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Cell Signalling (cell-cell communication) and entropy change of the cellular system

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Abstract

Cell signalling is a complex process of communication among cells and organs that governing cellular activities and cooperative cellular function. The ability of cells to perceive and correctly respond to their microenvironment is the basis of development like tissue repair, immunity as well as normal tissue homeostasis. We have attempted to show that cell signalling (or information transmission) is associated with the entropy change of the cellular system. Disordered (higher entropy) diseased cells produce error signals in cellular information processing. Error signals are responsible for diseases such as cancer, autoimmunity, and diabetes and what not. Every disorder for any internal or external reason is associated with the entropy change of the system. We have shown that entropy change and information (cell to cell communication) are related. By understanding cell signalling or the change of entropy, diseases may be treated effectively and, theoretically, artificial tissues may be regenerated.

1. Introduction

In a living organism cells are always dynamic particles secreting different chemical (enzymes etc.) which changes when the cell is diseased. Entropy of the disordered cell is higher than the corresponding normal cells [1-3]. Moreover, in a living organism, signalling [4] between different cells occurs either through release into the extracellular space which might be , over short distances (paracrine signaling) and over long distances (endocrine signalling), or by juxtacrine signalling (known as direct signalling . Signalling information is transmitted to the brain through neurons for functioning.

A special case of paracrine signalling is Synaptic signalling (for chemical synapses) or juxtacrine signalling (for electrical synapses) between neurons and target cells. Signalling molecules (when stimulated its entropy increases which is transmitted) interact with a target cell (actually some as a ligand to cell surface receptors).This generally results in the activation of second messengers, leading to various physiological effects. Different signalling are actually different ways of transmission of entropy (energy) associated with cells under consideration. The signalling within, between, and among cells is subdivided into the following classifications [3].

1.1. Paracrine signaling

In Paracrine signaling (form of cell-cell communication) a cell produces a signal to induce changes in nearby cells, altering the behavior or differentiation of those cells. Signaling molecules known as paracrine factors diffuse over a relatively short distance

Cells that produce paracrine factors secrete them into the immediate extracellular environment. Factors then travel to nearby cells in which the gient of factor received determines the outcome.Here we like to mention that cell signalling process is very quick .For signaling molecules or paracrine factors travel from one place to the other would take long time which is not feasible. It is actually the entropy change which produces information (shanon theory) for cell to cell communication. Growth factor and clotting factors are paracrine signalling agents. The local action of growth factor signalling plays an especially important role in the development of tissues. Also, retinoic acid, the active form of vitamin A, functions in a paracrine fashion to regulate gene expression during embryonic development in higher animals.(local action).In mature organisms, paracrine signaling is involved in responses to allergens, tissue repair, the formation of scar tissue, and blood clotting.

1.2. Endocrine signaling:

Endocrine signs target inaccessible cells. Endocrine cells produce hormones that go through the blood to arrive at all pieces of the body. at the point when cells need to impart a message over a significant distance, they can utilize the endocrine framework. Endocrine flagging uses synthetic compounds called hormones to send messages all through the body. The hormones are delivered from the cell into the circulation system and can go around the whole body. Conversely, the exocrine framework secretes its items into the extracellular climate. Insulin from pancreas to blood to muscle cells to make them take up glucose.

1.3 Autocrine signaling:

Autocrine flagging is a type of cell motioning in which a phone secretes a hormone or compound courier (called the autocrine specialist) that ties to autocrine receptors on that equivalent cell, prompting changes in the cell.This flagging is genuinely quick and Prominent in tumor cells and in resistant cells. A case of an autocrine operator is the cytokine interleukin-1 in monocytes. At the point when interleukin-1 is created in light of outer improvements, it can tie to cell-surface receptors on a similar cell that delivered it.

1.4. Synaptic signaling:

It is similar to paracrine signaling but there is a special structure called the synapse between the cell originating and the cell receiving the signal. Synaptic signaling only occurs between cells with the synapse; for example, signaling between a neuron and the muscle that is controlled by neural activity.

