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Article

A Strange Thing Called Love: in View of Thermodynamics

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Abstract

An attempt is made to explore the nature of love in view of the laws of thermodynamics, namely zeroth, first, and second laws. In doing so, a human is modeled as two entity structure: the physical body as a heat engine, and the mind as a neurological-resembled active species or a radical. A human thermodynamics variable table is presented. From the standpoint of chemical kinetics, love is interpreted as a form of energy that gets transferred from one object to another. This view is supported by the second law, which states that the change in entropy is either zero or positive but not negative. The present article is a theoretical extension of an earlier practical illustration by the authors in the form of a short film on the same theme wherein a man falls in love with nine women, following which point comes a time when he is supposed—according to protocol—to 'choose' the *one*.

Introduction

Thermodynamics of love has been an emerging field of interest in the recent years.[7] In this field of study, the theoretical redefinition of a human may take on different perspectives. Earlier studies represented human as a molecule (Jean Sales), point atom (Humphry Davy), human atom (Erich Fromm), particle (Joel de Rosnay), and element (William Fairburn). The model employed herein, as outlined in the following table, divides the human, using a semi-chemical, semi-Cartesian dualism framework, into two separate entities, based on the logic that 'form' is part physical part neurological.[C1] A *thermodynamic equivalent* is assigned to each in approximation as follows:

Variable	Thermodynamic equivalent
Human body (physical)	Engine
Human body (neurological) – '*mind*'	Radical/ion
Money	Internal energy (state function)
Residence time/Activity span/Activation	Work (path function)
Love	Heat (path function)
Measure of love	Entropy
Transferability – '*change of mind state*'	Change in entropy

In the context of newly-emerging science of human thermodynamics, in 2007 American electrochemical engineer Libb Thims established a molecular formula for human that is comprised a total of 26-elements, wherein the primary structural elements are: C, H, N, O, P and S.[1] This is a more exacting formulaic redefinition of a human as compared to the earlier category of animals and plants described a 'CHNOPS-plus' elemental systems, such as was done in 1936 by American plant physiologist and ecologist Frank Thone.[9] This formula point of view redefinition of a human has recently found thermodynamics textbook inclusion in the 2011 *Advanced Thermodynamics Engineering* by Indian-born American mechanical engineers Kalyan Annamalai, Ishwar Puri, and Milind Jog.[8] Thims' 26-element definition of a human can be compared, in the context of ecological stoichiometry, to the independent 2002 derivation of a 22-element molecular formula definition of a human by American limnologists Robert Sterner and James Elser.[2] These works along with the known fact that a major amount of gas exhaled by human body being O_2, H_2O vapor and CO_2 with trace amounts of H_2, CO suggests that the human physical body be modeled as an 'engine'.[3]

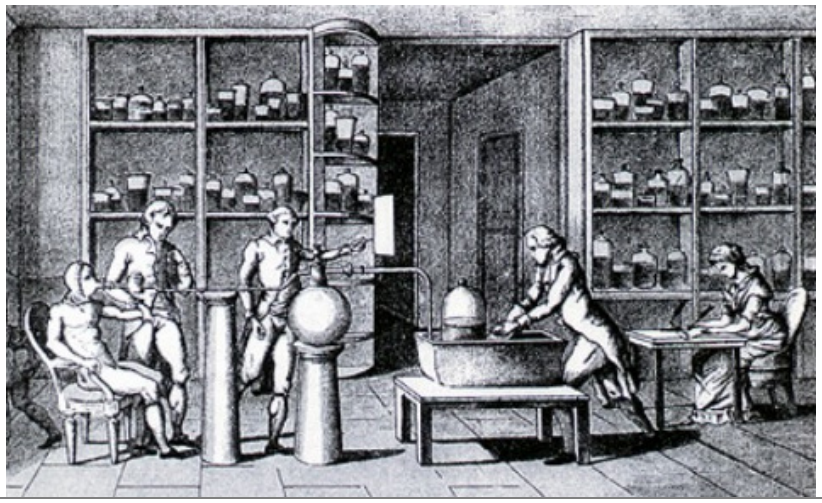
Human body ≈ engine

An engine works on the principle of combustion of reactant mixture wherein a fuel, typically hydrocarbons, is mixed at high temperature and or pressure with oxidizer, air or O_2, in a chamber forming products that includes CO_2, H_2O, and other by-products, depending on the initial and working conditions namely pressure, temperature, and species concentration. Combustion in general can be expressed by the following chemical reaction model:[N2]

$$\text{Fuel} + \text{oxidizer} \rightarrow CO_2 + H_2O + (\text{other}) + \text{heat release} \qquad | 1$$

