Spindle Assembly by QED Induced Radiation

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***Abstract*—Spindles in cells assemble around tangled chromatin by self-organization of microtubules (MTs). In centrosomal spindles, MTs are thought catalyzed by centrosomes at the spindle poles, but this is questionable because anastral spindles without centrosomes also assemble. In this paper, MTs in both chromosomal and anastral spindles are proposed to self-organize by photolysis from the QED induced EM radiation emitted from the MTs themselves. QED stands for quantum electrodynamics and EM for electromagnetic. In the cell, MTs are straight fibers while the chromatin fibers are tangled, but otherwise both have diameters of about 25 nm, and as such are subject to constraints of zero specific heat capacity imposed by quantum mechanics (QM). Hence, thermal energy absorbed by the fibers from collisions of water molecules cannot be conserved by an increase in temperature. Instead, conservation proceeds by the creation of QED induced photons *inside* the fibers under EM confinement by total internal reflection (TIR). TIR confinement creates energetic QED photons that by photolysis provide both the energy to nucleate MTs on chromatin fibers and grow MTs from tubulin by polymerization. However, QED photolysis is indiscriminant and allows disassembly upon binding of MTs by severing proteins. MT growth therefore competes with disassembly depending on the molecules in the surroundings. The MTs self-organize into spindles having overall diameters from 150 to 250 nm also emit QED induced radiation, thereby charging the spindles positive to attract negative charged MTs from the surroundings. QED radiation is fundamental physics applicable to diverse range of phenomenon, and is therefore is extended to a discussion of how life itself began on the early Earth.**

Keywords - spindle, chromosomal, anastral, self-organization, autocatalytic, quantum mechanics, quantum electrodynamics

I. INTRODUCTION

The mitotic spindle comprised of MTs mediates chromosome separation during cell division. Spindle assembly arranges MTs around tangled chromatin fibers in the cell nucleus. While centrosomes are considered the main source of MT production in mitotic spindle assembly, the mechanism of MT production during assembly of anastral spindles, which do not have centrosomes, is unknown. Anastral spindles assemble during meiosis in oocytes and egg cells. See .e.g. [1].

But the spindle assemblies whether chromosomal or anastral are never stable. Since the discovery of dynamic instability in the mid-1980s, MTs are thought [2] stabilized by the spindle environment. However, single molecule imaging has recently shown tubulin molecules spend only a few seconds in the spindle contrary to the standard models of polymerization dynamics. Lacking a credible physical mechanism for dynamic instability, phenomenological models are therefore formulated, e.g., motion of MT ends by a biased random walk.

In this regard, the lack of a physical mechanism for spindle assembly has prompted [3,4] the notion of autocatalytic MT production. The literature abounds with explanations of how autocatalytic processes by creating order out of disorder violate the Second Law of Thermodynamics. But in fact, the First Law is also violated because autocatalysis is assumed to occur without a source of energy, e.g., the energy necessary to order random motion into uniform motion. The problem is the energy source may not be obvious, and therefore the observer concludes that autocatalysis explains how disorder may proceed to order without a source of energy.

Such is the case with MTs in spindle assembly. Autocatalytic MT production is generally thought to explain spindle assembly, but is disguised as QED induced radiation produced in the MTs from thermal energy absorbed from collisions with intracellular water molecules. Collisions of water molecules having far smaller mass than the MTs are inelastic, and therefore the full kinetic energy of the water molecules is very efficiently absorbed by the MTs. In this way, QED radiation transforms molecular disorder into energetic QED photons that drive chemical reactions by photolysis.

Not only does QED induced radiation emitted by a MT provide the energy for chemical reaction, the QED radiation induces the electrostatic attraction that organizes the MTs into the cylindrical shaped spindle. Individual MTs have a diameter of about 25 nm while the spindle has a diameter from 150 to 250 nm. The EM confinement of the MTs by TIR therefore is greater than that of the bundle, and therefore energetic QED photons in the individual MTs are more than 6 times more energetic than in the bundle as a whole. Nevertheless, the QED photons in the composite spindle still have Planck energy beyond the UV sufficient to remove electrons by the photoelectric effect, thereby charging the spindle positive. But individual MTs separated from the spindle [5] carry a negative charge. Electrostatic attraction of individual MTs in the surroundings to the spindle is therefore the mechanism by which the MTs assemble into a cylindrical bundle.