1.5. Juxtacrine signalling:

juxtacrine flagging (or contact-subordinate flagging) is a kind of cell/cell or cell/extracellular framework motioning in multicellular creatures that requires close contact. Henceforth, this stands rather than delivering a flagging atom by dispersion into extracellular space, or the utilization of long-range courses like layer nanotubes and cytonemes (much the same as 'spans'), or the utilization of extracellular vesicles like exosomes or microvesicles (similar to 'vessels'). There are three sorts of juxtacrine flagging: (a)A layer ligand (protein, oligosaccharide, lipid) and a film protein of two neighboring cells collaborate. (b) An imparting intersection connects the intracellular compartments of two contiguous cells, permitting travel of moderately little atoms. (c)An extracellular lattice glycoprotein and a film protein communicate. Furthermore, in unicellular creatures, for example, microbes, juxtacrine flagging alludes to associations by layer contact. The expression "juxtacrine" was initially presented by Anklesaria et al. (1990) to depict a potential method of sign transduction between TGF alpha and EGFR.

Juxtacrine signaling has been observed for some growth factors, cytokine and chemokine cellular signals, playing an important role in the immune response. It has a critical role in development, particularly of cardiac and neural function. Other types of cell include paracrine signalling and autocrine signalling.

2. Entropy Information (cell-signalling) relation

2.1. Probability function (cell-cell communication) and mathematical methods

Interestingly, it should be noted that the probability function is related to both entropy and information (hanonn theory). That I, both information or entropy can be defined in terms of the probability p. Our special interest is concentrated to probabilities of an event (i.e., real numbers between 0 and 1 in case classical information of unit bit which can be easily converted to quantum information (qbit orqutrit). From this consideration, Shannon theory[5-6]of information can be written as

$$I(p) = - L \ln p = L \ln (1/p) \quad \textbf{(1)}$$

where L is an arbitrary number. Shannon considered binary system and logarithms to the base 2. Forming all possible sequences of two digits (0 and 1, say) of length n, the $P=2^n$ possibilities. Therefore, one can write

I = Lln p = Ln ln 2,

where $L= I/\ln2=\log_2 e$

(2)

and

$$I= \log_e p \quad (2a)$$

One bit of information, minimum unit of information, in defined by I= ln2. Now let us consider the message (information created by entropy change) of a system containing N dynamic living cells. Each of N cells has one of the M variables (enzyme etc.). The message consists of N_1 variables A_1, N_2 variables A_2…etc.

We have

$$N= \sum_{j=1}^{M} N_j \quad (3)$$

j-1 to M

The number of various possible messages is equal to the probability

$$P= (N!)/\sum_{j=1}^{M} N_j! \quad (4)$$

The probability of occurrence of a particular variable is

$$p_j = Nj/N, \; j=1,2, 3…..M$$

and $\sum p_j =1$

(5)

Following Shannon information theory

$$I= - \ N\sum_{j=1}^{M}p_j \ln p_j$$

(6)

Therefore, information per cell

$i = I/N= - \ L\sum p_j \ln p_j$ (7)

J-1 to M

The C.G.S. unit of energy (E) is erg which might be considered as the smallest unit of energy. Again this energy unit is related to mass and velocity of light ($E=Mc^2$). Similarly, information is expressed in its smallest unit of bit. Equation (7) [10](8) is the most general formula for information due to Shannon (1948) which gives the sequence of events that have different probabilities p_j. If L= 1, the information is expressed in bits. If L= Boltzmann constant (k_B) = $1.38x10^{-23}$J/K (=1.38 $x10^{-16}$erg/K), information is expressed in J/K or erg/K (or E/K).

2.2. Probability function and entropy

In terms of probability, the thermodynamic entropy can be written as

$S= - k_B \sum p_j \ln p_j$ (8)

So both entropy and information can be written by a general formula and same units.

$I/S = \ - L \sum p_j \ln p_j$ (9)

Thermodynamic entropy (S) L corresponds to $L=k_B$ and information (I), L=1 bit of information (ln2) unit. This identity can also be verified from the probability theory. Both information and entropy can be strictly defined in terms of the probabilities of events. We consider a set of probabilities (a probability distribution) P = (p_1, p_2, …., p_n). Therefore, one can define S of the distribution P by

$S = \ \sum p_i \ \log(1/p_j)$

(10)

i=1 to n

which indicates entropy S and information (I) has the same expression (not same , as mentioned above). In other words, entropy of a probability distribution is the expectation value of the information of the distribution. This concept looming large many thought provoking ideas in cell biology to be enlightened.

Conclusion:

In the present findings, we have demonstrated that entropy change and data (cell to cell correspondence) are connected. By understanding cell flagging or the difference in entropy, infections might be dealt with adequately and, hypothetically, fake tissues might be recovered. This relation of entropy and information might be considered as a new tool of further studies of chemical affinity, cell signaling mechanism, call-cell communications and astrophysical problems involved with entropy, mass and energy which will probably be flourished in further studies.

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