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Synthetic Biology: An Engineering Life

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Abstract: Over the past decade, synthetic biology has emerged as an engineering discipline for biological systems. Synthetic Biology is a science dealing with designing of new biological devices and systems and also redesigning the existing natural biological system as green technologies that can act as alternatives for various chemical and petroleum industries. It is an interdisciplinary area that basically utilizes engineering principles to modify the existing organisms or altogether make a novel one for conventional biological research. Synthetic biology is a multidisciplinary zone of exploration that seeks to construct new biological fragments, devices, and systems, or to reshape systems that are at present found in nature. This new branch of science has contributed significantly to human health, environment, basic life science and pharmaceutical science and many more. The development of these enabling technologies requires an engineering mindset to be applied to biology, with an emphasis on generalizable techniques in addition to application-specific designs. Synthetic biology technologies are budding, fetching the way that almost everything can be contrived sustainably and competitively. Industries must learn to utilize syn-bio to grow new products and methods, improve on the existing ones, and lessen the costs to remain viable in the upcoming times. This review aims to discuss the progress and challenges in synthetic biology and to illustrate areas where synthetic biology may impact biomedical engineering and human health.

Keywords: Artificial life; Biomedical engineering; Bioreporters; Biosensors; Synthetic cell

1. Introduction

Experts have said that the 21st century will be a century of the life sciences. But until recently, the national security community has often overlooked both the biological sciences and biotechnology. In the post-pandemic world, however, the national security community will need to rethink its biosecurity strategy and emerging technology like synthetic biology will play a critical role. Synthetic biologists use engineering principles to design, build and manufacture biological systems and products. In this field, engineers think about biology as code and just like software code engineers can read, write and edit genetic code. In 2016, James Clapper, director of Nation Intelligence suggested that gene editing technology like CRISPER should be consider a weapon of mass destruction (Andrianantoandro, Basu, Karig, & Weiss, 2006). Opportunities also exist to elaborate this technology for good. For example, scientists today are using synthetic biology to intentionally design coronavirus vaccines. Synthetic biology capabilities can also be used to manufacture food, fuel, medicines and other materials like spider silk. Spider silk is light weight and strong and could one day be used as body Armor and hence is an interest in U S Army. Kraig Bio craft Laboratories in US produces genetically engineered spider silk at large scales for a wide range of utilization in the military. More broadly, synthetic biology is an emerging driver of the rolling economy, which according to the national academies make a 5% of the US best domestic products that are over 900 billion dollars (Cheng & Lu, 2012). As economic and national security are increasingly entwined and shaped by technology, Synthetic Biology is poised to emerge as a critical enabler of both economic competitiveness and feature nation and health security. Synthetic Biology is a next step revolution of genomics and proteomics. In the life science industry, it provides solutions to them so that they can do the experiments for rational purpose. It is the inner section of the life sciences, the information sciences and the engineering disciples.

