

Quantized ATP Production

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Abstract: Although ATP production is very important for mitochondria, little is known about the actual rate of production and the value of “unit of currency” for mitochondrial energy transactions. “Unit of currency” for all transactions in general is named “quantum” in Physics, and no value of ATP quantum is accurately given in bibliography, other than rough estimates.

This work focuses to calculating produced energy unit in mitochondrial metabolism (Quantum for ATP, or QATP for sort) and the rate of ATP production (power of “mitochondrial factory”).

Keywords: Abrikosov, ATP, Q_{ATP} , Cooper Pairs, ROS

I. Introduction

The work presented here is based on the hypothetical mechanism described in “Quantized Mitochondrial Metabolism” [1]. Specifically, parts II, III and IV concern the case where frequency f is within limits $f_{\min} \leq f \leq f_{\max}$.

Part II is the study of CP’s (Cooper Pair) motion in order to calculate:

1. Distance (d) from entry point of CP to collision
2. Acceleration (a)
3. Velocity Just Before Collision with oxygen (U_{JBC}).

These results will be used to calculate kinetic energy in part III.

Part III, named “Energies In Quantized Mitochondrial Metabolism”, is presented in two subparts:

1. Following hypothetical model [1], kinetic and potential energy for two CPs (Cooper Pairs) [2] is calculated.
2. Then, a thorough analysis is presented based on energy balance, which is applied on reaction that produces water. Kinetic and potential energy for two CPs is again calculated, this time based on energy conservation.

The two separate results are compared to check the validity of initial hypothesis and to calculate Q_{ATP} . This way, the very important role for Abrikosov’s quantum flux [3] is revealed.

Part IV describes the mitochondrial factory in terms of its output power and is also presented into two subparts:

1. Description of calculating method.
2. Application of equations from the first subpart, in order to obtain value of power (P_{ATP}).

II. Study of CP motion

2.1 Calculating distance d

Mean velocity of CP motion has been already calculated in “Quantized Mitochondrial Metabolism” [1]

as $U = 8.391669255 \times 10^4 \frac{m}{s}$. This is the constant velocity that CP should have in order to cover distance d

in the same time t as in the real CP motion. Uniform motion allows for use of equation (1):

$$U = \frac{d}{t} \quad (1)$$

Time t is already defined in “Quantized Mitochondrial Metabolism” [1] as T_0 :

$$t = T_0 = \frac{1}{f_0} \quad (2)$$

Equations (1) and (2) combined and solved for d can give (symbol d_0 is used for value of d corresponding to frequency f_0):

$$d_0 = \frac{U}{f_0} \quad (3)$$

TABLES 1 and 2 below present values already derived and presented in “Quantized Mitochondrial Metabolism” [1]. Substituting frequency and mean velocity, equation (3) gives the value of d_0 :

Table 1: Calculated values for natural frequency, variation, and mean velocity, with an accuracy of 9 decimals (S. I. units)

f_0	Df	U
$5.948253377 \times 10^{14}$	$1.665011032 \times 10^{11}$	8.391669255×10^4

Table 2: Calculated values for f_{min} , f_0 , f_{max} as presented in “Quantized Mitochondrial Metabolism” [1]

f_{min}	f_0	f_{max}
$5.947420872 \times 10^{14}$	$5.948253377 \times 10^{14}$	$5.949085883 \times 10^{14}$

$$d_0 = 1.410778715 \times 10^{-10} \text{ m}$$

This is the distance value calculated for f_0 . When frequency f increases distance d decreases, as explained in [1]. Observing equation (3), this relation between f and d is also verified. Using values from TABLE 1 and TABLE 2, values of TABLE 3 below are calculated. This table presents values of d for f_{min} , f_0 , f_{max} , as calculated by (4):

$$d = \frac{U}{f} \quad (4)$$

Table 3: d for frequencies f_{min} , f_0 , f_{max} (S. I. Units)

$d(f_{min})$	$d(f_0)$	$d(f_{max})$
$1.410976192 \times 10^{-10}$	$1.410778715 \times 10^{-10}$	$1.410581293 \times 10^{-10}$

