Muscle Contraction by Endogenous UV

Thomas Prevenslik
QED Radiations, Berlin, Germany

Abstract

Muscle contraction is proposed to occur by electrostatic charge from endogenous EUV radiation created from the heat absorbed in myosin heads. The EUV is the consequence of the Planck law of quantum mechanics that denies head atoms the heat capacity for conservation to proceed by an increase in temperature. With both myosin and actin naturally carrying negative charge, the EUV charges the myosin heads positive allowing Coulomb attraction with the nearby axially disposed negative charged α-actin at the Z-line. Muscle attraction occurs for < 15 ms until the myosin tip contacts the α-actin, at which time the charge is neutralized and muscle contraction ceases. Muscle relaxation occurs as now both negatively charged myosin and actin undergo Coulomb repulsion.

Introduction

In the 1960's, the origin of life captivated biological research. Mitchell proposed [1] ATP synthesis in mitochondria followed hydrolysis given by chemiosmosis driven by the flow of H+ ions across the inner membrane. Chemiosmosis occurs by chain of complex redox reactions with electron transfer from donors to acceptors assisted by enzymes. In contrast, Sagan et al. [2] proposed life on the early Earth began by a dehydration reaction under intense UV radiation and showed experimentally ATP was formed from ADP + P under UV. However, ATP by hydrolysis and not UV dehydration was included in the sliding-filament model [3,4] of muscle contraction. The contraction between actin and myosin is thought to be a conformation [5] of myosin heads of ADP + P attaching to actin to perform the power stroke. Upon binding with another ATP, the head detaches from actin in recovery by a conformation change, the process repeating like a ratchet during sliding.

In 1971, the cross-bridge mechanism [6] comprising a repetitive ratchet attachment and detachment of the myosin head to actin [3-5] was adopted as the sliding-filament model of muscle contraction. Estimates of the axial force on the actin were based on the potential energy difference ΔU between myosin head positions of attachment of a cross-bridge, $\Delta U = 4\ k_B T$, where k_B is Boltzmann's constant and T is absolute temperature. Letting h be the travel the stable positions, the force $F = k_B T/h$ that for h = 8 nm gives F = 2 pN and link stiffness k = F/h = 0.25 pN/nm. Since actual muscle fiber pressure $p = 3 \times 10^5$ N/m^2, about 1.5×10^{17} bridges per m^2 are therefore required in each half-sarcomere. But the number of bridges in half-sarcomeres observed in micrograph (Plate III) of [7] is < 150 - far less than required by cross-bridge theory.

Beyond the fact that the cross-bridges lack the ability to produce contractile force, criticism [8] was based on the ratchetting in attachment and detachment to cause discrete forces instead of the smooth force measured during muscle contraction. Consistent with a smooth force, the myosin heads were assumed [8] to act like individual electric dipoles activated by ATP to electrostatically attract the actin filaments. Other electrostatic mechanisms proposed included: electrical double-layers between myosin and actin filaments [9], differences in axial atomic spacings between myosin and actin filaments [10], axial myosin filament contraction from radial charge repulson of surrounding actin filaments [11], and the release of positive Ca^{++} ions from actin attracting the negatively charged myosin filament [12]. However, the aforesaid electrostatic mechanisms appear to lack a credible muscle contraction process by which ATP energy is converted to electrostatic charge. The seminal question in muscle contraction as is: How is chemical energy converted to mechanical work?

In answering this question, similarity is found with endogenous UV providing an alternative [13] to creating ATP by chemiosmosis in mitochondria, the endogenous UV allowing ATP production to continue after ozone blocked solar UV from the early Earth.

PURPOSE

To propose muscle contraction as the consequence of converting heat from the surroundings into the mechanical work of contracting actin filaments by electrostatic forces induced by charge in the myosin, the charge created by the photoelectric effect from endogenous EUV radiation produced in myosin heads by simple QED radiation. The Sliding-filament model adapted for endogenous EUV in muscle contraction is shown in Fig. 1.