1.1. Biology and synthetic biology – what is the difference

Biology understands living organism in all their aspects. Biology often uses observations to study the behaviour of any living organism. For example, bacteria use flagella to search for nutrients in their proximity. The spiral movement of the flagella propels the movement in a particular direction (Chappell, Watters, Takahashi, & Lucks, 2015). So observation is a critical tool that a biologist can use. Another tool understands from creating mutations, mutations are the changes which are made at DNA level. The third important step that biology uses is anatomic dissection to study how the internal organs behave and work in any organism. Biologists are also inclined towards genetic dissection for study the whole genetic plan of a body, how a DNA interact towards the functioning of the organism. To study DNA one must find out the gene sequence which is base by base the genomic sequence. This is performed by various sequencing strategies including the latest nest generation (fast and cost effective) DNA sequencing methods. In the end, we get the entire read of the genetic makeup of an organism. Now the real goal of molecular biologists is to understand what this sequence means. How can this be an important plan for the living organisms? This is answered by performing sequence analysis (Heinemann & Panke, 2006). Sequence analysis is to gaze into the sequence and do analysis of the important features that the sequence can contain for proteins, for RNA, reading frame for signals on DNA that are important to direct the protein to read the instructions and forms the part that the cell is in need, transcription factor binding sites, promoter signals and many more. This is where biology ends, and synthetic biology starts. Synthetic biology tries to interpret this sequence in a schematic way (Xiong et al., 2008). One of the concepts of synthetic biology is to decompose the DNA sequence into its biological parts (DNA or Protein), converting DNA sequence to circuits. For a synthetic biologist a simple DNA sequence is a circuit of coding region, promoters, signals for ribosomes, binding site a regulator protein and a terminator sequence. We can go from sequence to the parts and can study the parts and then we can put them back together in different ways (Sachan, Johri, Trivedi, & Singh, 2017). Now the second concepts that is very important for synthetic biology is rules and models. So Synthetic biologists just do not want to dissect the sequence to know the exact As, Cs, Gs and Ts or the genome of the organism or the part of the DNA that we want to construct but how does the DNA sequence work together, which are the rules that the cell is following in order to make this part of the sequence functional (Anderson, Clarke, Arkin, & Voigt, 2006). For this synthetic biology uses some rules which could be some logic rules like a gene is on or a gene is off, it can also be models (mathematical model) that tries to predict how a particular stretch of DNA, promoters, binding sites are working for the cell. So, rules are basically the steps for the circuit to follow and execute the function. These rules could be put up in some mathematical models which will further predict what to do. The third concept of synthetic biology is standards (people from different laboratories and different industries can work on the same parts) for example stands for gene expressions (Das et al., 2019).

1.2. What is synthetic biology hoping to achieve?

There are two main things that synthetic biology is on tenterhooks to reach –

a. Understanding Biological processes through their (re)constructions (not dissection, as done in normal biology)

b. Facilitating the construction of new biological processes with new functionalities. (for example, not just producing one protein but producing a complex pathway that you engineer to a cell that was previously not possible) (Fig.1).

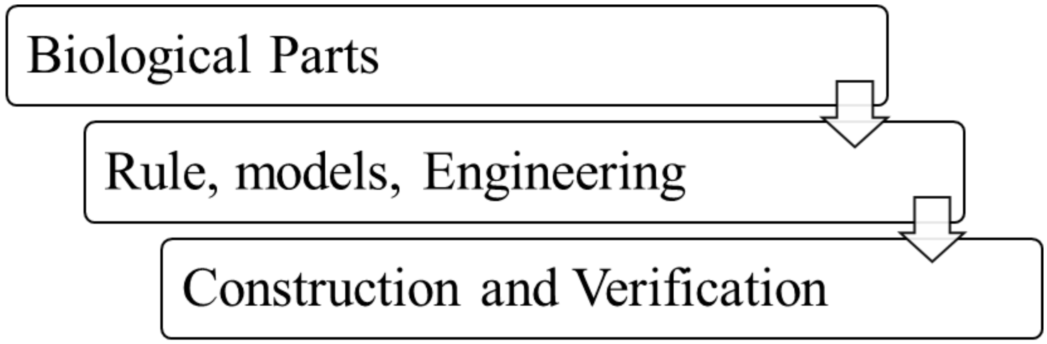

Figure 1. Engineering idea of synthetic biology.

2. Research activities in synthetic biology

Current research activity in synthetic biology goes consequently in all directions;

2.1. Standard Parts and methods

Making standardized parts, making new models, trying to come up with complex engineering strategies to put its parts together.

2.2. DNA synthesis and design of genomes or genome parts

Previously in genetic engineering it was difficult, cumbersome and took a lot of time to make mutations but now companies have started of DNA synthesis. The Biologist will simply write down their sequences, and send them through the computer to a DNA synthesis company that will make the construct which will facilitate large lead to put parts together in a particular way. So consequently, people try to design the whole genome which is a challenging task because we do not understand all the rules very well to be able to put the genome together (Salis, Mirsky, & Voigt, 2009).

2.3. Minimal cells and host production platforms

One can make bacteria of yeast that is just chassis, needed to make motor for the cell and everything else could be just plugged in. So, for people often think that the living being that exists naturally are way too complex. They contain viruses, and bacteria and that is why they want to design minimal cells being devoid of all the parts which is not needed.

