HEALTH, AGEING AND ENTROPY

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Abstract: *Entropy is a measure of order and disorder and entropic principle (second thermodynamic principle) is able to explain many phenomena in physics, chemistry, biology, our human bodies, corporations and even the universe. If left alone, these ageing systems go spontaneously from low entropy and order, to maximum entropy. This means the direction of time can be evaluated. The short survey of basic knowledge concerning of ageing of humans together with results of our opinions and research are the aim of our work.*

Key words: *entropy, order of system, disorder, ageing of humans*

1. Introduction

We are usually nervous to hear about ageing. But what is it ageing? It is the accumulation of changes in an object, organism or community. Ageing in humans refers to a multidimensional process of physical, psychological and social change.

Young people won´t hear about it. But time is going on and for example at eighty human heart can pump blood only at about half of what it could do at age sixty. For example some pine tree can live to 4000 years. A fly live a day, a flea 30 days, a white rat 4 years, dogs and cats 15 years, horses 40 years, hippopotamuses 50 years, Indian elephant 80 years, fresh water mussels and some other fish 100 years, great tortoises 150 years.

From the physico – chemical point of view is life a series of chemical reactions accelerated or moderated by enzymes. We store or expend energy and at constant temperature we transfer it to the surroundings as heat (metabolic product of fats, carbohydrates and proteins). Very important measurable quantity is the Basal Metabolic Rate (BMR), which is defined as the energy output of an individual under standardized resting conditions (bodily and mentally at rest, 12 to 18 hours after a meal, in a thermally neutral environment). This value vary by 10 % during the day, overfeeding can raise it and underfeeding can drop it up to 17 %.

2. Theories of ageing.

<u>2.1. Biological theories</u>

Most scientists agree that ageing is to a large extent genetically based (selected alternations in specific genes can extend lifespan). There is a short survey of these theories.

- *Telomere Theory*. Telomeres, i.e. structures at the ends of chromosomes have experimentally been shown to shorten with each successive cell division. Shortened telomeres activate a mechanism that prevents further cell multiplication (such mechanism can be important of ageing in tissues like bone marrow and arterial lining where active cell division is necessary.
- *Reproducive – Cell Cycle Theory*. According to this theory is ageing regulated by reproductive hormones promoting growth and development of cells early in life, but later drive senescence.
- *Wear and Tear Theory*. Ageing is a result of damage accumulation in organisms, accumulated over time.
- *Somatic Mutation Theory.* Ageing is a result of genetic integrity of the body´s cells.
- *Error Accumulation Theory.* Ageing results from damages in reading mechanisms of genetic code.
- *Viral Theory of Aging.* Viral infection could be the most likely cause of the DNA damage.
- *Accumulative – Waste Theory.* The waste products of cells merosis interferes with metabolism.
- *Autoimmune Theory.* Increasing level of autoantibodies attack the body´s tissue.
- *Ageing – Clock Theory*. Ageing results from a preprogrammed sequence, built into the operation of the nervous or endocrine system of the body.
- *Cross Linkage Theory*. Ageing results from accumulation of cross – linked compounds that interfere with normal cell function.
- *Free Radical Theory*. Free radical, i.e. unstable and highly reactive organic molecules create damage that gives rise to ageing symptoms.
- *Reliability Theory of Ageing*. This theory is based on a general theory about system failure. It is able to predict the late – life mortality deceleration and exponential increase of mortality rates with age (Gompertz Law).
- *Misrepair Accumulation Theory*. Ageing is the result of the accumulation of "misrepairs". Important in this theory is to distinguish among "damage" (newly emerging defect <u>before</u> any reparation, and "misrepair" which describes the remaining defective structure <u>after</u> incorrect repair.

<u>2.2. Nonbiological theories</u>

- *Disengagement Theory*. According to that theory the separation of older people from active roles in society is normal and appropriate (this theory has been much criticized).
- *Activity Theory.* According to this theory the more active elderly people are, the more likely they are to be satisfied with life.
- *Selectivity Theory.* The theory mediates between Activity and Disengagement Theory. Old people should be more active in some aspects of their lives and more disengaged in others.
- *Continuity Theory.* According to this theory individuals in later life make adaptations to enable then to gain a sense of continuity between the past and the present. This sense of continuity helps to contribute to well – being in later life.

– *Entropy Theory of Ageing*. (very similar to Wear and Tear Theory). This theory will be shortly presented in following part of the work. But at first some basic physical knowledge will be introduced.

3. Basic Thermodynamical Knowledge

The science of thermodynamics is based on two fundamental laws, both of which have tremendous significance for nature processes, industry and also economy. The first Law of Thermodynamics is actually a restatement of the Law of Conservation of Energy for the special case involving heat:

$$\Delta U = \Delta Q + \Delta W \qquad (1)$$

where ΔU is the change of internal energy, ΔQ is the change of added heat and ΔW is the work performed (added) on the system. The first law for the heat engine is shown on the Fig.1.