A similar analogy is made in the current model herein wherein *fuel* are the compounds having 'C', 'H', and or other elements present in the body and the *oxidizer* is the inhaled air (79% N_2, 21% O_2 neglecting other trace amounts of impurities) and the *products* being standard products of combustion (O_2, H_2O vapor and CO_2) as mentioned earlier. This 'human engine' model, historically, has it precursors in the *circa* 1780 combustion theory of animal heat respiratory experiments of French chemist Antoine Lavoisier, pictured below, and the later 1856 mechanical theory of heat of human work experiments of French physicist Gustave Hirn, among others.[N1]

Hirn, in particular, conducted experiments in the determination of the mechanical equivalent of heat of a human being in working action. In particular, Hirn calculated a value for the mechanical equivalent of heat for a man doing work, i.e. running on a paddle-wheel like stair-climber treadmill, in a sealed chamber. To achieve this end, a man was placed in a hermetically closed chamber, and made to turn a wheel which could, at choice, revolve with or without doing work. The heat given out in the chamber was then ascertained by the ordinary calorimetric process. From these experiments, Hirn deduced a valuation of the mechanical equivalent of heat for animated motors; but the number which he obtained differed considerably from the standard obtained by English physicist James Joule in the previous decade via physico-mechanical methods.[5]



French chemist Antoine Lavoisier (center) shown conducting **animal heat combustion experiments** on his assistant, French chemist Armand Seguin; his wife chemist Marie-Anne Paulze seated (right).[4]

Apart from engine operation, a human body's maintenance and repairs can be analogized to the hygiene and or medications that the body undertakes.[N3]

Human mind ≈ Radical/Ion

Although forms whom we call the 'people' seem to exist as what we 'see' from outside, there is some other 'formless' form residing inside them. In this context, the analogy of body to engine is made based on the interpretation that the physical body is purely 'maintained and driven' by the *mind*. An illustration can be a man (mind) driving a car (body) or the flow of current lighting up the bulb. This latter example is what hints at the analogy of human mind to a radical/ion or a collection of these. The basic definition of a radical is:[10]

> "Radicals (often referred to as free radicals) are atoms, molecules, or ions with unpaired electrons or an open shell configuration. Free radicals may have positive, negative, or zero charge. With some exceptions, these unpaired electrons cause radicals to be highly chemically reactive."

A radical, accordingly, consists of very high chemical reactivity and in fact the presence of radicals is what makes combustion process to prolong until all the reactants are burnt to products releasing heat. A general chemical kinetic model for any combustion process may be represented by the following reaction mechanism:[11]

$$R \rightarrow R^{*} \quad | 2$$

$$R^{*} \rightarrow P \quad | 3$$

where R is a reactant, R^{*} is a radical, and P is a product. This whole process of combustion is what makes an engine run and absence of such radicals will hinder running of engine, due to no combustion!

Similarly the body works or moves as long as there is presence of mind. Having said so, it should be made clear about the word 'presence'. An extensive amount of research was made in the past and continues on 'conscious' and 'sub-conscious' mind.[12] So when it is mentioned as 'absence of mind', it should be understood as say the 'un-conscious' mind. Hence by representing human mind as a radical, the current model highlights the *highly reactive nature of mind* almost all the time. This might be well captured by German polymath Johann Goethe's 1799 comment on the lack of realism in the work of French author Prosper Crebillon, stated in a letter to his friend German author Friedrich Schiller—particularly in the use of the word 'delicate' to describe the chemical affinities and their external force mediator effect on the mind of people—individuals, in Goethe's *human chemical theory* view, being metamorphosized-evolved types of reactive chemicals:[13]

> "Crebillon … treats the passions like playing cards, that one can shuffle, play, reshuffle, and play again, without their changing at all. There is no trace of the *delicate*, chemical affinity, through which they attract and repel each other, reunite, neutralize [each other], separate again and recover."

The intention of saying 'almost' instead of saying 'all the time' is to include those instances wherein people do attain so called peace of mind or a state of equilibrium like seen in meditation, yoga exercises, etc. Such a behavior of mind can be interpreted by the additional feature that a radical has. This feature can be represented by the following equation:

$$R^{*} + R^{*} \rightarrow Q \quad | 4$$

where Q is an arbitrary compound having no reactivity.