2.2 Calculating acceleration a and velocity U_{JBC}

Every CP is accelerated from copper to oxygen. As already explained in [1], duration of this motion is given by the inverse of frequency and, based on TABLE 2, the order of magnitude for this time interval is 10^{-15} s. Acceleration is produced and affected by voltage difference between Cu^{+1} and Fe^{+3} . Carriers bringing ions at their places and produce this voltage difference. These carriers cannot supply ions in such rate to affect voltage during time interval of order 10^{-15} s. Therefore, they cannot affect acceleration within time interval of order 10^{-15} s. As a consequence, acceleration can be considered constant during CP’s motion and equations (5) and (6) can be applied.

$$d = \frac{1}{2} \cdot a \cdot t^2 \quad (5)$$

$$v = a \cdot t \quad (6)$$

From equation (5) solving for a , (7) is produced:

$$a = \frac{2 \cdot d}{t^2} \quad (7)$$

Using equation (2) in its general form (8):

$$t = T = \frac{1}{f} \quad (8)$$

(7) leads to (9):

$$a = 2 \cdot d \cdot f^2 \quad (9)$$

where d is the distance covered in time interval $t = T$ and f is the corresponding frequency. Using values of TABLES 2 and 3, acceleration of TABLE 4 is calculated.

Table 4: a for frequencies f_{min} , f_0 , f_{max} (S. I. Units)

$a(f_{min})$	$a(f_0)$	$a(f_{max})$
$9.981757775 \times 10^{19}$	$9.983154998 \times 10^{19}$	$9.984552220 \times 10^{19}$

Within time $t = T$ CP reaches oxygen. So after $t = T$ CP's velocity is equal to U_{JBC} (velocity just before collision). Equation (6) due to (8) becomes:

$$U_{JBC} = \frac{a}{f} \quad (10)$$

Applying values of TABLES 2 and 4 to equation (10), values of TABLE 5 are produced, which describe something very interesting.

Table 5: U_{JBC} for frequencies f_{min}, f_0, f_{max} (S. I. Units)

$U_{JBC}(f_{min})$	$U_{JBC}(f_0)$	$U_{JBC}(f_{max})$
1.678333851×10^5	1.678333851×10^5	1.678333851×10^5

All values are equal to the last digit! The same is true for every value of f within limits $[f_{min}, f_{max}]$.

Below is a mathematical proof for this:

Substituting a from (9) to (10):

$$U_{JBC} = 2 \cdot d \cdot f \quad (11)$$

and then by applying (4), equation (12) is produced:

$$U_{JBC} = 2 \cdot U \quad (12)$$

So, velocity of collision is two times the mean value and is independent of frequency (is affected by temperature as mean value does)! If mean velocity (U) is constant, collision velocity (U_{JBC}) will be constant too.

Therefore, every CP accelerated under function f within limits $[f_{min}, f_{max}]$, will perform collision with the same velocity as any other CP. TABLE 5 describes the same, only in numbers.

2.3 Summary of part II

1. As distance between copper region and oxygen gets smaller, CP's corresponding frequency gets higher and vice versa.
2. Mean distance from entry of p-n-p to crash point is $d = 1.410778715 \times 10^{-10} \text{ m}$.
Considering that mean size of mammalian mitochondria is ranging from $0.5 \text{ mm} = 0.5 \times 10^{-6} \text{ m}$ to $1 \text{ mm} = 10^{-6} \text{ m}$ [4], the calculated value of $d = 1.410778715 \times 10^{-10} \text{ m}$ cannot be rejected. Length d can provide an estimate of the size of the region where every CP accelerates. If a line of length $\gg 1 \text{ mm}$ is drawn at the side of a boat with length $\gg 7 \text{ m}$, then if the boat represents mitochondrion the line is the accelerating ramp for CP, from entry of p-n-p to crash point.
3. TABLE 4 presents very high acceleration values. This is a "side effect" of Quantum Mechanics (Cooper Pair formation and Abrikosov's magnetic flux). If the same voltage were used to accelerate electrons in the same environment, this time as single electrons and not as Cooper Pairs, acceleration would be significantly lower.
4. When temperature is constant, collision velocity is constant and equal to $U_{JBC} = 1.678333851 \times 10^5$. This value is two times the mean velocity of CP.

