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# Synthetic Biology Will Reinvigorate New Generation Drugs, Vaccines and Biofuels Research and Development

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**Abstract:** Genomics and its related studies boosted explorations when applied in various dimensions of biology. The most common concept employed is to mix natural abilities of various living organisms or distant biological sources in the form of genes targeted for their products. With the advent of 21st century, this field gained a pace due to the attention by various scientific communities worldwide. Though, many hurdles still exist on its way but synthetic biology has led the basis for advanced outcomes by merging the potentials of genetic engineering and electronic techniques. This piece of literature reviews the research and development of synthetic biology accomplished since past in various life sciences with emphasis on pharmaceuticals, vaccines and biofuel development. The efforts of international scientific community and international organizations are also highlighted, who developed regulations and transmitted the importance to applied level. The production of biofuel, anti-microbial drugs, vaccines or other biological components with the help of genetic engineering technology was the first generation which after integration in synthetic biology has successfully transferred to a new generation. Along with the past, this paper also forecasts the future of synthetic biology in minimizing the limitations and problems faced in biological research with the help of synthetic biology.

**Key words:** Synthetic Biology, Drugs, Vaccines, Biofuels

## Introduction

In current era of biological sciences, advanced research practices with sophisticated tools and well-developed techniques are commonly recruited to combat naturally occurring problems like diseases, nutritional requirements, production of environment-friendly biological fuel and many more.

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Due to limitations in employing the natural resources directly, usually, encounters of such natural biological problems are done with unnatural or synthetic biological products or with modified biological systems. In all these perspectives, synthetic approaches are so widely applied that has led to the development of a new area of biological sciences, known as; "Synthetic Biology".

Synthetic biology is the designing and construction of biological components unavailable in nature to induce/perform novel functions or manipulates existing natural biological components to enhance its selective natural function with the help of engineering approach (König et al., 2013). According to synthetic biology, the biological molecular components and pathways are correspondingly referred as electronic devices and circuits, respectively while manipulation in these biological components are commonly termed in literature as re-wiring or re-programming of biological components. In simple words, with the help of synthetic biology, through engineering/manipulation, biological systems/organisms are upgraded to enhance its abilities, such that, it can be recruited for broad range of our desired functions (Serrano, 2007).

**Synthetic Biology and Genetic Engineering**

Synthetic biology, at first sight, seems to be a synonymous term for genetic engineering but it deviates from genetic engineering with many perspectives. Synthetic biology is differentiated from genetic engineering, as; genetic engineering involves manipulation of existing biological parts or its transfer among biological systems while synthetic biology, in addition to manipulation, creates novel bio-molecules and pathways not found in nature before and such creation is supported by engineering principles with guidance by mathematical, statistical and computer-simulated studies (Neumann and Neumann-Staubitz, 2010). The basis for such studies involve many techniques like genetic engineering/genomic (Lu et al., 2009), proteomic (Zhang et al., 2009), and physiological approaches (Yeates et al., 2008) merged with engineering and computing principles.

Synthetic biology brings various disciplines such as molecular biology, physics, chemistry, computer-modeling and engineering, all together to one platform and applied to targeted biological parts like DNA/RNA and protein (de Lorenzo and Danchin, 2008). So far, synthetic biology has achieved numerous goals in various dimensions. Such as health/diagnostic techniques (Lu et al., 2009), development of pharmaceutics (Neumann and Neumann-Staubitz, 2010), controlling and monitoring environmental concerns (Higashide et al., 2011), production of desired compounds/products like plastics and certain chemicals (Zhou et al., 2005) and production of energy or fuel from wastes or low-price natural substances (Atsumi and Liao, 2008).

**Applications of Synthetic Biology**

Since late twentieth century, synthetic biology is applied to many fields like health, diagnostics, environment, quality control and production of pharmaceuticals. Outcomes of this knowledge leads to manipulated or engineered organisms for their enhanced selective abilities coupled with engineering principles and tools that are further employed as agents for the purpose of research, commercial-scale production of various bio-products as well as applied technically in daily life (Chang et al., 2007).