(a)

(b)

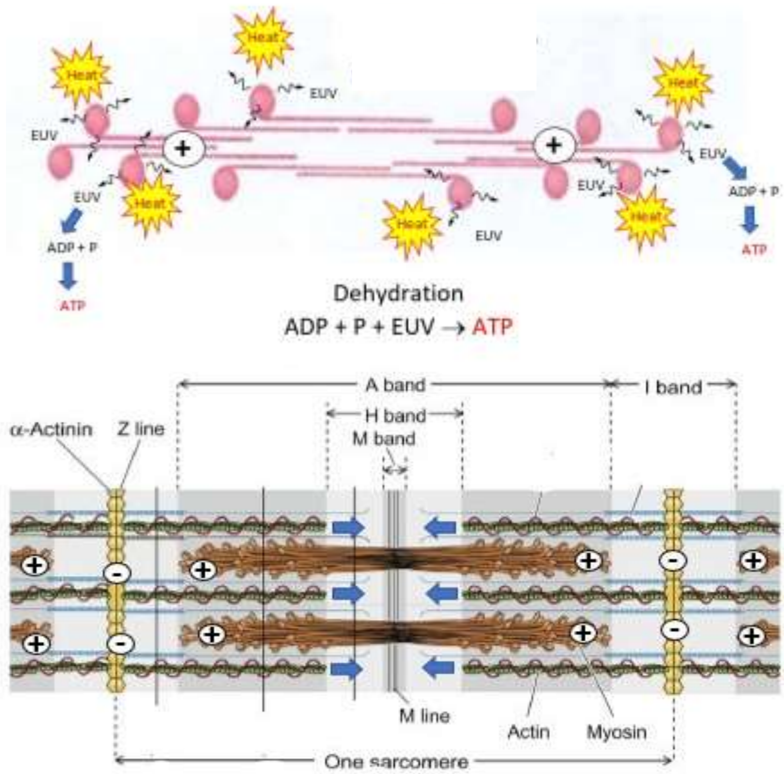

Figure 1. Endogenous EUV induced Muscle Contraction

The myosin molecules including heads absent actin filaments is shown in Fig. 1(a). The myosin heads are depicted locally absorbing heat Q. The heat is inherent in the thermal surroundings from all sources, not necessarily ATP alone. On a relative basis, a single ATP heat released in binding to the head is a small fraction of the heat contributing to the temperature of thermal surroundings.

The myosin heads are treated as 20 nm spherical nanoparticles (NPs) comprised of atoms absent heat capacity by the Planck law. The NPs cannot conserve heat Q by an increase in temperature and instead emit spherical EUV radiation that fluoresces down to UV levels. The EUV is used in a dehydration reaction with available ADP and P to produce ATP. However, the EUV also removes electrons from the myosin heads by the photoelectric effect to create positive charge as shown in Fig. 1(b).

With both myosin and actin initially charged negative, the positive charged area near the myosin tips undergoes Coulomb attraction to the negative charged α-actin ends at the Z-line. Upon contact of the myosin tips with the actin at the Z-line, the positive charges are neutralized and muscle contraction ceases. Muscle relaxation occurs by Coulomb repulsion of negatively charged myosin and α-actin.

ANALYSIS

Endogenous EUV from myosin heads depends on simple QED - a method of analysis applicable [13] to nanoscale heat transfer. Simple QED is not the complex light and matter interaction based on virtual advanced by Feynman and others. Instead, simple QED based on real photons is immediately understood by the Planck law of quantum mechanics that requires the heat capacity of constituent atoms in nanoscale structures to vanish under EM confinement. In contrast, classical physics always assumes the atom has heat capacity and produces an increase in temperature upon the absorption of heat. Simple QED differs as the nanostructure conserves heat by the creation of standing EM radiation inside and across the thickness d of the nanostructure as illustrated for a NP in Fig. 1.

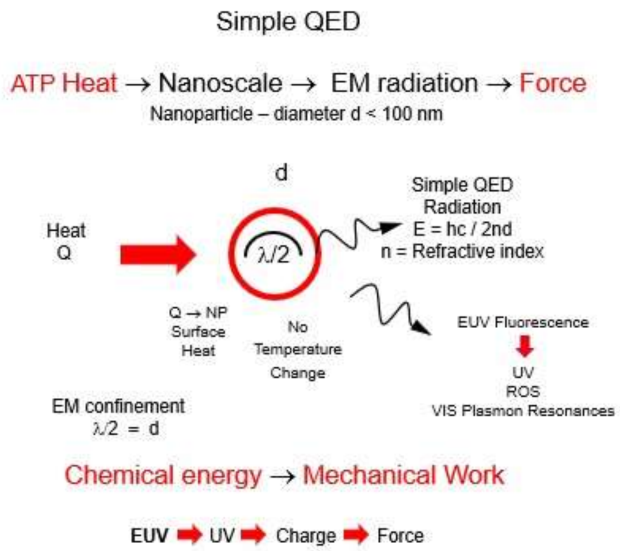

Figure 1. Simple QED conversion of Heat to EM radiation

The heat Q into the NP is transferred from blood or tissue as a thermal bath. Because NPs have high surface-to-volume ratios, the heat Q is almost totally absorbed in the NP surface. The NP temperature cannot conserve the surface heat by an increase in temperature, and instead a standing EM wave is created inside and across the diameter d of the NP having half-wavelength $\lambda/2 = d$. Correcting the velocity of light c for the refractive index n of the NP gives the time $\tau = 2d/(c/n)$ for 1 cycle. Hence, the wave frequency $c/\lambda = 1/\tau = c/ 2nd$ gives $\lambda = 2nd$.