III. Energies in "Quantized Mitochondrial Metabolism"

3.1 Calculating kinetic and potential energies for two CPs

(The hypothetical model [1] is used to calculate kinetic and potential energies for CPs) Calculations will be done for two CPs because, for H_2O and ATP to be produced, two CPs must be used. As already shown and explained in "Quantized Mitochondrial Metabolism" [1], equations (13), (14), (15) describe the model and will be used in this work too. Equation (13) calculates the frequency:

$$f_0 = \frac{2 \cdot e \cdot V_{H_2O}}{h} \quad (13)$$

while frequency variation is given by:

$$Df = \sqrt{\frac{6 \cdot k_B \cdot T_C \cdot e^2 \cdot V_{H_2O}^2}{m_e \cdot c^2 \cdot h^2}} \quad (14)$$

where f_0 is each Cooper Pair's (CP) frequency, k_B is the Boltzmann's constant, T_C is the body temperature, e is the single electron's charge, V_{H_2O} is the voltage for water production, m_e the single electron's resting mass, c is the speed of light in vacuum and h is the Planck's constant.

Doppler relation can easily give mean velocity, as:

$$U = \frac{Df}{f_0} \cdot c \quad (15)$$

Each electron couple, when accelerated by voltage between Fe^{+3} and Cu^{+1} , with corresponding frequency f_0 , receives energy $h \cdot f_0$. For 2 CPs:

$$E_{Total} = 2 \cdot h \cdot f_0 \quad (16)$$

This energy is used in one part as potential energy, to form the two Cooper Pairs [2] and the rest of it as kinetic energy of CPs. Because:

$$m_{CP} = 2 \cdot m_e \quad (17)$$

Table 6: Constant values (S. I. units)

Speed of light in vacuum	2.997924580×10^8
Electron resting mass	$9.109383560 \times 10^{-31}$
Planck's constant	$6.626070041 \times 10^{-34}$
Electron / elementary charge	$1.602176565 \times 10^{-19}$
Body temperature	3.097500000×10^2
Water voltage	1.230000000×10^0
Boltzmann's constant	$1.380648520 \times 10^{-23}$

kinetic energy just before collision can be calculated as:

$$E_{kin} = \frac{1}{2} \cdot 2 \cdot m_e \cdot U_{JBC}^2 \quad (18)$$

which for 2 CPs becomes:

$$E_{kin_{tot}} = 2 \cdot m_e \cdot U_{JBC}^2 \quad (19)$$

Table 7: Calculated values for natural frequency, variation, and collision velocity, with an accuracy of 9 decimals (S. I. units)

f_0	Df	U_{JBC}
$5.948253377 \times 10^{14}$	$1.665011032 \times 10^{11}$	1.678333851×10^5

Therefore, potential energy for 2 CPs can be easily produced as:

$$E_{pot_{tot}} = E_{Total} - E_{kin_{tot}} \quad (20)$$

Applying values from TABLES 6 and 7 to equations (16), (18), (19), the total, kinetic and potential energies for two CPs are calculated and are shown on TABLE 8.

Potential energy is the corresponding Abrikosov's quantum flux [3] energy. This is the bonding energy of CP, the energy that holds two electrons together in CP form. So the potential energy values given in TABLE 8, describe for each frequency the necessary and sufficient amount of potential energy, to form two CPs that would be capable to free oxygen.

Table 8: Calculated values for total, kinetic and potential energies for two CPs and for f_{min} , f_0 , f_{max} (S. I. units)

f	E_{Total}	$E_{kin_{tot}}$	$E_{pot_{tot}}$
$f_{min} = 5.947420872 \times 10^{14}$	$7.881605452 \times 10^{-19}$	$5.131870549 \times 10^{-20}$	$6.855231342 \times 10^{-19}$

$f_0 = 5.948253377 \times 10^{14}$	$7.882708700 \times 10^{-19}$	$5.131870549 \times 10^{-20}$	$6.856334590 \times 10^{-19}$
$f_{\max} = 5.949085883 \times 10^{14}$	$7.883811948 \times 10^{-19}$	$5.131870549 \times 10^{-20}$	$6.857437838 \times 10^{-19}$

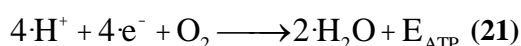
3.2 Investigating energy conservation on H₂O reaction

(This part is the study about the energies in reaction that produces water and ATP)

3.2.1 Relativistic energies

(Here, the method used to do the calculations is explained)

Water reaction is shown below:



The energy balance applied here, uses energies as in relativistic point of view [5]. According to this relativistic view, the energy of a body is calculated as in the two cases below:

First case: a slowly moving (compared to c - speed of light in vacuum) or not moving body of mass m (resting mass) corresponds to energy E , which is calculated as:

$$E_1 = m \cdot c^2 \quad (22)$$

Second case: A body moving with speed U , it corresponds to energy:

$$E_2 = (g - 1) \cdot m \cdot c^2 \quad (23)$$

All reactants and every product, fall into the first case, with the notable exception of the four electrons (former two CPs), which as moving bodies with high velocities, fall into the second one. Therefore, the energies for each reactant and product can be written, as follows:

Energy for 4H^+ :

$$E_{4\text{H}^+} = 4 \cdot m_{\text{p}^+} \cdot c^2 \quad (24)$$

Energy for 2CPs:

$$E_{2\text{CPs}} = 4 \cdot (g - 1) \cdot m_{\text{e}} \cdot c^2 \quad (25)$$

$$\text{where } g = \frac{1}{\sqrt{1 - \frac{U_{\text{JBC}}^2}{c^2}}} \quad (26)$$

Energy for O_2 :

$$E_{\text{O}_2} = m_{\text{O}_2} \cdot c^2 \quad (27)$$

Energy for H_2O :

$$E_{\text{H}_2\text{O}} = 2 \cdot m_{\text{H}_2\text{O}} \cdot c^2 \quad (28)$$

ATP should not be left out of this investigation! It is energy appearing as a product of the same reaction (21).

This amount of energy is noted as E_{ATP} .

3.2.2 Calculating energies of reaction

(This subpart presents results and explains why only $E_{2\text{CPs}}$ is calculated)

Using values from TABLES 6 and 7, equations (26) and (25) produce values shown in TABLE 4.

Table 9: Calculated values for g and relativistic energy for two CPs as reactants (S. I. units)

g	$E_{2\text{CPs}}$
1.00000015670592	$5.131871758 \times 10^{-20}$

Comparing $E_{2\text{CPs}}$ from TABLE 9 with $E_{\text{kin}_{\text{tot}}}$ from TABLE 8, it is easily observable that they differ only in the last four digits, meaning that kinetic energy of two CPs is the energy used in water production. The two values are computed with two independent methods and their convergence is acceptable. From hereafter the value of $5.131871758 \times 10^{-20} \text{J}$ will be used for kinetic energy of two CPs. The result of the small difference cannot be considered as verification of the mechanism described in "Quantized Mitochondrial Metabolism" [1].

It is just an application of energy conservation principal, which simply did not reject the model. Furthermore, the difference being so small, can lead to a significant conclusion for CP's potential energy: If two CPs have their kinetic energy used in water production reaction, their potential energy should have been used to set oxygen free. Balancing energies between reactants and products, equation (29) is produced:

$$E_{4H^+} + E_{2CPs} + E_{O_2} = E_{H_2O} + E_{ATP} \quad (29)$$

E_{H_2O} is equal to the sum of energies of all constituents of water. So:

$$E_{4H^+} + E_{O_2} = E_{H_2O} \quad (30)$$

Equation (29) due to (30) becomes:

$$E_{2CPs} = E_{ATP} \quad (31)$$

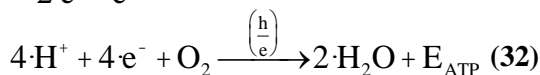
This is why only E_{2CPs} needs to be calculated.

3.2.3 Meaning of Abrikosov's quantum flux, in "Quantized Mitochondrial Metabolism" model

(This is primarily an analysis of consequences of equation (19))

Equation (31) presents another meaning to energy transformations that occur inside mitochondria. CP's potential energy is expended to produce O_2 and consequently water, but also to help CP's kinetic energy transform, through water reaction, into E_{ATP} . This way another key role of Abrikosov's quantum flux [3] is revealed: The amount of potential energy is still present during water reaction (9); is trapped inside O_2 . In other words potential energy exists starting with CP formation until ATP production, and helps the reaction in all its stages, from preparing the necessary reactants, all the way up to successfully produce water and ATP. It can be concluded that Abrikosov's quantum flux [3] presents catalytic behavior and the double of this quantum flux

$2 \cdot \frac{h}{2e} = \frac{h}{e}$ is the catalyst. Reaction (21) can be rewritten as:



Therefore, water production reaction uses an electromagnetic catalyst, the double Abrikosov quantum flux $\frac{h}{e}$.

