# Logical impossibilities in biological networks

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**Abstract: Biological networks are complex and involve several kinds of molecules. For proper biological function it is important for these biomolecules to act at an individual level and act at the level of interaction of these molecules. In this paper some of the logical impossibilities that may arise in the biological networks and their possible solutions are discussed. It may be important to understand these paradoxes and their possible solutions in order to develop a holistic view of biological function.**

In today's world voting is not only relevant to public competitions and electorates but advanced technological missions using space systems are often under the control of a odd number of computers which vote to decide whether the launch takes place or not. Besides this there are theories of working of human mind that envisage it as a multi leveled system of separate influences, each voting for a particular course of action. These separate influences act rather like a society and this "society of mind" was pictured by Marvin Minsky.

In this paper the ways in which the overall structure of biological networks can create impossibilities are explored. It is shown that collective impossibility can emerge from the number of perfectly rational individual choices.

Here we take the example of a hypothetical operon. Possibility 1 is there is only activator, Possibility 2 is there is only repressor and possibility 3 is there is a mixture of the two molecules. Let us envisage three situations. Let us assume there are three possible voters in the cellular network A, B and C (say, A activating a repressor protease, B: activating an activator protease and C absence of A and B). The possibility 1 is favored to possibility 2 to policy 3 (repressor is degraded completely) by voter A , the possibility 2 is favored to possibility 3 to 1 by voter B and possibility 3 is favored to possibility 2 to possibility one by voter C. Thus the "decision system" of the cell prefers possibility 1 to 2 by a clear majority of two votes to one and possibility 2 is preferred to possibility 3 by two votes to one. The solution seems simple: possibility A prevails. However, the situation is not so simple possibility 3 is preferred to possibility one by two votes to one, 1 beats two, and two beats 3, but 3 beats 1.Taking another relevant example, the analogous situation may arise in the following manner: let voter A, voter B and voter C choose molecules of guanylyl cyclase and cGMP phosphodiesterase. Voter A prefers degradation of cGMP to synthesis of cGMP to intermediate concentration of cGMP (due to presence of both cGMP phosphodiesterase and guanylyl cyclase). Voter B prefers synthesis of cGMP to intermediate level of cGMP to degradation of cGMP. Voter C prefers intermediate concentration of cGMP to synthesis of cGMP to degradation of cGMP. Thus at first it may seem that degradation of cGMP is preferred to synthesis of cGMP. However at closer inspection, one may conclude that cGMP degradation beats intermediate concentration of cGMP, and cGMP synthesis beats intermediate concentration of cGMP, however intermediate concentration of cGMP beats cGMP degradation.

This sort of problem was first identified by a French mathematician and social scientist, Marquis de Condorcet in 1785. The above paradox is not restricted to biological systems only but as we progress from individual choices to collective choices, these kinds of paradoxes arise. The sum of individual rationalities is not simply equal to collective rationality. Collective social choices sometimes exhibit an arbitrariness that is very different from the way individual choices are made.

If A prefers B and B prefers C does mean that A prefers C then the scenario is transitive. We have seen the example of an intransitive situation above. In 1950 an American economist Kenneth Arrow analyzed the problem of democratic choice in a general fashion. H developed what is called Arrow's possibility theorem.

Arrow wanted to see whether there were any conditions under which intransivity in voting systems could be avoided. He assumed that individual preferences satisfy following rules:

(a) Comparability of alternatives: This rule implies that alternatives have some property in common which can be used to compare the. Ties are not allowed in the individual preferences.

(b) Transitivity: If a is preferred to b and b is preferred to c then, essentially a is preferred to c.

Next, a system, which defined characteristics of collective democratic choice, was chosen. These were:

Condition 1: Unrestricted freedom of individual choice
Every individual voter is free to choose any one of the possible orderings of the candidates. No organizations can prevent any voter preferences.

Condition2: Social choices should positively reflect choices of individuals

Condition3: Irrelevant alternatives should have no effect

Condition4: The voice of the people matters

Condition5: No dictatorship

These conditions allow a rigorous examination of result of many possible links between individual and collective choice. Arrow proved that if individual choices are finite in number and obey the conditions (a) and (b), then there is no method of combining individual preferences to produce a social choice which meets all the conditions (1)-(5). Every method of making a social choice that satisfies the conditions (1)-(3) either contradicts the requirements (a) or (b) or violates the conditions (4) or (5). It is noteworthy that social intransitivity does not arise from any intransitivity of individual voting, since they are explicitly forbidden by assumption (b). Arrows theorem states that if the democratic conditions (1)-(5) and (a) are satisfied, then there must be intransitivity in the outcome. It is very hard to achieve social consensus.

Duncan Black (Black, 1958), whose work was further developed by Amartya Sen (Sen, 1966 and Sen, 1970) , showed that a majority decision is never possible in the situation where each alternative is ranked differently by each voter. Situations in which each possibility is ranked differently by every voter create paradox and intransitivity. Though the conditions 1-5 listed may not be relevant to biological networks, the intransitive and paradoxical situation may arise in these networks.

Complex molecular biological networks have been revealed by systematic approaches to study large numbers of metabolites, proteins and their modification. The biological processes require the proper functioning of molecules at individual level as well as at the level of interaction with other molecules. The biological networks exhibit significant differences from random networks and have common properties with respect to their organization and structure. The understanding of developmental and cellular events at molecular level has become a major focus for modern biology and understanding the networks and their properties has in turn become indispensable for such analysis. The example mentioned above (of cGMP biosynthesis) is a simplistic example. The actual situation in a cell may be quite complex, with many “voters” and many possible “situations”. The understanding and analysis of these kind of paradoxes may be essential for understanding of biological function.

**How this paradox might be resolved by biological networks?**

A way to resolve this paradox in the voting systems may by using a randomizer, some random way of imposing a social choice in intransitive situations (Barrow, 2005). It has been suggested by Frank Tipler that it may be necessary to introduce a randomizer as a sublevel; with in mind (human or artificial) in order to resolve paradoxes created by intransitivities. (Tipler, 1994). The quantum uncertainties might be linked to the randomizer (Barrow, 2005). Besides these quantum uncertainities have been proposed to play a role in consciousness.

The elementary particles which are the fundamental building blocks of the matter constitute the quantum world. The brain is made up of physical matter and a cherished goal of scientists working on brain has been to explain that how the higher cognition and consciousness raise from the physical matter in the brain. Recently some investigators have begun to explore the answer to the above question in the quantum domain .

We have seen above that the paradoxes may not only be present in the neurons in the brain but in cellular networks also. The living cell is an information processing and replicating system that abounds in natural nanomachines which at some level require quantum mechanical explanation**.** Therefore the possible candidates for quantum randomizers are many in the cell**.**

## References

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