2.4. Protocells and artificial life

There is a huge interest and to try and understand that from where the life is coming from. We do not know but synthetic biologist may be able to recreate certain life forms that would help to understand where life is coming from and what are the different paths that can lead to life.

2.5. Xeno DNA Biology

Synthetic biologists can alter DNA and proteins and can incorporate different types of amino acids that the cell normally doesn't like but it could be really important to incorporate so as to provide new functionalities to these proteins that we cannot currently make.

2.6. Do it yourself biology

Amateurs becomes interested to understand biology and make instruments that could be used in organized groups to try and understand biological phenomenon (Chuang, Hofree, & Ideker, 2010).

3. Potential applications in synthetic biology

There are several different applications for synthetic biology. A researcher can use synthetic biology to figure out how to optimize organisms for specific applications, they can speed up their research so that they don't have to do routine proteomics and genomics research. For example, one can make an antibody through synthetic biology that has a higher level of expression. There is a lot of hope that synthetic biology will be able to help produce new things that will be useful to human health, animals, pharmaceuticals, gene or cell therapy, tissue engineering, probiotics, diagnostics and so (Mukherji & Oudenaarden, 2009). Another area of importance is agriculture biology where we are trying to improve plants that are resistant to diseases, plants that are resistant to droughts, give better feedstocks, in industry like generating bioenergy, biofuels (synthetic biology helps in producing such animals which can contribute in generation of biofuels and bioenergy at higher efficiency), production of bulk chemicals (this is very important as one day we might run out of all of them and need an alternative way for the production of chemicals that we need daily). Synthetic biology has potential applications in the environment like biosensors, bioremediation, bioreporters, waste treatment that may be helped by producing specific organisms to achieve what we cannot not in normal conditions (Chuang et al., 2010; Tripathi, Siddiqui, Sharma, Johri, & Singh, 2018).

4. Bio-reporters for environment

Bio reporters are intact living microbial cells that have been genetically engineered to produce a measurable signal in response to a specific chemical or physical agent in their environment. Bio reporters contain two essential genetic elements: a promoter gene and a reporter gene. The promoter gene is transcribed when the target agent is present in the cell's environment. The promoter gene in a normal bacterial cell is linked to other genes that are there likewise transcribed and then translated into proteins that help the cell in either competing or adapting to the agent to which it has been exposed. In the case of a bio reporter, these genes have been removed or replaced with reporter gene. Consequently, turning on the promoter gene now causes the reporter gene to be turned on. Activation of the reporter gene leads to production of a reporter protein that automatically generates on type of detectable signal. Therefore, the presence of a signal indicates that a bio reporter has sensed a particular target agent in its environment. The Bio reporters are very simple engineered bacterial cells that are not pathogenic in the lab. These cells have small circuit inside which will recognize the compound that will diffuse inside the cell. The compound will bind to the sensory proteins present in the cell. This sensory protein can bind to DNA and direct the synthesis of a new protein in the cell, and the new protein made is such that it will give light or fluoresce (Fig.2).

These bacterial cells are very simple and helps us in making analytical devices to sort of interrogate the part of environment where we think there is contamination (for example arsenic

Table 1. Different applications of synthetic biology.

S.N.	Applications	Examples
1	Biosensors	Detection of petroleum pollutant by an engineered computer chip coated with bioluminescent material Detection of pathogenic organism such as SARS-CoV2
2	Food and drink	Production of genetically engineered microbial food culture Artificial synthesis of agricultural products
3	Materials	Synthetic production of spider silk by photosynthetic microbial cells
4	Biological computers	Identification and killing of human cancer cells using biological digital computation
5	Cell transformation	Production of synthetic Artemisinin, an antimalarial drug, by engineered E. coli and Yeast
6	Designed proteins	Synthesis of industrial enzymes with ideal yields, high activity and adequacy
7	Synthetic life	Production of complete synthetic bacterial chromosome, such as in Mycoplasma laboratorium
8	Bio-printed organs	Reconstitution of tissues from various body regions utilizing 3D bio printing
9	Other transplants and induced regeneration	Research is ongoing for the creation of transplantable artificial organs as well as inducing regeneration in humans

