*fdp$	The virial theorem. $Es = 0.4*10^{-12}$ erg, $Mp = 1.67*10^{-24}$ gr $R(H1) = 2*R(H2) = 1.4*10^{-8}$ cm (Fig.1a) $Ls = 25.6*10^{-27}$ erg*sec $\approx 25*\hbar$ $Nd = 6*10^{-23}\ cm^3$, $Ld = 4.2*10^{-8}$ cm $Dd = 3.8*10^{-8}$ cm, $Dw \approx 1.3*10^{-8}$ cm $Dwp = 2.5*10^{-8}$ cm $Mw = 3*10^{-23}$ gr $Vwp = 1.4*10^3$ cm/sec $Ewp = 3*10^{-17}$ ergs $Edp = Emw = 6*10^{-17}$ ergs $fdp = fmw \approx 10^{10}$ cycles/sec
C. The soliton's dimensions: $L(H^+)$, $t(H^+)$ – H^+ flight length and duration. Ns – number of water molecules per soliton. Ms, v, ρ, Rs, Ls – soliton's mass, volume, density, radius and length. Nd/r, Nr/s - number of dimers per ring, and number of rings per soliton.	$t(H^+) = 1/fmw$ $L(H^+) = 0.5*V(H^+)*t(H^+)$ $Ns = \Delta E/ Ewp = Ms/ Mw$ $Ms = Ns*Mw = v*\rho$ $v = \pi*Rs^2*Ls$, $Ls = L(H^+)$ $Rs = [v / (\pi*Ls)]^{½}$ $Nr/s = 0.5*Ns/Nd/r$	$t(H^+) = 10^{-10}$ sec $L(H^+) = 0.5*10^{-4}$ cm = 0.5 μm Ns = 26768 water molecules, $\rho = 1\ gr/cm^3$ $Ms = 0.8*10^{-18}$ gr, $v = 0.8*10^{-18}\ cm^3$ $Ls = 5*10^{-5}$ cm = 500 nm $Rs = 7*10^{-8}$ cm = 0.7 nm Nd/r = 8, Nr/s = 1673
D. The soliton hydraulic action: ΔE, ΔPo, ∇P, Fs – the soliton's energy, pressure-head, pressure-gradient, force, Fp(r), Ft(r), T(r), Vf(r) – pressure-head force, tangential motive force, shearing stress, and effective flow velocity of AS, at radius r ≤ Rs. η, FRs – water viscosity and soliton flow rate. Vs, τ - the soliton's translation velocity and propelling duration across ΔPo, in absence of external work production. V1s, H1s, f1s – velocity per unit length, power and shearing factor per unit volume. HR1s – the hydrolytic-rate per unit volume of the A-M ATPase, corresponding to H1s.	$Fs = \pi*Rs^2*\Delta P = \pi*Rs^2*L*\Delta P/L = v*\nabla P$ $\Delta E = \int v*\nabla P*dl = v*\Delta Po$ Thus: $\Delta Po = \Delta E / v$ $Ft(r) = Fp(r)$ $T(r)*2\pi*r*L = \Delta Po*\pi*r^2$ $T(r) = ½*\Delta Po/ L* r = k*r$ $T(r) = -\eta*dVf(r)/dr$ $Vf(r) = \int dVf(r) = k/\eta* (Rs^2- r^2)$ $FRs = \int Vf(r)*2*\pi*r*dr = k/(2\eta)*\pi*Rs^4$ $= \Delta Po*\pi*Rs^4/(4*\eta*Ls)$ $\tau = v/ FRs = Ls/ Vs = 1/ V1s$ $H1s = (\Delta E/v)/ \tau = \Delta Po/ \tau = \Delta Po*V1s$ $f1s = H1s/ V1s^2 = \Delta Po*\tau = \Delta Po/ V1s$ $HR1s = H1s/ \Delta E$	A general version of Archimedes Law. Bernoulli's Equation. $\Delta Po = 10^6\ erg/cm^3 = 0.1 Joule/cm^3 =$ $= 10\ Newton/ cm^2 \approx 1\ kgwt/cm^2$ Balance between the shearing force of AS and the opposing pressure-head force. Newton's Stress-Viscosity Relation. Active version of Poiseuille's Law. $\eta = 10^{-2}$ Poise = 1cP (at 20° C) $FRs = 4*10^{-17}\ cm^3/sec$ τ = 20 msec $V1 s = 50\ sec^{-1}$, Vs = 25 μm/sec $H1s \approx 5*10^7\ erg/sec/cm^3 = 5\ Watt/cm^3$ $f1s \approx 2\ mJ*sec/cm^3$ $HR1s \approx 100$ (μmole ATP)/ cm^3/sec
