Recent Advances in Biomolecular Computation-Information Security Applications

*Nidhi Sharma, *Ridhi Aggarwal
Ph.D*, Indian Institute of Technology, Jodhpur,Rajasthan
pg201384009@iitj.ac.in

Information security is the practice of protecting information from unauthorized access. The core of security system lies in the CIA triad - Confidentiality, Integrity and Availability. The most commonly used security methods are passwords, encryption and cryptography. The same computational principles and logics can be applied to biomolecules for information security applications. The specific characteristics of biomolecules such as reliability, stability, size, speed, architecture and their nanoscale engineering are extracted for building security systems.

Molecular electronics explores the encoding, manipulation and retrieval of information at the molecular or macromolecular level. Biomolecular electronics is a subfield of molecular electronics and shows the significant promising future because of the sophisticated control and manipulations that is obtained through self-assembly mechanism and genetic optimization of large macromolecules. Keypad lock is the simplest mode of information security that can be realized using biomolecules. The basic concept of keypad lock system is analogous to the simple 3-Input electronic circuit using AND gates. In this system, Switch S1, S2 and S3 serve as the key to activate the circuit. All the three switches should be closed to complete the circuit and make LED glow. The essential condition is the 'specific' combination of switches among all the other possible combinations. Therefore, the correct combination results in the activation of LED which signifies the unlock condition of the keypad system.

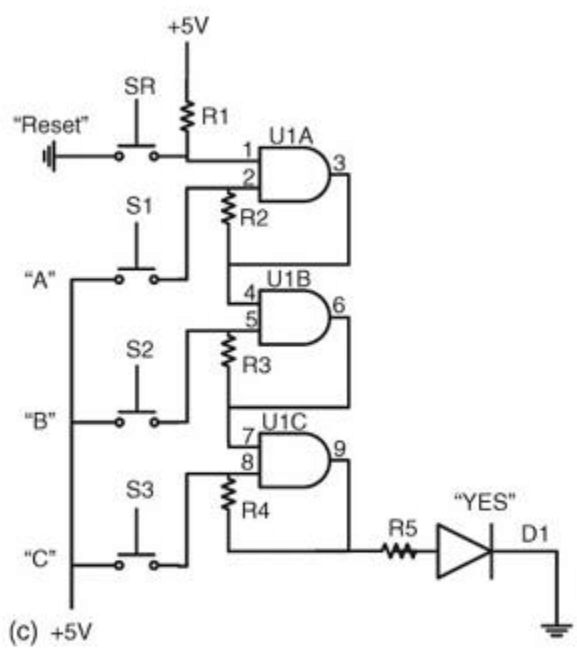

Figure1(a): Electronic Keypad Circuit

The principle of first enzyme based keypad lock system was based on the biochemical pathways. In these pathways, biocatalysts act as switches. The implication of the biocatalysts in a proper sequence decides the fate of a biochemical pathway. If a biocatalyst is inhibited or absence of an activated substrate results in blockade of biocascade. On the basis of this principle, a biochemical reaction chain was being modeled that involved three catalytic steps. The inputs sucrose, oxygen and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) are already present in the chemical system. The first step involves the hydrolysis of sucrose to glucose, second is reduction of oxygen by glucose to yield hydrogen peroxide and finally oxidation of synthetic dye ABTS takes place by H_2O_2. The reactions are catalyzed 'specifically' and 'exclusively' by the enzymes-invertase(Inv), glucose oxidase (GOx), microperoxidase-11 (MP-11). Each enzyme is exposed to the system until a specific amount of product concentration is achieved to carry the reaction forward. This biochemical pathway involves three concatenated AND gates. The output from first gate serves as input for second whose output to third gate generates the signal that activates the lock and colored product is formed due to oxidation of third input ABTS.