The importance of QED radiation in providing the energy to allow the self-organization of MTs in spindles may be extended to life itself. Indeed, autocatalytic models of self-organization [6] claim living systems are maintained by dissipating matter and energy, and therefore require a continual source of energy for nourishment, e.g., the adenosine triphosphate (ATP) molecule that acts as a chemical catalyst to break down food proteins by hydrolysis is likely enhanced by QED radiation. Enzyme catalysts in ATP hydrolysis are globular proteins having a spherical diameter of about 5 nm while the ATP itself has a 10 nm diameter. Both ATP and enzyme in water will emit QED radiation beyond the UV capable of breaking the ATP bonds. Unfortunately, traditional biology [1] claims food proteins are converted mostly to lost heat instead of QED radiation.

Self-organization of biological systems based on QED induced photolysis from thermal energy of colliding molecules is not mentioned in the literature. But QED radiation has been proposed as a mechanism of DNA damage by UV emission from metal and metal oxide nanoparticles (NPs) in body fluids [7] including the UV radiation from the natural fragmentation of NPs of epithelial tissue. The importance is DNA damage if not repaired correctly can lead to cancer. Closely related to MT production by QED radiation are gold NPs thought to enhance surface chemical reactions as nanocatalysts. However, gold NPs are inert and cannot enhance any chemical reaction. Instead, the chemical reactions are enhanced [8] by QED induced emission from accumulated kT energy of colliding solvent molecules.

QED radiation at UV levels from MTs implicitly assumes the thermal kT energy from collisions by water molecules accumulates without radiation losses such as the MT leaking photons or radiationless losses by increasing MT temperature. Typically, a kinetic barrier [9] is necessary to form a metastable state that protects against radiation losses before reaching UV levels. In QED radiation, the kinetic barrier takes the form of the TIR confinement of photons within the MT that assures photon emission is always beyond the UV, e.g., the UV beyond 5 eV corresponds to about 500 kJ/mol and is far more than 31 kJ/mol claimed [9] for ATP hydrolysis. On this basis, QED radiation suggests ATP hydrolysis releases 200 – 400 kJ/mol. With regard to radiationless losses, QM that imposes zero specific heat precludes any increases in MT temperature thereby assuring radiationless losses that otherwise escape the TIR barrier are insignificant

QED induced radiation applies not only to biological processes, but also to diverse areas [10] of physics. In astronomy, QED radiation allows the light from distant galaxies to be redshift in cosmic dust instead of by Hubble's interpretation that the galaxy is moving away from us, thereby negating an expanding Universe. Charge In flow electrification is induced by nanoparticle impurities in the liquid. Human olfaction is enhanced by the emission of microwave spectra of the scent molecule upon colliding with epithelial surface in the nose. Cancer is enhanced from DNA damage by NPs, etc.

II. PURPOSE

To show cell spindle assembles by the self-organization of MTs is caused by photolysis from QED induced EM radiation driven by the disordered thermal energy of water molecules. Alternatively, the ordering of disordered thermal systems by self-organization or autocatalytic processes is shown to be QED induced radiation in disguise.

III. THEORY

Self-organization of MTs by QED induced radiation is depicted by disordered molecular thermal energy from colliding water molecules converted to order EM radiation is illustrated in Fig. 1.

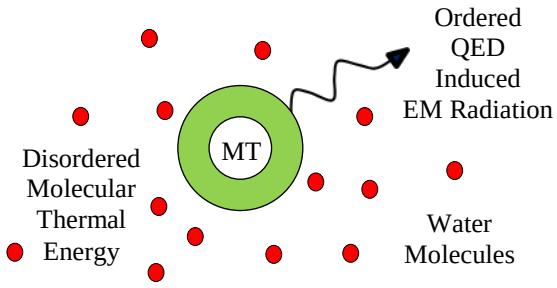


Figure 1 MT - QED Induced EM Radiation

QM and Classical Oscillators. QM differs from classical physics by the heat capacity of the atom. The average Planck energy <E> of the QM oscillator is,

$$< E > = \frac{hc/\lambda}{\exp\left(\frac{hc}{\lambda kT}\right) - 1} \qquad (1)$$

where, h and k are Planck's and Boltzmann's constants, c is the speed of light, T is absolute temperature, and λ is wavelength. At 300 K, the QM dispersion of average Planck energy with wavelength is shown in Fig. 2