E. Solitons in a half sarcomere (hs): Fhso – the isometric hydraulic force in sarcomere compression. Lhs, Ahs, Vhso, Nhs – length, cross-section area, unloaded shortening velocity, and volume of a half sarcomere. V1o, H1o, f1 - velocity per unit length, power and shearing force factor per unit volume for a half sarcomere, at unloaded contraction. These relations are applied for the quantitative formulation of muscle contraction (Box3).	$Fhso = \Delta Po*Ahs = \Delta Po*Nhs/Lhs$ $Vhs(max) = V1o (max)*Lhs = V1s*Ls = Vs$ $H1o(max)*Lhs = H1s*Ls$ $\Delta Po = f1*V1o (max) = f1s*V1s$ Therefore: $H1s/ H1o(max) =$ $= V1s/ V1o(max) = f1/ f1s = Lhs/ Ls$ The same value of f1 is related in general to striated muscle contraction, therefore: f1*V1o(max) = Po = 1000grwt / cm^2 H1o = f1*V1o^2	ΔPo is independent of HR. Fhso is proportional to Ahs. $Lhs/ Ls \approx 2$ Vhs(max) = Vs = 25 μm/sec; $V1o(max) \approx 25\ sec^{-1}$; (at 20° C) $H1o(max) \approx 2.5 W/cm^3$; $f1 \approx 2*f1s = 4\ mJ/cm^3 * sec$ $= 40\ grwt*cm/cm^3*sec$ $H1o \approx 4*V1o^2\ mW/cm^3$ (at 20° C)

Box 2. Heat contributions due to elastic and baro-entropic components in a half sarcomere

Definitions	Parameters, Relations, Results
A. Heat due to series and transverse elastic elements: N, Ao, Lo – half sarcomere volume, cross-section area, and length. Sel, Tel - series and transverse elastic elements. $\Delta Lo/Lo$ - the relative extent of quick release from Po to 0. C', C1 - compliance and compliance per unit cubic volume of muscle, related to the Sel that reside in the Z-regions. Eel(=)/N, Eel(+)/N – maximal density of mechanical energy stored in Sel and Tel during isometric contraction. Q(SH) - Shortening Heat, the heat released by ongoing relaxation of the transverse elements, Tel, during isotonic shortening. Qel - the total heat released by Sel and Tel Del – Approximate duration of full tension development on the elastic elements under the intrinsic power H1o (Box1, V; Box3, III).	$(\Delta Lo/ Lo) = 6{\cdot}10^{-3}$ [1] $\Delta Lo/ Lo = C'{*}Fo/ Lo = (C'{*}Ao/Lo){*}Po = C1{*}Po$ Therefore: $C1 = (\Delta Lo/ Lo) / Po = 6{\cdot}10^{-3}\ (kgwt/cm^2)^{-1}$, and $Eel(=) / No = ½{*}C'{*}Fo^2 / (Lo{*}Ao) = ½{*}C1{*}Po^2 = 0.3\ mJoule/ cm^3$ Assuming equal contribution of elastic energy in each orthogonal direction: $Q(SH)/ N = Eel(+)/ N = 2{*}Eel(=)/ N = 0.6\ mJ/ cm^3$ $Qel / N = Eel(total)/ N = E1el = 0.9\ mJ/ cm^3$. These values account for measurements of heat of shortening, which depends on the isotonic load, and for the duration of tension development in isometric contractions, namely: $Del \approx E1el/H1o \approx 1/(4{*}V1o^2)$ sec (at 20° C)