3.2.4 Q_{ATP} value

(In this subpart Q_{ATP} is calculated)

According to TABLE 9 and equation (31) the value of E_{ATP} is: $E_{ATP} = 5.131871758 \times 10^{-20} J$.

This is the least amount of ATP produced, because (20) describes the production of the least amount of water possible. Therefore this E_{ATP} is the Q_{ATP} , the quantum of ATP energy.

So, finally: $Q_{ATP} = 5.131871758 \times 10^{-20} J$.

It is common practice in Biology to measure ATP in $\frac{KJ}{mole}$ or in $\frac{Kcal}{mole}$. The equivalence is shown in TABLE 10 below:

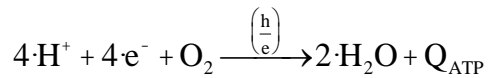
Table 10: Q_{ATP} in $\frac{J}{mole}$, $\frac{KJ}{mole}$ and $\frac{Kcal}{mole}$. There are 4.1868 KJ in 1 Kcal.

$Q_{ATP} \left(\frac{J}{mole} \right)$	$Q_{ATP} \left(\frac{KJ}{mole} \right)$	$Q_{ATP} \left(\frac{Kcal}{mole} \right)$
$5.131871758 \times 10^{-20}$	30.90926360	7.382550778

3.3 Summary of part III

1. For every two CPs with frequencies f within range $f_{min} \leq f \leq f_{max}$, their total potential energy (energy corresponding to Abrikosov's quantum flux [3]) is used to release O_2 , while their kinetic energy comes as final product in form of ATP.

2. Abrikosov's quantum flux [3], corresponding to two CPs, plays a catalytic role to the overall procedure. To emphasize its role as electromagnetic catalyst, the double Abrikosov's quantum flux $\left(\frac{h}{e}\right)$ is noted as:



3. Q_{ATP} value is consistent with ATP value found in bibliography (about $7.3 \frac{KJ}{mole}$ [4]).

IV. Output Power of "Mitochondrial Factory"

(Having calculated the amount of quantum ATP and under the assumption that H^+ flow continually, this part is dedicated to calculating mitochondrial energy production rate.)

4.1 Description of calculating method

(Definition of power, explanations of symbols and correspondence to "Quantized Mitochondrial Metabolism" model [1], are included in this subpart)

Avoiding much of mathematical details, trying to keep things as simple as possible, the following definition of power is given: power in general, is defined as the ratio of energy E that is transferred or converted, over time t that is required for this amount of energy to be transferred or converted. Equation (33) describes this definition:

$$P = \frac{E}{t} \quad (33)$$

For "Quantized Mitochondrial Metabolism" model [1], energy E is Q_{ATP} and time t is the corresponding time interval necessary for Q_{ATP} production. Because Q_{ATP} requires two CPs, this time interval is equal to $2\cdot T_0$, where T_0 is the corresponding time for one CP to complete its job (trigger p-n-p and achieve a successful hit). Of course, this is valid under the following three assumptions:

1. CPs are successful
2. CPs come in sequence - one after the other - with no delays
3. There is continual flow of H^+

Thus, equations (34) and (35) are justified:

$$t = 2\cdot T_0 \quad (34)$$

$$E = Q_{ATP} \quad (35)$$

Combining equations (33), (34) and (35) the formula for P_{ATP} - power of ATP energy production, is formed:

$$P_{ATP} = \frac{Q_{ATP}}{2\cdot T_0} \quad (36)$$

Because of (37), (36) can be written as (38):

$$T_0 = \frac{1}{f_0} \quad (37)$$

$$P_{ATP} = \frac{Q_{ATP} \times f_0}{2} \quad (38)$$

4.2 Calculating P_{ATP}

(Using (38) P_{ATP} is calculated)

Equation (38) calculates power for frequency f_0 . Using frequency f instead of f_0 , where f is within limits $[f_{min}, f_{max}]$, equation (39) is produced:

$$P_{ATP} = \frac{Q_{ATP} \times f}{2} \quad (39)$$

Equation (39) describes a proportional relation between frequency and power. Substituting values of f from TABLE 2 and $Q_{ATP} = 5.131871758 \times 10^{-20} J$, TABLE 11 below is formed:

Table 11: P_{ATP} for frequencies f_{min}, f_0, f_{max} (S. I. Units)

$P_{ATP}(f_{min})$	$P_{ATP}(f_0)$	$P_{ATP}(f_{max})$
$1.526070060 \times 10^{-5}$	$1.526283676 \times 10^{-5}$	$1.526497291 \times 10^{-5}$

4.3 Summary of part IV

- P_{ATP} is calculated by $P_{ATP} = \frac{Q_{ATP} \times f}{2}$
- Equation for P_{ATP} is valid under the following three assumptions:
 - CPs are successful
 - CPs come in sequence - one after the other - with no delays
 - There is continual flow of H^+
- P_{ATP} is proportional to frequency. Higher frequency means Q_{ATP} is produced faster.