Hence, in this regard, there is a possibility of two highly reactive radicals to combine forming compounds with low or least reactivity. Two highly reactive radical minds, it is argued, can thus combine forming human chemical compounds with low or least reactivity. This, again, is captured in Goethe's penetrating statement that people—as chemicals—can act, if the reaction is right, to *neutralize* each other. Even this reaction scheme is seen in combustion chemical kinetics wherein some radicals combine themselves forming a low or zero reactive compounds.[11] A similar comparative radical model of the mind can be seen in Thims' 2009 article 'Neuro Octet Trajectory Theory', wherein it is argued that certain

hydrocarbon structures of the mind, in the form of repressed or stored memories and or desired thoughts, seek to satisfy Abegg's rule of achieving a noble gas configuration and hence stability of the mind.[15]

Money ≈ Internal energy

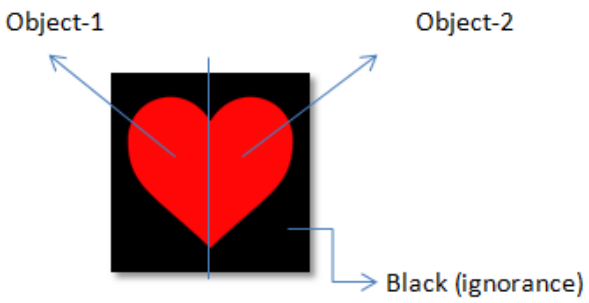
Money has had a long history of being conceptualized thermodynamically in terms of energy.[14] Money, in this direction, is conceptualized herein as a state function—one which doesn't depend on path—in particular as a form of internal energy U. It is a monetary variable which purely gives the information as to 'how much' one possess irrespective of 'in what way' was that earned. In this context, the means of earning can be included in *reaction existence*, i.e. 'life', which will be discussed shortly, leaving the 'money' variable as a *state function*.[N3]

Residence time ≈ Work

Having interpreted a human as two separate entities: body and mind, the amount of work W done by either of these depends on the residence time, which can be defined in terms of the durability of body and Gibbs free energy of the active radical. The former is something straightforward that as long as the body is in good or at least threshold condition, a non-zero work is possible. The latter case needs further explanation since it is hardly a natural tendency of humans to understand abstractions at a nanoscale. Coming back to the radical analogy for mind, work is done by an active radical as until it dissociates or depletes due to corresponding chemical reactions, as in eq. 4, and the body comes to rest. On the whole, as the amount of work done depends on 'activity span' of either body or mind, residence time is considered a *path function*.

Love ≈ Heat

It is a common notion, seen in the world, to represent love with a heart shaped symbol filled with red. While the 'heart' shape articulates heart, bonding, and other perceptions, the 'red' color says blood, passion, etc. This latter perception of passion is what hints to compare love with heat Q. In the following figure love is symbolized as two objects, object 1 and object 2, which were initially in ignorance (de-activated), as represented by the black background, but when they 'come across' each other—replicating movement of radicals, mean-free path, etc.—gets 'activated', shown by a change in color to red.



Hence the color 'red' in the current model is interpreted as *life* or—in chemically-neutral terminology—*activation*.[6]

Thermodynamics of love

On an elementary level, heat exists due to molecular level vibrations and collisions in an object. This again highlights the current proposal that love is formed due to chemical reactions among radicals belonging to the same object or between radicals of two different objects. This latter statement may be related to prior, independent, bond formation theories of Indian chemist and organizational behavior management researcher Surya Pati and American electrochemical engineer Libb Thims, the work of the latter based on the relationship laboratory measurements of American mathematical psychologist John Gottman, as outlined in his 1994 *Why Marriages Succeed or Fail*, wherein these works demonstrated human relations with chemical reactions:[16]

$$A + B \rightarrow A{\equiv}B \text{ | Thims model (2007)} \quad | 5$$

$$A + B \rightarrow AB \text{ | Pati model (2009)} \quad | 6$$

where *A* and *B* are single non-attached humans considered as 'human molecules' (Thims' terminology) or 'chemical molecules' (Pati's terminology) that chemically react to form products, namely the A≡B 'dihumanide molecule' (Thims' terminology) or the AB 'molecule' (Pati's terminology), the difference in bond notation, *AB* and *A≡B*, owing to the fact that Thims has done a significant amount of work into an investigation of the nature and mechanism of the human chemical bond.[17] The history of human chemical reaction theory, however, dates back to 18th century work of German polymath Johann Goethe.[18]