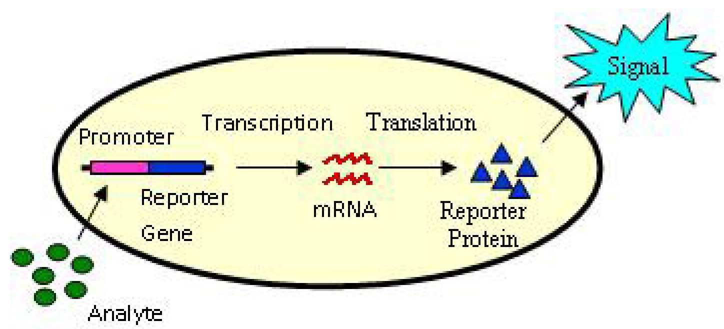

Figure 2. Bio-reporters.

contamination) (Ellis, Adie, & Baldwin, 2011).

5. Future prospects of synthetic biology: building life to understand it

Synthetic biology is a relatively new interdisciplinary field of science and the major areas for future research include:

5.1. Industrialization and a utomation

Lots of research groups are working on synthetic cells but the real progress is probably happening at companies that automate the design, build test, learn to cycle and particularly focus on strain optimization for stains that make molecules metabolically engineered (Erickson, Singh, &

Winters, 2011).

5.2. Machine learning for DNA design

There is a huge opportunity for machine learning in synthetic biology because fundamentally DNA is the code that is written in a language like certain strings of letters and are understood by cell in certain orders and context to mean things and direct the cells to do stuff . Yet there is not full understanding of this language and what this code is because its learning has been started in the last 70-80 years in molecular biology and biology (Bueso & Tangney, 2017).

5.3. Synthetic cell mimics from biochemistry

Synthetic cells from biochemistry are big area for research. There are multiple communities that are partly in synthetic biology and sometimes just a bit more adjacent to synthetic biology, looking to put together biochemical reactions into things like liposomes and vesicles and try to build a cell and that is the nature of the US community, or make a synthetic cell which is more the name of the sort of European community. It may be possible to put a whole load of components into vesicle and start to actually perform like life and then maybe we can stick DNA programs into it and they can become self-sustaining (Karoui, Hoyos-Flight, & Fletcher, 2019).

5.4. Cellular communities and multi- cellularity

Building cells from scratch is the ultimate gain of function research because we are taking something that's not living and making it living. Better understanding of the entire new dimension where complexity and functionality include multiple different cells that do different tasks and have themselves arranged into multi-cellular systems.

5.5. Designing with whole cell simulations

The current era is of whole cell simulations. Presently many young bioinformatitions are working on the algorithms for designing the same. There is a whole cell simulation of a cell cycle for M. genitalia and for E. coli and human cell are in progress. Computational biologists study the intricate network of genetic circuits, biological circuits and studies and information that we get from computational biology studies can actually inform the way we build cells.

5.6. Engineered organism for sustainability goals

United Nations have multiple different sustainability goals and it is pretty hard to find any of those goals that don't involve biology because there are things to do with healthcare, water purity, scarcity of resources and so all these things link in with biology and the younger generation are growing up knowing there is going to be scarcity and it's going to get worse for their lifetimes (Gardner, Cantor, & Collins, 2000). Synthetic biology encompasses any way manipulating biological systems and systems biology defines those systems and help us understand what should we work on. Synthetic biology is driving a manufacturing revolution that explores alternative feedstock's and production processes, and further extends towards the development of products of better performance.

6. Recent development

There are different ongoing synthetic biology advancements that are made to work on living principles and tackle issues that exist now. A portion of these improvements incorporate Pigeon D'or, Spider-goat, vaccines and the synthetic version of Artemisinin.