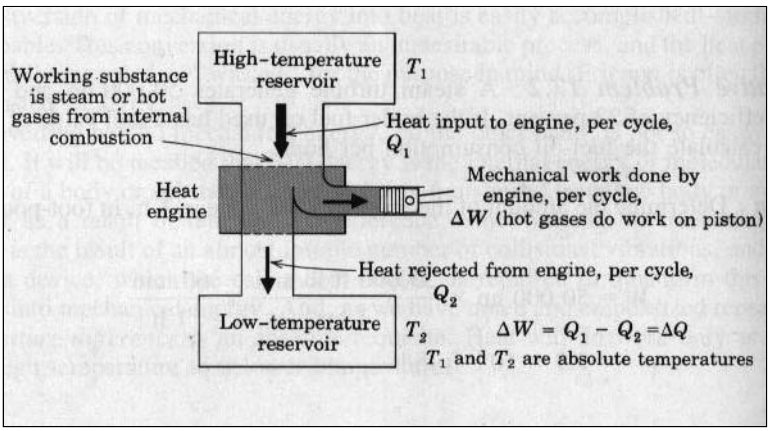

Fig. 1. Schematic representation of First Law of Thermodynamics

The source of the heat is the high-temperature reservoir and work is done as heat energy flow through the system to the low-temperature reservoir. A generalized statement of the first law of themodynamics is: The increase of internal energy is equal to the algebraic sum of the change energy added and external work done.

The Second Law of Thermodynamics has to do with the *availability* of heat energy for the purpose desired, i.e. mechanical energy cannot be obtained from any source of heat unless that source undergoes a drop in temperature. The second law of thermodynamics is independent of the first law and it says that energy processes always move from order to disorder, and that heat flows of its own accord from high temperature to low temperature. Three men of science who devoted much of their lives to the study of heat and thermodynamics have made separate but equivalent statements of the second law:

1. It is impossible to construct an engine which will convert a given quantity of heat into an equivalent amount of work (Sadi Carnot 1796-1832).

2. It is impossible for any self-operating device to take heat continuously from a reservoir at one temperature and deliver it to a reservoir at a higher temperature (Rudolph Clausius (1822-1888)).
3. As a result of natural processes, the world´s supply of energy available to do work is continuously decreasing (Lord Kelvin (1824–1907)).

The second law in graphically form is shown on Fig.2.

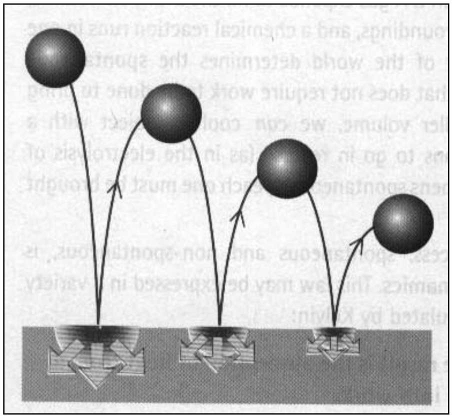

Fig. 2. Second Law of Thermodynamics.

The thermodynamics property of a system which measures its degree of disorder is called *entropy* (from a Greek word meaning "transformation"). Entropy may be thought of as a measure of the degree of energy degradation in any process. The second law of thermodynamics is sometimes called the *law of entropy*. Clausius defined entropy mathematically as follows: If ΔQ is a small reversible change in the heat content of a body, and if the change takes place at temperature T, then the entropy ΔS is:

$$\Delta S = \frac{\Delta Q}{T} \qquad (2)$$

Natural phenomena always occur (in isolated systems) in such a direction that entropy (the state of disorder or unavailability of energy) increases. Only in an idealized reversible process can ΔS be zero. Referring again to Fig.1, we can see that heat from a reservoir of hot gas (temperature T_1) is allowed to flow into a reservoir of "cold" gas (temperature T_2), with an engine in the path of the heat flow converting some of the heat to mechanical energy.

Suppose no engine be there. The high-temperature gas would then merely get cooler, and the low-temperature gas would get warmer until the mixture reached some equilibrium temperature. There is no decrease in total energy in this second process (first law), but the opportunity to convert some of the heat in the "hot" reservoir to mechanical work has been lost, not temporarily, but forever (second law). Energy itself has not been lost, but the opportunity to get some work done has been irretrievably lost. The mixture will not, by itself, separate back into hot gas and cold gas. In this process, entropy will have increased in accordance with Eq.2, and *availability* of energy for conversion to mechanical work will have decreased.