Further interpretation of love to heat is based on a modified form of original first law in that work in the present model is approximated as a combination of analogous heat and internal energy, as follows:

$$\delta W = dU + \delta Q \quad | 7$$

where work δW is conceptualized as residence time, internal energy dU is conceptualized as money, and heat δQ is conceptualize love. The differential operators delta δ signifying a path-dependent function and small d signifying a path-independent function. Eq. 7, to note, differs in some respect to the conventional definition of the first law where heat is a vectorial summation of energy and work:

$$\delta Q = dU + \delta W \quad | 8$$

in the standard Clausius-definition that when a differential amount of heat is added to the system it will cause a change in the internal energy of the system and concurrently an expansion of the boundary of the system resulting in the system doing an amount of work on the surroundings. In other words, the current analogous human radical variables reproduce first law with different 'sign convention' as used in first law of thermodynamics.[C2]

This logic leads to three conclusions. Firstly, no life or more technically no activation:

$$\delta W = 0 \qquad | 9$$

implies no money and hence no love, with respect to that particular object. One may, for instance, have amounts of love (heat) with respect to his or her parents. But once the activation is lost, i.e. expired, though they may have love (heat) on the object, i.e. him or her, it does not have an option to take in that love (heat), i.e. love is not taken by him or her.[C3] If there is no residence time, there is no radical and its movement, and hence there is no love. Secondly, as money is decreased, to retain activation, love should be increased. Lastly, as love is decreased, to retain activation, money should be increased.

Measure of love ≈ Entropy

According to zeroth law of thermodynamics: 'systems are in thermal equilibrium if they have no net exchange of heat.' The law implies that thermal equilibrium between systems is a transitive relation, which introduces the definition of an empirical physical parameter, called temperature. The temperatures are equal for all systems in thermal equilibrium.

A similar interpretation is made with the types of systems discussed herein, namely that these systems, people of interest in the current discussion, are in 'equilibrium' if they have no exchange of heat (love). For an instance, consider a situation wherein a person needs to form a group to participate in an event. If that person has a friend, lover, or relative, etc., to whom he or she shares his or her love, in the constructed team, he tries to be more inclined to that person knowingly or unknowingly which is not the characteristic of equilibrium. On the contrary, if the same person forms a team with someone whom he or she, met for the first time, say in a hall, there can be two possibilities, assuming he or she is not talking to only one mate possibility. These two possibilities, assuming the male perspective, are as follows:

Case 1: He may not be showing any interest in the rest (group).
Case 2: He may be contributing equally to the rest (group).

In the above two cases, he is in 'equilibrium' with the rest.

This zeroth law based discussion introduces the next analogy for a 'measure of love', namely to that of entropy *S*. A measure of love in the current model is ideated from the interpretation made from the zeroth law. But coincidentally, such an evaluating parameter was suggested by American physicist Jack Hokikian, namely that 'human beings can be classified into low-entropic and high-entropic people.'[19] However, entropy in the current model is a measure of love. Back to the analogy of radical and its movement and corresponding consequence of love, entropy is related to that of a radical. All radicals do not lead to the same results. Some radicals while undergoing chemical reactions get destroyed due to wall collisions and or surface reactions. Others successfully turn into products. Taking this context to a larger scale, all human minds do not contain the same radicals nor do they contain radicals with the same energy levels. So depending on whether radicals are excited, whether these radicals are active until products are formed, and other such factors, different objects may possess different measures of heat (love).

Transferability of love ≈ Change in entropy

After explaining the intent of measure of love**,** the authors would like to discuss the last, in fact the most crucial variable for the current study, namely: transferability of love. In the previous discussions, the relation between love and mind, which is represented by radical content, was covered to a certain extent. Also it was mentioned that love is analogous to heat; measure of love is analogous to entropy. Now a change in entropy is taken as an analogy for transfer of love from one object to another. All through our discussion, it was mentioned that a radical is a non-stabilized matter by its nature. Hence, by highlighting this fact that mind is always moving (non-stabilized), the authors would like to continue with their argument on 'transfer of love from one person to another.'