Depending on NP size, simple QED creates standing EM waves from the UV to the EUV. For diameters d < 50 nm, the EM radiation is in the EUV while near the upper limit of 100 nm produces simple QED produces UV and IR. The EM confinement to create the standing wave is the momentary surface heat imposed by the high surface-to-volume ratios of NPs. The EM radiation is emitted once the surface heat is dissipated in creating the EM standing wave. Typically, EUV waves excite lower quantum states by fluorescence, i.e., lowering EUV to UV, ROS, and VIS plasmon resonance levels, although at < 10 percent efficiency. For myosin at UV wavelengths having refractive index $n \sim 3$, the simple QED wavelengths $\lambda = 2nd$ produced for Myosin diameters d < 100 nm is shown in Fig. 2.

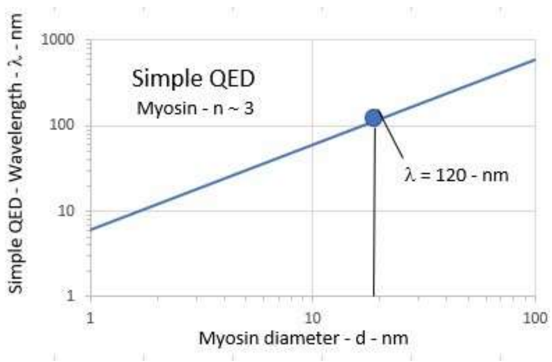

Figure 2. Simple QED wavelength v. Myosin diameter

In muscle contraction by endogenous UV, the Coulomb attractive force F in terms of the distance X between a positive q charged head and negative charged surroundings is,

$$F = \frac{q^2}{4\pi\varepsilon_o \varepsilon X^2}$$

where, ε_o is the permittivity, and ε the relative permittivity of the medium. The relative permittivity of water $\varepsilon \sim 80$ is not applicable. In low KCl concentrations [14] the relative permittivity ~ 4.7. In the early analysis [6] of the cross-bridge, the F = 2 pN force was found at X = 8 nm. The corresponding charge q is,

$$q = X\sqrt{4\pi\varepsilon_o \varepsilon F}$$

chargeHence, the head has q = 1.6 e electron charges, a single positive charge occurring at X = 4.9 nm. What this means is the myosin head was charged by at least 1 EUV photon. In general, the electrostatic force F occurs between many positive myosin heads and the negative charged α-actin hard stop at the Z-line. In simplification, the average of positive charges is taken to be located at X shown in Fig. 3.

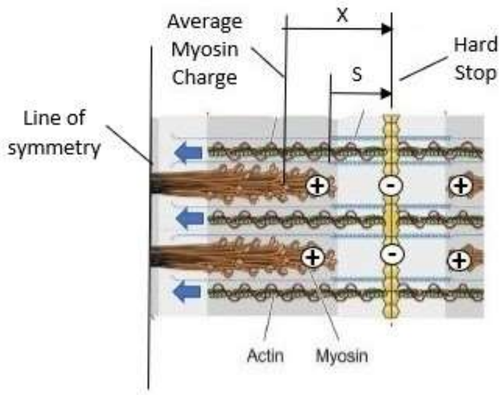

Figure 3. Average positive Myosin head

Once again, taking the electrostatic force F = 2 pN and assuming the average distance X = 500 nm, the positive charge q ~ 100 electron charges or 100 singly charged myosin heads. Assuming each myosin head produces 1 EUV photon that fluoresces down to 1 UVC photon, 1 electron is emitted leaving the head with a single positive q charge. Since about 150 myosin heads are available in a half-sarcomere, 100 heads producing the 2 pN contraction force is possible.

But is the single EUV photon created by thermal metabolic heat or ATP binding?