- Pigeon D'or includes planning an exceptional bacterium that is as innocuous to pigeons, when taken care of to them; it transforms their dung into cleanser. The place of this is to have cleaner urban areas (Reynolds, 2005). Pigeons travel a great deal and can arrive at places in the urban areas where people probably won't have the option to reach proficiently and probably won't visit a great deal. Synthetic Biology is utilized in this task by making the microorganisms that alters the digestion of pigeons.
- Spider silk is an amazingly impressive, significant material that can be utilized to make a variety of items however is it is absurd to expect to gather huge amounts of spider. For this reason the insect drag line silk quality has been relocated into a goat ' Freckles ' which delivers huge amounts of arachnid silk. This "silk milk" could then be utilized to produce a web-like material called bio-steel (Foong et al., 2020).
- Genetically engineered foods, for example, banana, potato and lettuce are brimming with infection proteins. Whenever they are consumed, individuals' insusceptible framework develops antibodies to battle the infection. These products of the soil behave like custom antibodies, they have the capacity to treat infections like hepatitis B (Khalil & Collins, 2010).

The above improvements are only the start. As information on Synthetic Biology proceeds to progress, so does the innovation that goes with it. The control of DNA marks extraordinary significance inside the field. As referenced previously, it can give qualities to things that don't as of now have enough or every last bit of it (Lu, Khalil, & Collins, 2009). In any case, the most encouraging progression must be the improvement of "Synthia". Because of this advancement, DNA can be built from scratch. Things that can't be transferred can be constructed. This is a colossal progression since it can change our reality totally. The making of the new semi-synthetic living being is most certainly engaging and an accommodating advancement (Isaacs et al., 2004).

7. Advantages and disadvantages

Synthetic Biology has the inclination to reform various fields including medication and energy creation. Researchers could utilize it to recognize and eliminate impurities from the air and water which could destroy various medical issues. Less fortunate nations could profit from head ways of Synthetic Biology by having fresher water to drink and food with additional protein (Macdonald, Barnes, Kitney, Freemont, & Stan, 2011). Synthetic Biology can likewise contribute in the cultivating business by adjusting harvests to become quicker and better. It could likewise be the justification for building-coordinated agribusiness to work! Manufactured science applications could likewise be applied to analyze and screen infections in people and creatures and foster new medications and antibodies that sounds more successful. Moreover, since Cancer is an illness that happens inside the cells of our body, it is conceivable that the cure for it exists in Synthetic Biology (Khalil & Collins, 2010). Synthetic Biology can likewise be applied to track down options to fuel, for example, the bio-fuels. Since everything revolves around controlling/making DNA, a little 'slip of a hand' or blunder can make the immense things. The apprehension about having an end times or an existence where robots rule the world could transform into reality through Synthetic Science (Lu et al., 2009). Aside from this, there are different ventures that could appear to be wonderful with Synthetic Biology yet in all actuality can really hurt. An illustration of this is 'Resuscitate and Restore'. This includes resurrecting terminated species. Having the most extraordinary and wiped out species alive again sounds commendable anyway it very well may be unsafe in numerous viewpoints. Synthetic Science is additionally supposed to be off-base since it tends to be utilized in exceptionally hurtful ways. This incorporates making medications, weapons and development on microorganisms that are deadly to people (Parul, Mala, & Pratap, 2021; Smolke, 2009).

8. Conclusion

Synthetic biology works with a bottom up construction not dissection and instruction of organisms but taking parts and building something again. The move from portraying science to taking advantage of it for our necessities has forever been a piece of the organic endeavor, and in this way continuously mirrored the flow primary lines of natural examination. Thus, as sub-atomic science has for quite a while endeavored to disentangle the atomic components that are significant in cell work, biotechnology has taken advantage of this information and embraced some of these instruments to create synthetic substances, chemicals and biopharmaceuticals. Presently, manufactured science is taking on an extremely aggressive plan in building novel organic substances on a perpetually perplexing level for novel applications. Several results are there within close reach not something for which we need to wait for another twenty-five years to see, like bio-reporters are used immediately for detection of contamination in the environment. The majority of synthetic biology is currently drilled in organisms. Notwithstanding, a significant number of the most therapeutic issues, and specifically those of human well being, are intrinsically issues with mammalian frameworks. Subsequently, a more purposeful exertion towards propelling mammalian engineered science will be critical for cutting edge restorative arrangements, including the designing of manufactured quality organizations for undifferentiated cell age and separation.

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