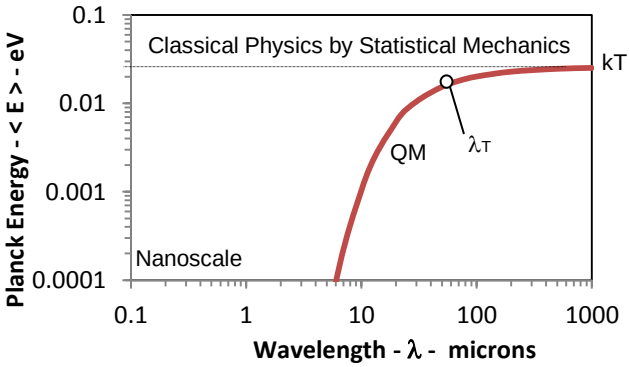


Figure 2 Classical and QM Oscillators at 300 K

In Fig. 2, the thermal wavelength $\lambda_T = hc/kT$ separates classical physics from QM. Classical physics by statistical mechanics allows the atom to have heat capacity (constant kT energy) from the macroscale ($\lambda > \lambda_T$) to the nanoscale ($\lambda < 0.1$ microns). Hence, classical physics allows atoms under EM confinement at the nanoscale to have heat capacity. In contrast, QM allows the atom to have kT energy only at the macroscale ($\lambda > \lambda_T$). However, QM does not allow the atoms at the nanoscale to have heat capacity.

TIR Confinement MTs lack specific heat and cannot conserve absorbed EM energy by an increase in temperature. Instead, conservation may only proceed by the QED induced frequency up-conversion of the absorbed EM energy to the TIR confinement frequency of the MT. TIR stands for total internal reflection. Since MTs have high surface to volume ratios, the absorbed EM energy is confined by TIR almost entirely in the MT surface. The TIR confinement is momentary and occurs only upon absorption of EM energy, and therefore, the TIR confinement effectively sustains itself.

QED creates photons inside the MT from the absorbed EM energy in water molecule collisions. For MTs of diameter D, the QED photon energy E and frequency f are:

$$E = hf \quad f = \frac{c}{\lambda} \quad \lambda = 2nD \tag{2}$$

where, n is the MT refractive index.

Collision Power and QED induced Radiation The collision power Q_C of water molecules of mass *m* transferred to MTs having diameter D and length L is,

$$Q_C = \frac{\pi}{\sqrt{3}} pPDL\sqrt{\frac{kT}{m}} \tag{3}$$

where, *p* is the unit probability of full kT energy transfer for inelastic collisions and P is ambient pressure. The mass m = MW/N_{Avag} where MW = 18 and N_{Avag} is Avagadro's number. The power Q_C / L for MT diameter D is given in Fig. 3.

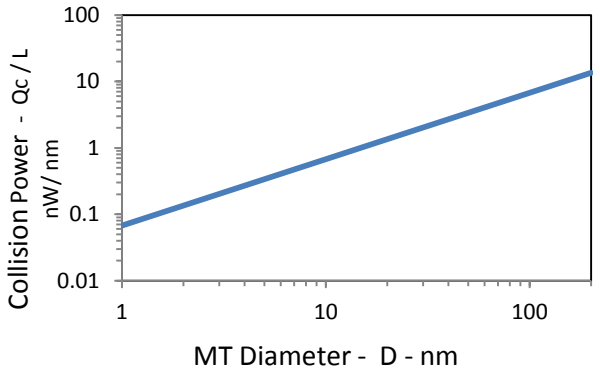


Figure 3 Collision Power and MT Diameter D

Absent an increase in MT temperature, the collision power Q_C is conserved by the emission of QED induced radiation,

$$Q_C = < E > \frac{dN}{dt} \tag{4}$$

where, dN /dt is the rate of QED induced photons per unit length having Planck energy <E> created *inside* the NP. For MTs having n = 1.36, the QED induced photon energy and rate is shown in Fig. 4.

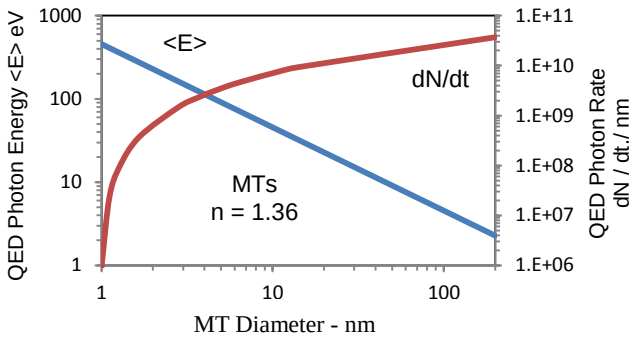


Figure 4 QED Photons – Energy and Rate

Fig. 4 shows 25 nm MT fibers absorb about 1.7 nW of power per unit nm length and produce about $6x10^8$ - 18 eV QED photons. Properties of the spherical ATP molecule and globular protein enzymes having diameters of 10 and 5 nm may be estimated from (3) by taking L = D/2.