Consider the heat Q from the thermal surroundings to create the EUV photon and ignore the heat from ATP binding. The change in surface temperature ΔT under the absorption of the Planck energy E of a EUV photon is given [15] for large muscle and blood surroundings by,

$$\Delta T = \frac{1.2H}{\beta\sqrt{\pi}}\left[\sqrt{t+\Delta t} - \sqrt{t}\right]$$

where, t = time, Δt = pulse duration, H = E /Δt and E = hc/2nd, β = thermal effusivity, $\beta = \sqrt{K\rho C}$ where K, ρ, and C are thermal conductivity, density, and specific heat. Combining,

$$\Delta T = \frac{1.2}{\pi d^2 K}\left(\frac{E}{\Delta t}\right)\sqrt{\frac{\alpha}{\pi}}\left[\sqrt{t+\Delta t} - \sqrt{t}\right]$$

Here, α = thermal diffusivity, $\alpha = K/\rho C$. The Planck energy E of the EUV photon for d = 20 nm and refractive index n ~ 3 gives λ = 120 nm and E =1.66 x 10^{-18} J = 10.35 eV assumed spread over the spherical surface area $\pi d^2$of NP diameter d. The EUV photon is created in time Δt = 2d / (c /n) = 0.4 fs. Hence, the EUV heat Q = E/Δt ~ 4 mW. Taking α = 1.24 x10^{-7} m^2/ s and K = 0.52 W /m-°K, the surface temperature increasing ΔT ~ 19 °K that rapidly vanishes in < 1 ps as shown in Fig. 4.

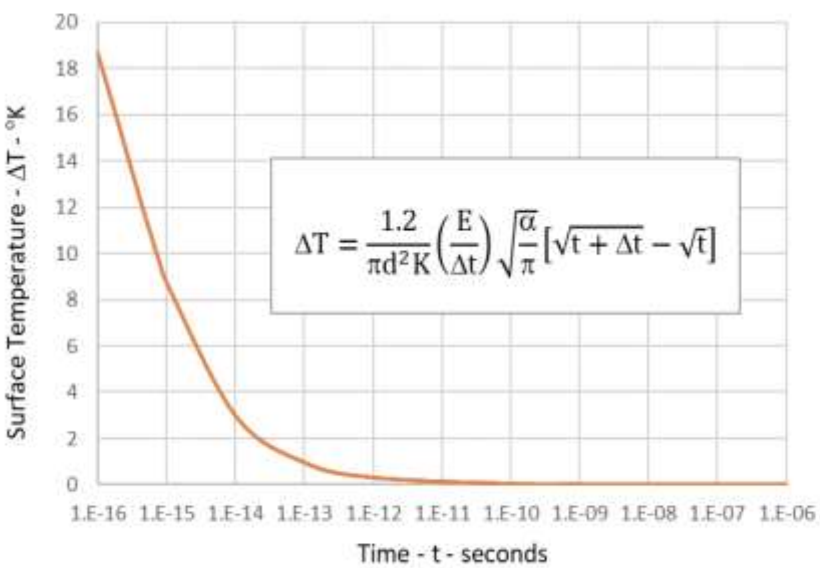

Figure 4. Myosin head surface temperature in creating EUV photon

What this means is EUV creation in the myosin heads do not depend on the heat of ATP binding. The single EUV photon is created from the thermal surroundings alone. This is necessary as a single ATP binding to the myosin head only releases 0.304 eV - far less than the 10.35 eV required to create the EUV photon. Moreover, the < 150 myosin heads on the half-sarcomere are more than sufficient to produce muscle contraction.

Consistent with the 3-15 ms response observed in muscle contraction, the X = 500 nm between the average position of myosin charge and the Z-line only initiates the contraction force. Moreover, the force F is likely > 2 N causing the positive myosin tip to neutralize upon contacting the negative charged α-actin at the Z-line. The myosin head now charged negative undergoes Coulomb repulsion in returning to its initial position for the next muscle contraction.

CONCLUSIONS

Muscle contraction in the sliding-filament model by cross-bridges is superseded by electrostatic attraction from positive charged myosin heads near the negative α-actin Z-line, the charge created from endogenous EUV by conserving heat from the thermal surroundings.

ATP In mitochondria extended to muscle contraction is produced by endogenous UV instead of hydrolysis by chemiosmosis from a H+ ion gradient through the membrane wall.

Metabolic heat creates the EUV photon inside the myosin head to allow photoelectric charging. A single ATP binding to a myosin head releases 0.304 eV, but a UVC and EUV photon require 4.88 and 10.35 eV. Heat from the thermal surroundings powers muscle contraction and not ATP binding.

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