V. Discussion

(Part V analyses further findings of parts II, III and IV)

5.1 Analysis of Q_{ATP} results

- ATP formation could be considered as “quantum phenomenon” that is taking place at the output of p-n-p mechanism, under the assumption that f is within limits $[f_{min}, f_{max}]$. Quantized ATP production is synchronized with quantized CP action.
- Quantum of ATP is a standard value, unrelated to frequency.
- $Q_{ATP} = 5.131871758 \times 10^{-20} J$ is produced every four successfully used H^+ . A useful analogy, if someone needs not to use the Q_{ATP} value with precision, is: $\gg 7 Kcal$ or $\gg 31 KJ$ are roughly $1 \times Q_{ATP}$ and are produced every 4 successfully used protons (H^+).
- Energy conversions from entry point until ATP formation can be described as follows (it is assumed f within limits $[f_{min}, f_{max}]$ so it could lead to ATP):
 - Energy $E_{Total} = 2 \cdot h \cdot f_0$ is converted to CP’s potential energy and CP’s kinetic energy.
 - Potential energy is released and breaks bonds between metals and oxygen. CP electrons are not in pairs anymore.
 - For every pair of non-CP electrons, total kinetic energy is equal to former CP’s kinetic energy, increased by any residue of potential energy. But, potential energy is chosen based on f value, which also determines the value of d and consequently the strength of bonds between oxygen and metals. Therefore, when f is within limits $[f_{min}, f_{max}]$, potential energy is at the appropriate value to free oxygen with no residues and it is fully expended at the crash. Thus, for non-CP electrons total kinetic energy is equal to kinetic energy of former CP.
 - Kinetic energy of non-CP electrons is packed at the output of the “factory” as ATP.
- Energy study could explain ROS (Radical Oxygen Species) formation when frequency exceeds f_{max} , this time by another viewpoint, than the one used in [1]. Potential energy is used to free oxygen, as been noted before. After breaking bonds, normally CPs would break their formation and would participate to water and ATP production as individually moving electrons. When frequency increases potential energy increases as well, and CPs are “armed heavier”. If f exceeds f_{max} , potential energy is not just appropriate but it comes in excess, and excessive potential energy - due to energy conservation - is converted to excessive kinetic energy of non-CP electrons. One of the two electrons after collision retains higher kinetic energy and cannot remain at oxygen's vicinity. This is the case where oxygen is released as ROS, no water is produced and no ATP is formed at the output.
- Fig. 1 below summarizes the total behavior of Q_{ATP} production system.

5.2 Analysis of P_{ATP} results

- P_{ATP} value measures how fast ATP is produced, under the three assumptions presented on subpart 4.1. As equation (39) describes, power is proportional to frequency. Because Q_{ATP} is constant, the effort to produce this energy faster appears to be a dangerous gamble. To increase power, frequency must be increased and there is no other way to do it. But when frequency exceeds f_{max} ROS is formed. At the edge

- of high performance, there lays the greatest danger for mitochondrion.
- The way this model functions is consistent with the “principle of least action”. Everything is used in an economic way and nothing is wasted.
 - CP’s use is very important because:
 - Helps to free oxygen and consequently to create water.
 - Carries the amount of ATP in the form of kinetic energy.
 - With respect to its frequency the energy production rate (P_{ATP}) is decided.