As the love (heat) on something changes, so does the transferability for a given measure of love for a particular object. As the love on something decreases, transferability of love (heat) on that object is more. For instance, let a person X like apples. Once he had enough of them, and is still provided with extra apples, his love on them starts reducing and finally may reach threshold (starting point of 'hate'). While his love of apples is reducing, his measure of transferability increases—he may start to 'look' for something else. Note that *seeking* nothing is also something in this context. On the other hand, for a reversible process i.e. if there is no change in heat (love)—again this is an idealized case, as we do have such a case in thermodynamics—then obviously there is no transferability, in which case:

$$dS = 0 \qquad | 10$$

This illustration applies to anything moving such as human or immovable objects like furniture. This is where the concept of 'transfer of love (heat) from one person to other' comes into picture.

Exploring second law of thermodynamics on entropy and its change, we are led into three conclusions. First, if the change in entropy is greater than zero, then the process is irreversible, which is seen in nature. The interpretation of this is that if the love on something or someone reduces, the transferability is greater than zero. This logic is quantified by the following expression, which is the state function definition of entropy:

$$dS = \frac{\delta Q}{T} \qquad | 11$$

where T temperature in which the radical resides or reacts. In the above context, the authors argue that T may also be considered, for instance, as the temperature of body and or brain. This is said in order to highlight that the current study is more emphasized on the change in love measure and transferability rather than change in temperature.

A second conclusion reached is that if the change in entropy is equal to zero, then the process is reversible. The interpretation here is that if there is *no transferability* in heat | love, then it is a reversible process, in the idealized sense. That means the source or system is either a machine or a person who doesn't really have love and or hate towards anything! In this case we are thinking along the lines of

radical neutralization reaction (eq. 4). Referring back to our sign modified first law model (eq. 7), when $\delta Q = 0$, then by repercussion $\delta W = dU$, i.e. work equals money.. So living, technically a 'state of activation', in this scenario, was meant only for earning which is what a machine does, although it may not give money always, it provides output that only depends on input.

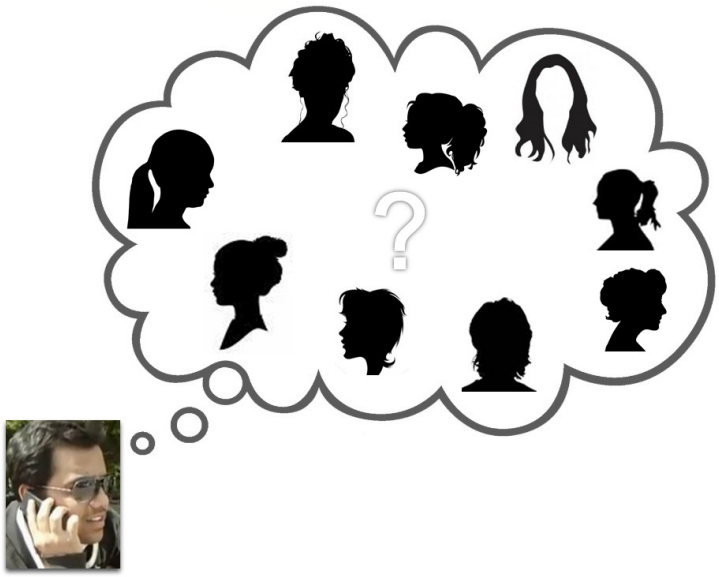
The last conclusion reached is that a negative change in entropy is not possible. The interpretation here is that even when the case of love on something to increase is considered, transferability on that thing or person stays at what it was before or may reduce in absolute values *S*, but the change in transferability *dS* stays positive. This statement can be justified by the never-ending flow of thoughts in mind, except, of course, when in non-REM deep sleep, in which case, in large part, one is not interested in dealing with the current laws. This all directly ties into the second law of thermodynamics, which states that 'the entropy of the universe is increasing', as can be quantified as follows:

$$dS \geq 0 \qquad | 12$$

Therefore, the conclusion reached is that transferability of love is always increasing in the real-world. Hence comes the proposal, originally stated in 4 Feb 2012 short film precursor to this article, entitled 'A Strange Thing Called Love', that:[20]