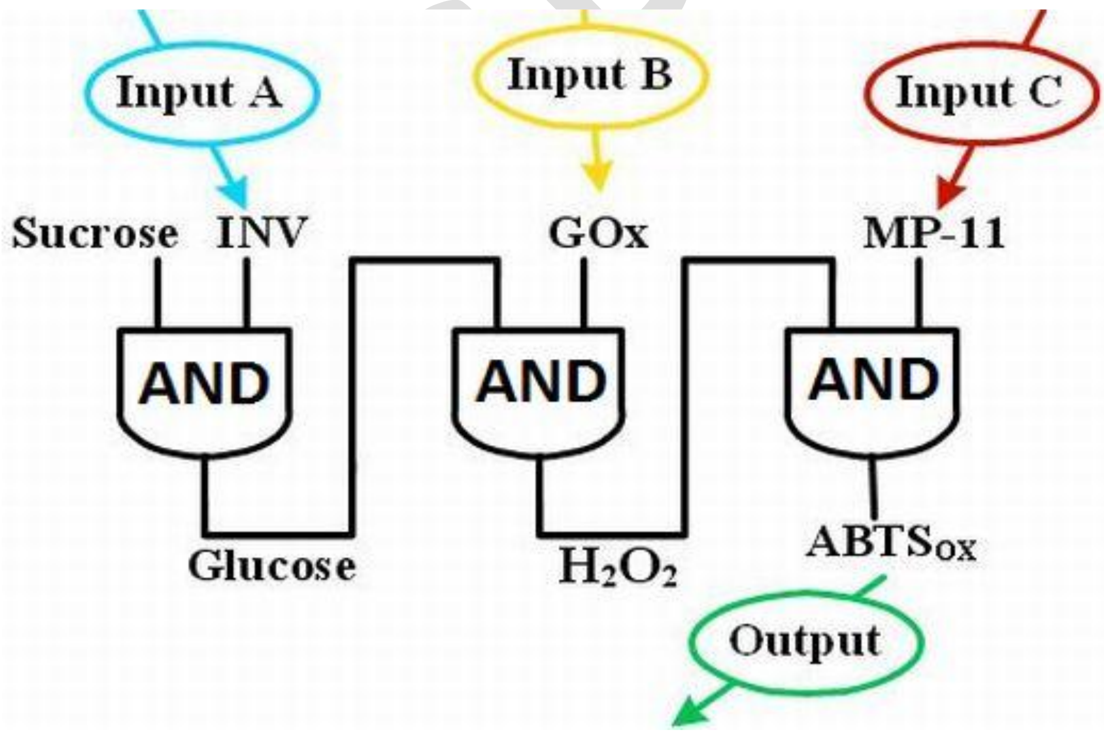

Figure1(b): Biocatalytic Cascade

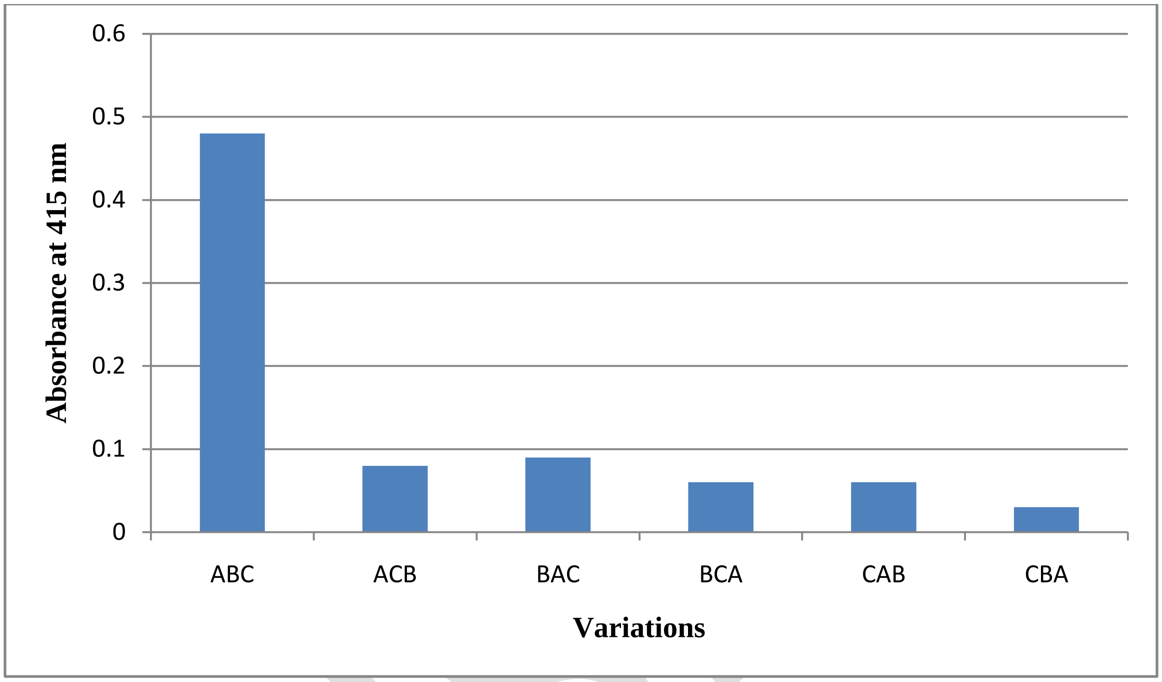

Figure 1(c): Combination of input to activate the lock

The figure1(c) shows that from all six possible combinations, the correct input order i.e. ABC activates the lock which can be confirmed by absorbance change at wavelength of 415 nm.

Therefore, the inherent selectivity of biomolecules and biocatalysts allow us to control and regulate the reactions and design them as logic circuits for various bioelectronics applications. The circuit architecture design is based on the mechanism of the selected biocascade of interest. Various other functionalities can be implied using biomolecules for information security which has not been possible using the existing in silico computing techniques. The biomolecules form the basis of unconventional computation which is applicable to multiple scientific areas such as steganography, encryption, code relay, developing smart biosensors and actuators, peptide based computation, bioelectronics devices controlled by enzyme-based information processing systems, antibody or enzyme based biosensors for injury identification and other biomedical applications.

References:

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