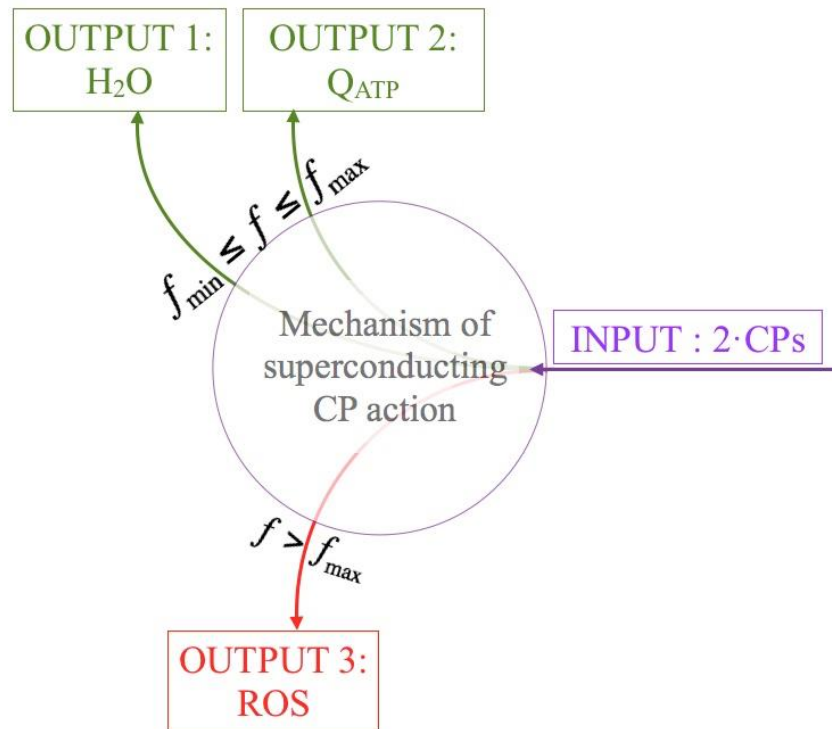


Figure 1: Schematic representation of superconducting mechanism. For every two CPs as input, either the green set of outputs or the red one is activated. The output choice is made based on frequency value. So, when outputs 1 and 2 are activated (they do so simultaneously - they belong in the same “green” group), output 3 remains inactive. When output 3 is activated, green group is shutdown.

VI. Conclusions

Conclusions are presented as Q & A, in order to maintain a simple, useful and meaningful form and also help readers remember them.

1. Q: For someone who reads this work and would like to use it in science, what parts are recommended as “highly important”?

A: The following parts are of high importance:

- The distance from copper to oxygen is $\gg \frac{1}{7000}$ of mitochondrial diameter and is inversely proportional to frequency.
- CPs collide with oxygen having every time the same velocity, assuming f is within limits $[f_{\min}, f_{\max}]$.
- Assuming f is within limits $[f_{\min}, f_{\max}]$, CP’s potential energy is appropriate to break the metal – oxygen bond. There is no amount of potential energy left to convert to kinetic energy of electrons. In this case, the total kinetic energy of electrons after collision is the same as CP’s kinetic energy just before collision. However, if there is an excess of potential energy, meaning f is higher than f_{\max} , ROS is produced.
- Q_{ATP} is the total sum of kinetic energy that two CPs have, just before collision with oxygen.
- $Q_{ATP} = 5.131871758 \times 10^{-20} \text{ J} = 30.90926360 \text{ KJ} = 7.382550778 \text{ Kcal}$. This amount is produced per mole of ATP and requires 4 protons (H^+).

6) Without Abrikosov's quantum flux acting as a catalyst, ATP and water cannot be produced.

7) Power (P_{ATP}) is the rate of Q_{ATP} production and is proportional to frequency. It is given by

$$P_{ATP} = \frac{Q_{ATP} \times f}{2} \text{ which is valid under the following three assumptions:}$$

- CPs are successful
- CPs come in sequence - one after the other - with no delays
- There is continual flow of H^+

2. Q: If someone calculates acceleration of a single electron under the same voltage using equation

$$a = \frac{e \times V_{H_2O}}{m_e \times d} \text{ (which comes from the same study as for CP's motion), will find an extremely large value,}$$

greater than CP's (for $d(f_0)$ this value is $1.533442865 \times 10^{21} \frac{m}{s^2}$). In what way CPs are needed? Why

single electrons cannot achieve the same result?

A: The mitochondrial environment is a resistant environment and formula for acceleration, presented on this question, came from studying motion as uniformly accelerated with no resistance. Thus, this equation is applicable when there is no resistance at all. CP formation ensures resistance - free motion, something that single electrons cannot achieve. The above formula cannot be applied to single electron's motion within mitochondria, because mitochondrial environment's resistance is high enough to forbid it. Therefore, result

$1.533442865 \times 10^{21} \frac{m}{s^2}$ is not correct. This is why "Quantized Mitochondrial Metabolism" [1], as well as the work presented here, may be valid only under hypothesis of CP formation and use of Abrikosov's quantum flux.