B. Heat due to a bulk baro-entropic effect in water: N, P, T - volume, pressure, and temperature (°K) of the water phase. $\beta=1/N{*}(\partial N/\partial P)_T$ - water compression coefficient. $\gamma = 1/N{*}(\partial N/\partial T)_P$ - water coefficient of thermal expansion. Q(BEH) - Baro-Entropic Heat, heat exchange due to change in entropy (ΔS) associated with change in the bulk water pressure (ΔP): By the Gibbs' thermodynamic potential: $dG = -S{*}dT+N{*}dP$ $(\partial S/\partial P)_T = - (\partial N/\partial T)_P = - \partial^2 G/(\partial P{*}\partial T)$ $\Delta S = \int (\partial S/\partial P)_T{*}dP = - \int (\partial N/\partial T)_P{*}dP = -\gamma{*}N{*}\Delta P$ $Q(BEH) = T{*}\Delta S = -\gamma{*}N{*}T{*}\Delta P$ (T in °K)	Bulk water expansion and entropy heat exchange are anticipated during isometric contraction due to a maximal decrease in hydrostatic pressure, $\Delta P = -Po$, within about half sarcomere volume. Thus: $\Delta N/N = 1/2{*}\beta{*}\Delta P = 25{*}10^{-6}$ Where $\beta = -50{*}10^{-6}\ (kgf/cm^2)^{-1}$ at 20 °C, as observed [2] $Q(BEH)/ N = T{*}\Delta S/ N = 1/2{*}\gamma{*}T{*}Po = 3{*}10^{-2}\ kgwt{*}cm/cm^3 = 3\ mJ /cm^3$, Where for water at T= 300°K, $\gamma = 2{*}10^{-4}\ deg^{-1}$. This relation predicts heat absorption during a rise in tension, and reversible heat release during relaxation, above 4°C, and vise-versa below 4°C where $\gamma < 0$, as observed [3,4].

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Box 3. Mechano-chemical conversion into hydraulic compression by active streaming in isotonic and isometric contractions (Fig.3; Interactive Workbook 1)

Definitions	Relations
I. A. The power-balance and force-velocity relations **J. (for a half sarcomere of 1μm at 20˚C)*:** Hm', Hq', Hh' – mechanical, heat and hydrolytic power components. u, e – rate, and mechano-chemical energy, of ATP hydrolysis. Ht', Hc' – heat components due to translation and circulation of AS. Vt', Vc' – flow velocity of the translation and circulation of AS. V' = Vt', F' - shortening velocity and the hydraulic force. Ft' = f*Vt', Fc' = g*Vc' – fluid shearing forces related to Vt' and Vc'. L, A, N – length, cross-section area and volume. V1 , P1 , H1 – velocity, force, power, per unit of length, area, volume. V1o, P1o, H1o – the above unloaded and isometric values. V , P, , H - the variables normalized by the isometric values. * Note that no account is made for the expansion effect and for viscosity changes with temperature.	Hm' + Hq' = u*e Hm' + Ht' + Hc' = Hh' $F'*Vt' + f*Vt'^2 + g*F'^2$ = Hh' / A*L = N $P1*V1 + f1*V1^2 + g1*P1^2$ = Hh1 / Normalize $P1o*V1o*P*V + f1*V1o^2*V^2 + g1*P1o^{2*}P^2$ = Hh1 Divide by $Hh1o = f1*V1o^2 = g1*P1o^2$ to get the normalized relation: **Hm + Hq = Hh (1)** **$a*P*V + V^2 + P^2 = Hh$ (1')** **a** = Fo'*Vo'/ Hho' = P1o*V1o/ Hh1o = P1o/(f1*V1o) = V1o(max)/ V1o Where: P1o = Po = $1 kgwt/cm^2$, V1o(max) = 25 1/sec (at 20˚C)