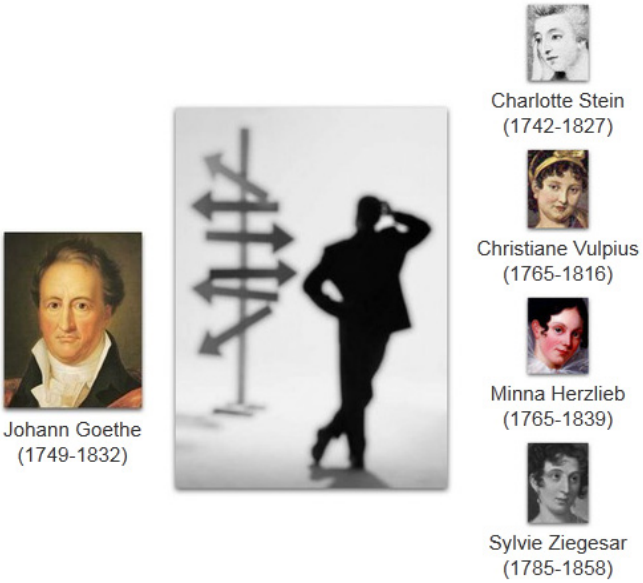
> "Love is a form of energy—that can neither be created nor be destroyed--which gets transferred from one person to another."

The plot of the original pre-article video is about a man falls in love with nine women, depicted below, wherein the day comes when he is supposed to make a decision on choosing 'the one':



Surprisingly, unbeknownst to the authors of video at the time, in 1809, German polymath Johann Goethe published a physical chemist based book named *Elective Affinities* based on a similar concept of love and marriage relations among two couples and their associations. The book itself was a precipitate or rather affinity chemistry expansion an earlier draft entitled *The Renouncers*, about a hero simultaneously in love

with four women, both of which being based in a semi-autobiographic nature to Goethe's own existence and his own puzzlements about the nature of love, marriage, and relationships, as depicted below:[21]



These so-called 'love thought experiments', in turn, are similar to Thims' *circa* 1992-1993 attempts to figure out how to go about choosing whom to marry—as this is supposed to be a step, according to cultural precedence, in the colloquial standard model of existence—as a freshman pre-engineering student, wherein Thims made an excel-style spread sheet table of the top nineteen girlfriends, whom he could potentially marry, listing each person on the horizontal and listing a range of point ranked attributes, qualities, or factors on the vertical, such as grandmother would like her, spontaneity, fun factor, physical attraction attributes, mental attraction factors, repulsive factors, etc., in an attempt to get a numerical 'marriage quality value' for each girlfriend, the result of which nearing the point of Thims almost asking the question in his 1995 chemical engineering thermodynamics class, in regards to how such matchings would be done thermodynamically according to the Gibbs free energy change spontaneity criterion of reaction prediction. Similar to how it took Goethe a full-decade to work out his model, would be dozen years before he could figure out the nuts and bolts of how this could be quantified via enthalpy and entropy determinants, the results published in the 2007 *Human Chemistry*. It is a pure coincidence and the current authors actually didn't know about these similar thermodynamics based love thought experiments until they started preparing this article.

Conclusion

Different human thermodynamic variables were chosen and proper relations were established among them on the basis of standard laws of thermodynamics. Further, the second law was explored in the context of love and after certain interpretations, it was concluded that love is a form of energy and that transferability of love is always increasing.

Acknowledgements

We would like to thank Libb Thims for introducing us to the newly-developing field of human thermodynamics and for providing crucial guidance that made this article possible to be in the current status.

Editorial clarifications

C1. Is this 'form' division based on the Platonic forms model?
C2. Why is the sign convention modified first law utilized?
C3. Sentence is a bit blurry.

Notes

N1. (a) Substantial editorial, historical, and pictorial additions and redactions were implemented/added into the article, per JHT readability standards. Compare original draft submission, below:
(b) humanthermodynamics.com/ASTCL_O.pdf
(c) eoht.info/page/Human+engine
N2. In the combustion reaction, the authors note that as 'O' which acts as an oxidizer in real world is already present in the human body, the authors claim that there is a continues/never-ending (all through its life-span) combustion process happening in the human body which needs external oxygen to 'sustain' this combustion fire. In addition, this claim is supported by the idea that such a fire is the source of digestion phenomenon in any living-being including human body.
N3. Per the Tesla (1915)-Sherrington (1938)-Ubbelohde (1954)-Nordholm (1997)-Thims (2009) 'defunct theory of life' perspective, all bio-related terms, such as 'living, alive, life, etc., and their antonyms, e.g. dead, death, etc., have been editorially rewritten into thermodynamically-neutral terms.[6]

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