3. Q: In what way the present work contributes to science?

A: There are major and minor benefits of this work to science. Surely, someone could give an extended answer to this particular question. It would be better though, to limit ourselves to what is absolutely necessary. This is why only four major benefits are presented below:

- 1) Under the assumption that this work corresponds to a valid hypothesis, an accurate calculation of ATP amount is given. If there is experimental validation of model described in [1], Q_{ATP} "calculation" will be turned into "measurement" in no time, and it will be the first time to measure it. Because CPs move unrestricted, calculated and measured values should have little or no divergence. So, the "measured ATP value" is the first benefit.
- 2) The second contribution is the calculated rate of ATP production. Again if this work proves to be valid, P_{ATP} value seems to hold a prominent role to ROS production. Especially P_{ATP} 's proportional relation to f simplifies the thinking behind ROS production, and summarizes ROS production in one sentence: "The greater demands a mitochondrion is met with for energy, the higher P_{ATP} must be obtained to meet them and the greater the frequency, to regulate CP's acceleration, will be". So, by regulating the causes that push-up the needs in energy, frequency may always stay within limits $[f_{min}, f_{max}]$, resulting to a healthy mitochondrion and a healthier organism. This straightforward relation between P_{ATP} and frequency and its meaningful extensions, is the second contribution.
- 3) The third major contribution is the Abrikosov's quantum flux role to the overall procedure. If this work proves to be valid, superconductivity will be proved essential, used not only in lifeless superconductors by experimental physicists, but also in "life sciences".
- 4) The fourth major contribution is that this work, together with "Quantized Mitochondrial Metabolism" [1], it could serve as an example of collaboration between fields of science: Many scientific areas joined forces like Classical Physics, Quantum Physics, Special Relativity, Chemistry (oxidation reaction [1] and reaction for water synthesis) and Mitochondrial Biology, to create this work and [1].

4. Q: What energy transformations take place, from the moment CPs appearing in copper region until the formation of water?

A: CPs have potential energy and kinetic energy. They release their potential energy to free oxygen and they split their CP formation, keeping their sum of kinetic energy equal to former CP's kinetic energy. Next, electrons participate to water reaction and their kinetic energy is converted to Q_{ATP} .

5. Q: If this work is proved to be valid, what can be done to enhance – expand this work?

A: To begin with, it is of absolute necessity to verify the model experimentally. Apart from, that and assuming validity of the model is been proven, it would be useful to investigate mitochondria of various organs, in order to establish the causes that push mitochondria to increase their energy production rate. Mitochondria that work intensely are close to dysfunctional behavior. Their function becomes intense due to some causes.

These causes affect somehow (in a way to be explored) the frequency and thereby the power of the “mitochondrial factory”. Causes may be categorized in levels, for example causes of the first level, linked directly to over-active mitochondria, could be:

- 1) Excess of electrons
- 2) Excess of Fe^{+3}

Whatever reason creates these two conditions to arise, is classified as a cause of the second level, and so on. This way a mechanism is deployed, revealing who regulates what. Whatever causes over-activity to mitochondria, may lead to ROS production, so the role of anxiety and stress should not be left out of this investigation.

Causes can differ from organ to organ. For example, an action that leads liver mitochondria to increase their energy production rate, perhaps cannot mobilize lung mitochondria. This leads investigation, described in the previous paragraph, to be applied in this way:

- 1) Research for what causes P_{ATP} to increase
- 2) Through what mechanism it affects frequency (for example the first or the second cause of the first level above)
- 3) What is the limit of mitochondrial excitation by a certain cause, that drives frequency beyond its maximum - f_{max}

It is therefore, an interesting expansion of the current work, to investigate and find for mitochondria of every major organ of the body, a thread linking macroscopic actions to mitochondrial behavior. This thread is the mechanism of how a macro-cause (action of the macroscopic world, which is a cause of the last level) is translated, through a series of internal actions, to an increase or decrease of frequency in CP. This work, together with “Quantized Mitochondrial Metabolism” [1], is an attempt to start unwinding this thread from level one (micro-causes) to the last level (macro-causes).

References

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