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For example; these can be used as biosensors (de Lorimier et al., 2002), or may also be recruited to perform various *in vivo* functions in environments like bioremediations (Kiel et al., 2010; Ninfa, 2010; Topp and Gallivan, 2010). Among all these disciplines, research and development of drugs has been extensively studied (Neumann and Neumann-Staubitz, 2010), yet remains as challenge for scientists to discover more (de Lorenzo and Danchin, 2008). Synthetic biology is among the solutions to research and develop advance drugs. Later sections of this manuscript focus the history of advancements achieved in drug development with the help of synthetic biology.

## Major achievements in Synthetic Biology

Stephane Leduc; a French scientist introduced the term "Synthetic Biology" in 1912 (Leduc, 1912). However, about 50 years before, synthetic biology was quite practically implemented by applying the rationales of electrical engineering in biological process with the help of mathematical models (Monod and Jacob, 1961; Glass and Kauffman, 1973; Glass, 1975). Later on, techniques of genetic engineering and relevant genomic research supported more advanced research and innovations like constructing biomolecular components (McAdams and Shapiro, 1995; McAdams and Arkin, 2000).

In the beginning of this century, development of synthetic gene networks as genetic toggle switch (Gardner et al., 2000) and repressilator (Elowitz and Leibler, 2000) proved that engineering principles could be practically applied and the resulted biological systems possessed computing like behavior. The underlying mechanism behind these models was based on the electronic equivalents of transcriptional machinery for time and memory storage and could work in isolated manner.

These discoveries were gateways to produce today's synthetic genetic multi-switches (Dueber et al., 2003), memory storage elements (Ham et al., 2008), oscillators (Fung et al., 2005), genetic based pulse generators (Basu et al., 2004), logic gates (Anderson et al., 2007), filters (Hooshangi et al., 2005) and communication modules (You et al., 2004).

## Synthetic Biology and Diagnosis

Since health is the most important concern of all types of life-sciences researches, the same importance is replicated within the studies of synthetic biology. Among all types of diseases, focus has been given broadly to two categories; Non-Communicable diseases like cancer, diabetes, immune disorders and heart problems (Daar et al., 2007), and infectious diseases mainly caused by a pathogen like virus, bacteria and fungi (Becker et al., 2008). Complete understanding of diseased conditions supports development of a potent and efficient drug. For this purpose, synthetic biology is employed to detect and identify the condition and level of disease. The possible strategies to detect diseased condition of a cell with the help of synthetic biology are discussed below.

### Transcription Circuitries

For infectious diseases, synthetic transcription circuitries were built up which involved the construction of hybrid transcription regulators after combining viral and bacterial protein domains (König et al., 2013). Such models were hosted by bacterial cell and mammalian cell line for HIV and tuberculosis infections, respectively (Tavassoli et al., 2008; Weber et al., 2008).

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These method were utilizing host genome and were quite simple than any other synthetic technique. In circuitries technique, the circuit identifies interaction between EthR; an antitubercular pro-drug for tuberculosis (Engohang-Ndong et al., 2004) and $O_{ethR}$ Operator. The resulted EthR-$O_{ethR}$ is identified quantitatively followed by action of 2-Phenyl-ehtyl-butyrate which eventually increases the pathogen's sensitivity for ehtionamide in human and mice. The phenomenon was replicated and served as base to produce efficient synthetic defense system against resistant type of *M. tuberculosis* (Weber et al., 2008).

**Synthetic RNA and Complex Multi-Input Regulatory Circuits**

A cell affected by non-communicable diseases, like cancer and diabetes, tolerates high amount of changes in its components at molecular level and are easily identifiable by comparison with normal cells (Xie et al., 2011). Synthetic RNA and regulatory circuits, which possessed sensing ability for such multi input changes and complex changes in cells, were developed based on this concept (Venkataraman et al., 2010). Such RNA and circuits not only detects the cell's molecular-level changes but also has the potential to trigger the cell's programmed death / apoptosis (Culler et al., 2010).

More advanced devices termed as "prosthetic devices" are also developed by supplementing mammalian cells with synthetic gene circuits that results in a chimeric sensing system which has the integrated detect to cell's signaling pathways. In mouse models, these devices regulate the homeostatic condition of compounds like urate after being detected by chimeric urate sensors (Kemmer et al., 2010) as well as maintain glucose levels with respective glucose sensors (Ye et al., 2011). Despite such advancements, much has to be unveiled as such devices can be employed for drug screening, in vitro analysis and therapies (Xu and Anchordoquy, 2011).