IV. Discussion

A. Autocatalysis and the Second Law

Autocatalytic chemical reactions are reactions in which at least one of the reactants is also a product. Since the rate equations for autocatalytic reactions are nonlinear, it is assumed the spontaneous generation of order may arise in disorder. But this violates the Second Law of Thermodynamics that states the disorder of a physical or chemical system and its surroundings if left to itself must increase with time, e.g., orderly energy of a system like uniform motion must degrade [1] eventually to the random motion of particles in a heat bath.

Order and Disorder There are instances where disordered physical systems *appear* to spontaneously order, e.g., the random motion of air molecules is observed to form an ordered vortex in a tornado, and the ordering of biological molecules to create the order of life itself. Since order is created from disorder, the Second Law is thought violated. However, the Second law was not violated because the systems were not left to themselves, but rather influenced by an external source of energy not apparent to the casual observer.

Spindle Assembly and the Second Law The ordering of MTs into a spindle may appear to violate the Second Law in that the assembly needs a source of energy, e.g., UV to explain nucleation and growth by photolysis. Absent QED induced radiation, the observer simply explains the assembly of MTs into the spindle by an autocatalytic process thereby avoiding the contentious statement that the Second Law is violated. For example, spindle assembly experiments may be explained [3] by autocatalytic MT production whereby the MTs induce their own production. However, the contentious statement is not made that autocatalytic MT production violates the Second Law. QED induced radiation although appearing to be self-sustaining depends on the thermal energy of the surroundings, and therefore does not violated the Second Law

B Self -organization of Spindles

Anastral Spindle Assembly During centrosomal mitotic spindle assembly, centrosomes at the MT poles are the dominating source of MT production. But anastral spindles differ in that there are no centrosomes at the poles. The hypothesis [3] was made that anastral spindles assemble in the presence of a RanGTP gradient centered on chromatin and the assumption MTs can induce their own production in an autocatalytic manner. Tests showed MTs can induce their own production in an autocatalytic manner and the rate of change of MT production is proportional to the number of existing MTs.

The MT production data with RanGTP was fit well by the Logistic model that considers the rate of production is proportional to the existing population, and the rate of production is proportional to the amount of available resources. Hence, population growth is limited by resource depletion. When a population is far from its limits of growth, it grows exponentially, however, when a resource becomes limiting, growth slows down and saturation is reached asymptotically.

QED induced radiation is consistent with both the autocatalytic MT production data of anastral spindles and Logistic model. UV radiation is emitted from the MTs, and fragments thereof, which subsequently grows other MTs in an autocatalytic manner is proportional to the number of MTs present. However, the RanGTP gradient is not necessary, as the UV produced from QED radiation should be sufficient for spindle assembly. Indeed, the simulation without the RanGTP gradient shows the assembly to still cluster, but at a random location (Figure 3A, bottom panel of [3]). The random assembly *in vitro* should not be of concern *in vivo* because the cell membrane will confine assembly to a single spindle at the center of the cell.

Assembly by the Spindle itself Prior to the notion of autocatalytic MT production, the source of spindle assembly by MT formation was proposed [4] to be the spindle itself, thereby augmenting MT production at centrosomes and chromosomes. By depleting the γ - tubulin nucleating protein in the standard model of MT production, pathways other than centrosomes were found including the spindle itself. That centrosomes are not necessary for mitotic spindle assembly is suggested because spindles reassemble after centrosome function is disrupted [11] by laser ablation.

Tests of MT production with depleted γ - tubulin showed that MT formation initially relies on chromosomes, but the spindle itself acquires a mechanism to allow MT formation distal from the chromosomes. In the absence of γ - tubulin, a self-replicating template analogous to the nucleation of actin filaments by Arp2/3 bound to an existing actin filament was proposed whereby an unidentified protein mediates the formation of a MT in a side-by side manner (Fig. 4A of [4]).

QED radiation by the MTs emitting UV allows distal MT nucleation without the requirement of an unidentified protein bound to the new and existing MTs. There are many MT fragments present . The UV is emitted radially from the center of the MT along its length, thereby providing an EM template for nucleation of new MTs parallel side-by-side to the existing MT. But MT growth requires an available resource. The unidentified protein is therefore likely the γ - tubulin whether that remaining after depletion or in fragments of MTs. Since the UV radiation emitted by the MTs is uniform along their lengths, replication occurs by the EM template of UV radiation emitted by the MTs themselves.

C Hydrolysis

Enzymes Hydrolysis cleaves [6] polymers while dehydration slows down cleavage of peptide bonds and enhances the formation of longer polymers. In the plastein reaction, the enzyme trypsin in the stomach helps to digest food. If trypsin is mixed with large proteins in water, the proteins are cleaved into smaller peptides. But if the system is dehydrated, the trypsin catalyst shifts the equilibrium in favor of the synthesis of larger polymers from the peptide fragments.