4. Energy. Entropy and Lifespan

From the physico – chemical point of view life is a series of chemical reactions accelerated or moderated and modulated by enzymes. Human body has usually constant temperature and it means that on one said we receive energy in form of fats, carbohydrates and proteins and on the other side we transfer it to the surroundings as heat. Thermodynamically it means that ordered organic molecules are changed to totally unordered form of energy – heat. Highly ordered systems carry low entropy and much stored information. According to second thermodynamic principle such system left to itself inevitably deteriorate with time until its increasing state of disorder and achieves a maximum of entropy (= death). If the death of an organism is viewed as the state characterized by maximum disorder and if the wear and tear theory offers one reasonable explanation of our longevity, then it should be informative to determine the total entropy production during our lifetimes. The lifetime entropy production of animals (rats, horses, pigs, …) is quite the same order of magnitude except for humans who is 4 to 5 times higher. Why are humans different?

For living systems, energy content, entropy production, vitality and rate of living are dependent on chemical reactions within our bodies, affected by temperature. The heat evolved, measured under proper conditions is called the basal metabolic rate (BMR). For each of us there is an internal temperature at which we are comfortable. Under fasting conditions (no food for 12–14 hours) and at rest (subject lying quietly under, no overt stress), the energy of living is converted almost entirely into heat rejected to surrounding environment. Cancer patients record higher metabolic rates than normal. Also people suffering cardiovascular disease are likewise hypermetabolic. Smokers have greater sleep difficulties than nonsmokers because smoking raises blood pressure, heart rate and fatty acid concentrations. It means that smokers accelerate their living and are physiologically older than nonsmokers of the same age. According to wear and tear theory of aging they will suffer shortened lifespan. Children have high BMR (twice adults level) as their bodies develop and change rapidly. After 10 years of age BMR gradually declines. BMR is also affected by temperature (is lower at higher temperature) and is proportional to pressure. Vegetarians have lower BMR than nonvegetarians with high proteins consumption. Sleeping results in lowest heat generation an can be used as normal for other activities. Seated activities such as writing and typing may yield BMR values 50 % to 100 % above minimum sleep levels. Light activities (slow walking) show three times sleep level and moderate efforts (slow swimming, cycling) give 5 to 6 times the lowest sleep level. Very heavy work (rapid cycling, climbing) yield heat production rates 13 to 16 times the sleeping levels.

It seems to be a relationship between longevity and metabolic rate. If we divide the metabolic rate by body temperature, we obtain number (see equation (2) which is a general measure of our entropy production. Our live is a way from a highly ordered system to an increasingly disordered state and strive towards the ultimate disorder, death. At a given age (comparing two persons) the one with a higher rate of entropy production is living at a fast pace and less efficiently and will die sooner. As we age, the rate of entropy is curtailed, but anyway continues constantly. Thus entropy production may be the pointer of our life´s progress: rapid when we are young, slow when we are old.

According to life – science researchers the organizational entropy is

$$S_{org} = R\ln\left(\frac{u}{\rho}\right) + const \qquad (3)$$

Where S_{org} is organizational entropy, R gas constant, ρ is maturation rate for a definitive stage of development of the organism, u is mean metabolic rate for the energy stage, and then ρ/u is measure of the energy cost of carrying the development of an organism from one stage to another.

A lower rate of entropy production permits the organism to live longer and more metabolic work. The rate of ageing and maturation are apparently related to the rate of entropy production of the whole system: aging is related not only to how much metabolic work is performed but to how well the work is done, in entropic terms. Maximum entropy may correspond to death.

5. Conclusion

The ageing process is always accompanied by the continuous development of imperfections, characterized by entropy. The relationship between the entropy and other physical quantities is:

1. An increase in internal energy of a system increase its entropy.
2. A system will decay if insufficient work from its surroundings is applied to the system or insufficient internal work is done inside the system.
3. The passage of time will cause the entropy of a system to increase automatically unless adequate low entropy is supplied.
4. As the entropy of a system increase, the degree of random activities within the system will increase.
5. As a system´s entropy increases, its energy become less available for doing useful work.

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STÁRNUTÍ, ENTROPIE A LIDSKÉ ZDRAVÍ

Abstrakt: Entropie je veličinou, která charakterizuje uspořádanost systému (druhá termodynamická věta). Lze pomocí ní objasnit mnohé jevy fyzikální, chemické, biologické, společenské a dokonce i jevy ve vesmíru. Takové systémy ponechané přirozenému vývoji směřují totiž vždy ke stavu s maximální entropií. Cílem naší práce je přinést stručný přehled znalostí, týkajících se stárnutí lidského organismu a doplnit je výsledky našich výzkumů.

Klíčová slova: entropie, uspořádanost systému, starnutí organismu