***Chimeric Antigens***

Chimeric antigens are the commonly recruited diagnostic tool in advanced health services. These antigens are built up from different sources which increase the efficiency and broad-range identification of pathogens with the help of such chimeric antigens and it is relatively simple, efficient and novel procedure as diagnostic tool as it involves DNA synthesis (Burbelo et al., 2010).

## Synthetic Biology and vaccine development

One of the leading areas of biological sciences to solve various issues related directly to life such as health, food and medicine – is synthetic biology. In simple words, it is the application of electronic tools, techniques and principles merged within the biological systems aided with manipulations at genomic and proteomic level (Neumann and Neumann-Staubitz, 2010). The targets of this field include two broad categories; (1) manipulation of existing biological components and pathways, and (2) creation of novel synthetic biological active components or new pathways (Khalil and Collins, 2010). Genetic engineering is the pre-requisite followed by addition of engineering tools like biosensors, techniques like electrosynthesis as well as principles like charge-based practical applications (Serrano, 2007).

Among the various applications of synthetic biology, development of vaccines

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has got global attention due to variable genetic makeup of pathogens as well as limited conventional controlling methods. This piece of literature focuses the role of synthetic biology in development of vaccines as well as discusses the future challenges to overcome limitations.

**Engineered Pathogens as Vaccines**

Genetic engineering has been supplemented or supported by synthetic biology since decades. In simple genetic engineering technique viruses like adenoviruses are engineered for its genes responsible for viral replication such as E1A or E4 were controlled with the help of strong regulatory sequences from human gene (E2F1) which are repressed by the products of tumor suppressor genes (Johnson et al., 2002). As the cancerous cells loose such suppressor sequences, thus they are controlled by manipulation of selected viral genes and such viral genes take targeted action against cancerous cells and kills selectively. In similar pattern, poxviruses are able to kill the cancerous cells and proved in clinical trials showing that they can kill various types of cancerous cells at various levels on the basis of various endogenous as well as manipulated mechanisms (Kirn and Thorne, 2009).

Apart from viral involvement, bacterial cells are also equipped with various genes from broad range of natural sources as well as synthetically designed genes (Breitbach et al., 2011). In in vitro trials, genes responsible for production of invasins from various bacteria are incorporated in *E. coli* genome supported by sensor-based modules based upon the hypoxic condition and cell density of cancerous cells proved to be a helping hand to human's immune to encounter tumor cells (Anderson et al., 2006). In similar experiment, the expression of invasion was coupled with listeriolysin-O-gene expression supported by *HlyA* construct to favor the generation of shRNA (short hairpin RNA) which has the potential to interfere the factors produced by cancerous cells and with the help of *E. coli*, shRNA was delivered to normal as well as cancerous mammalian cells (both in mouse models and cultures) (Xiang et al., 2006).

A relatively new termed introduced by synthetic biology is genetic circuit, which means, a genetic network considered as a circuit driven by specific components/agents as it interferes a complete pathway. Synthetic proteins or genetic components (such as chimeric protein, chimeric regulatory protein or chimeric DNA sequences) have been successfully incorporated to control the population of the insects, resultantly, a strategy developed to control malaria as well as dengue-fever (Fu et al., 2010). A fine example of such genetic circuits is a specially designed genetic circuit that was brought in a mosquito (*Aedesaegypti*) which is the main causative agent for dengue fever. This circuit, after incorporation, was repressed by tetracycline which developed lethal effects in next generation of mosquitoes. Such engineered mosquitoes with synthetic genetic circuit resulted in killing female mosquitoes after mating with wild male mosquitoes (Wise de Valdez et al., 2011). Some synthetically designed mobile genetic elements also targets the population of mosquitoes that cause malaria and such genetically engineered mobile genetic elements inserted in mosquitoes makes mosquitoes to adopt resistance against the holding of parasites within it or simply it becomes resistant to serve as carrier for malarial parasites (Windbichler et al., 2011).

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**Synthetic Genome Parts or Whole Genomes as Vaccines**

Synthesis of complex DNA or whole genome is common approach in this perspective. In case of viral infections like influenza and SARS, whole viral genome has been developed to address respective host cells to combat diseases with diagnosis and cure (Tumpey et al., 2005). The same genomic approach is employed to produce attenuated viral genome with modified codon basepairs which are quite effective and designed with the help of computational analysis (Becker et al., 2008). The later approach is more common in generating effective and safe vaccines and has been tested upon mouse models (Mueller, et al., 2010). The simplest words to explain this paradigm is that whole genome is modified synthetically in such a way that virulence from pathogenic genome is eliminated while the rest sequences of genome are taken as vaccines to trigger host cell's immunity.