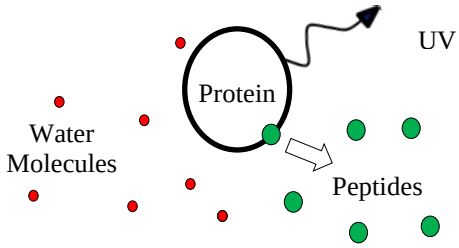
QED induced radiation views the enzymatic action of trypsin as a source of UV radiation that by photolysis polymerizes the growth of proteins. Indeed, the trypsin enzyme is a spherical globular protein having a diameter of about 4 nm while food protein diameters range from 3 – 6 nm. Both enzymes and food proteins are NPs, and therefore emit and absorb EM radiation beyond the UV from the kT energy of colliding water molecules. Cleavage of the proteins into peptides by chemical interaction is enhanced by the QED radiation created *inside* the proteins. The QED interactions among a protein, enzyme, and peptides in or out of water are shown in Fig. 5.

Fig. 5A shows the hydrolysis of the protein in water alone. Water molecules (red circles) collide with protein and QED photons are created *inside* the protein. QED photons at levels beyond the UV not absorbed by the protein itself are

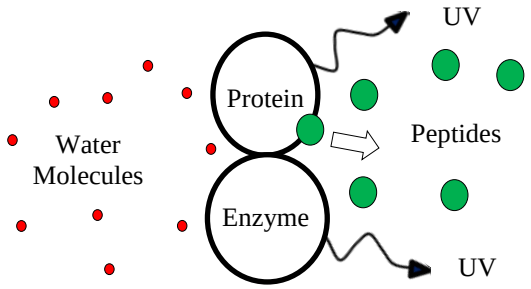
emitted and absorbed by other proteins in the surroundings. Photolysis by QED radiation beyond UV levels cleaves the protein with the emission of small peptides (green circles). Only a single protein is shown, but other proteins that interact by the UV radiation are not shown for clarity.

Fig. 5B depicts protein hydrolysis by a bound enzyme. Both protein and enzyme are shown emitting UV radiation from the absorption of kT energy by colliding water molecules. The greater peptide fragment emission (large green circles) is caused by the enzyme. The enzyme as a catalyst in reducing the activation energy of protein hydrolysis is the same as QED radiation by NP catalysis [8] in surface chemical reactions.

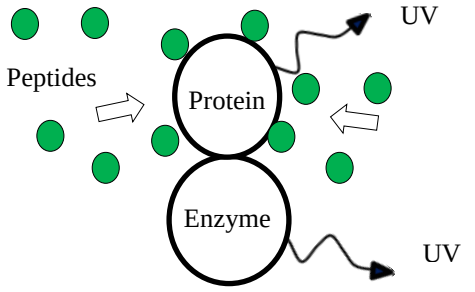
Fig. 5C shows a dehydrated protein interacting with a bound enzyme in the absence of water. Peptides from the surroundings driven by the UV emission from both protein and enzyme polymerize the protein by photolysis.



A. *Protein Hydrolysis with Enzyme in Water*



B. *Protein Hydrolysis with Enzyme in Water*



C. *Deydrated Proteinwith Enzyme without Water*

Figure 5 Protein Hydrolysis with and without Water

ATP Hydrolysis Of interest is the effect of QED radiation in reducing the ATP activation energy 200-400 kJ/mol or 2-4 eV compared to Density Functional Theory (DFT). QED induces the 25 nm MTs to create 18 eV photons in MTs, thereby exceeding the 2-4 eV necessary for ATP activation. QED is therefore consistent with DFT in that hydrolysis reduces the ATP activation energy, i.e., for ATP to ADP + Pi, DFT gives 31 kJ/mol. Perhaps, DFT should include QED radiation in calculations of ATP activation energy in hydrolysis instead of simply attributing reductions in ATP activation energy to enzymes alone.

V. SUMMARY AND CONC LUSIONS

1. The role of QED induced radiation in MT production and spindle assembly suggests the UV emission of the submicron proteins, enzymes, and ATP is important in creating the EM template for cell replication.

2. ATP and protein hydrolysis based on DFT give lower bound estimates of hydrolysis. QED radiation enhances hydrolysis suggesting that the full activation energy of ATP has been available since the early Earth to promote life.

3. This paper can at best only hope to be a preliminary attempt to present QED radiation as an energy source in living systems thereby supplementing mainstream theory of MT production and spindle assembly including the upward revision of ATP energy available for the ordering of life itself. Comments are solicited.

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