B. The Fenn Effect inclusion: The Fenn Effect was revealed as an increase of Hh in linear proportion to Hm. Theoretically, this effect is predicted by a decrease in the soliton lifetime upon external energy transfer. Thus, a change in Hm induces equal but opposite changes in both Hh and Hq, relative to Ho=Hho=Hqo = 1. This argument leads to the differential and integral relations of the Fenn Effect. As presented and enacted in the attached Microsoft Excel workbook, The P-V profile for a given value of **a,** is obtained by taking the variable parameter Hm in steps from zero to its optimum value Hmop, and down to zero. Thus, Eq.3 enables to construct the P-V profiles of isotonic contractions (Fig.3 A,B), isometric tetanus, and twitch contractions (Section **C**, Fig.3 C, D)). It further enables a theoretical evaluation of the phenomenological force-velocity relation of A. V. Hill.	**The differential relation for the Fenn Effect:** **dHh/dHm = - dHq/dHm (2)** Apply Eq.2 on Eq.1 to get the integral Fenn Effect relation: **Hh = 1+ Hm/2, Hq = 1- Hm/2 (2')** Substitute Hh = 1+ 0.5*a*P*V in equation (1'), to get: **$a*P*V + V^2 + P^2 = 1 + 0.5*a*P*V$ (3)** Substitute P = Hm/(a*V) to get: **$V^4 - b*V^2 + c = 0$ (3')** Where **b = 1- Hm/2 ; $c = (Hm/a)^2$** By symmetry, the solution of Eq.(3') for a given Hm and a is: **$(V^2)_{1,2} = (P^2)_{2,1} = b/2 \pm ((b/2)^2 - c)^{1/2}$ (3'')** At optimum : **Pop = Vop, (b/2)op = Hmop/a (3''')** Therefore: **$Hmop = 2*a/(a+4) = a*Pop^2$** **$Pop = (2/(a+4))^{1/2}$** **$a = 2/Pop^2 - 4$**
C. Isometric contractions against elastic elements: **Tetanus (Fig.3 C of the manuscript):** C', C1, C – compliance, compliance per unit cubic volume of muscle, and the normalized compliance. Em, Eq, Eh – Normalized mechanical, heat, and input energy. These values are obtained by numerical integration of successive isotonic states, as presented in the attached workbook (Suppl Workbook 1). To, Eo – the units of time and energy, defined by V1o and H1o. **Twitch (Fig. 3 D):** C(P, N(t)=1) – The load-normalized compliance for twitch contraction that develops the tension P, during the time t, when the AS circulation, Vs, just spans the whole sarcomere volume. This total circulation flow is presumed to allow for peripheral effective depletion of calcium ions by the sarcoplasmic reticulum.	dL\`= C\`dF\`=>V\`= C\`*dF\`/dt\` (4) The normalized formula is: dL/dt = V = C*dP/dt (4') Where: dL= dL\`/Lo, V = V'/V'o = V1/V1o ; F = F'/Fo'= P'/Po = P; C1 = C'*Ao/Lo = dL/dP' ; C=C1*Po; dt=dt\`/to; to=1/V1o; Eo = H1o*to dEm/dt = Hm => dt = dEm/Hm (5) $Em(t)=\int Hm*dt=\int a*V*P*dt=\int a*C*dP/dt *P*dt = 0.5*a*C*P(t)^2$ (6) $Eq(t) = \int Hq*dt = \int (1-Hm/2)*dt = t - Em(t)/2$ (7) $Eh(t) = \int Hh*dt = \int (1+Hm/2)*dt = t + Em(t)/2$ (7') Twitch condition: $N(t) = \int Vs*dt = 1$, where: $Vs = (Hh)^{1/2}$ (8)

Table 1.Molecular distances in a pair of dimers (Fig.1A)

	O12-H12		**O11-H11**			**O12-H21**	**O11-H12**				**O11-H21**			**O11-H22**
OH	1		2			3.16	3.61				5.83			7.81
		O12-O21			O11-O12			O11-O21					O11-O22	
OO		1.41			2.83			4.24					7.07	
								H12-H22 =						
		H12-H12		H11-H12	H11-H11			H11-H21	H12-H22'	H11-H21'		H11-H22		
HH		1.41		2.65	2.83			4.24	4.47	5.10		6.56		