**Synthetic Antigens for Diagnosis and Vaccine Development**

Antigens with diverse properties and from variable sources are assembled in such a way that it contains variable parts of diverse features – thus called chimeric antigens and its production with the help of genetic engineering and synthetic biology is a new paradigm. Chimeric antigens are produced with the help of genetic engineering and/or synthetic biology just to enhance its ability to induce or provoke more diverse class of antibodies in an immune system. Such antigens can be used as a sophisticated diagnostic tool for broad range of pathogens. For instance pathogens for lyme diseases are diagnosed by DNA synthesis (Burbelo et al., 2010). It is through the advancements and support of synthetic biology in genetic engineering that instead of synthesizing smaller portions of DNA, more complex segments of DNA as well as whole genome can be synthesized, practically performed to produce various viral genomes which have helped a lot in understanding and development of more targeted vaccines, for instance genomes of viruses causing SARS and influenza have been generated or synthesized (Tumpey et al., 2005; Becker et al., 2008). Likewise, with the help computational involvements such as computational models or computer-supported designing of vaccines, many pathogens are added with synthetic basepairs or modifications performed within the existing basepairs which resulted in the formation of attenuated pathogens that are commonly used as vaccines, practically confirmed on mouse models (Mueller et al., 2010).

**Synthetically Development of Pharmaceuticals Used as Vaccine**

Some naturally occurring plant-based pharmaceutically important compounds have the potential to serve as vaccine which can help immune system to control invading pathogens or the drug itself has lethal effects on pathogens. One of the classical examples is an anti-malarial compound called artimisnin (named according to the source plant's category *Artemisia*). It is the finest example as with the aid of synthetic biology, artimisnin genes have been engineered in various microorganisms' especially *E. coli* to produce it in bulks by altering genetic as well as metabolic pathways within the microorganisms (EGE, 2009). Artimisnin is an effective drug thus its precursor molecules have been produced by engineering microorganisms supplemented with exogenous genes in yeast or by modifying its pathways (Ro et al., 2006).

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Another example is taxol (also termed as paclitaxel) is also been engineered to to produce in *E. coli* with same idea (Ajikumar, et al., 2010). Such engineering led to the development of synthetic pathways which involved two main portions; a downstream process in microorganism, and the enzymatic machinery supplemented from plants. At this point, the whole scenario exemplifies the combination of synthetic biology and metabolic engineering (Nielsen and Keasling, 2011).

Some other strategies of synthetic biology involved in vaccine development include the formation of synthetic non-natural genetic parts or amino acids capable of actions in biosynthetic pathways (Scott et al., 1999), variations brought up in peptides supported by computer aided modeling comparable to libraries for screening and for properties identification (Tavassoli et al., 2008).

**Synthetic Biology and Anti-Microbial Drugs**

A repertoire of biological compounds are available in nature in various forms that can be the solution to various life-threatening concerns while such compounds are just required to be identified and utilized efficiently in respective problems (Neumann and Neumann-Staubitz, 2010). With the help of synthetic biology, many targets have been acquired since near past as well as can prove to be very helpful in producing novel targeted anti-microbial drugs.

**Synthetic Cyclic Peptides**

Polypeptides when arranged in such proportions that amino termini or side chains are covalently linked to other chains or termini of same polypeptide that results in cyclic arrangement of polypeptide are termed as cyclic peptides (Craik, 2006). Such arrangement of peptides into cyclic form gives many advantages like it minimizes pathogens resistivity, enhances efficiency and specificity for binding to its target and minimizes the chances of degradability of such compounds (Scott et al., 1999). Examples of such peptides include that are modified to cyclic form include various drugs like cyclosporine (an immunosuppressant), antibiotics like vancomycin, fungal toxins like actinomycin D and phalloidin and many more (Katsara et al., 2006). The vast number of such compounds required an organized module of storage. For this purpose Benkovic Lab maintained library in *Escherichia coli* for such cyclic peptides using split intein method (Scott et al., 1999). So far, many naturally occurring as well as modified cyclic peptides have been identified and reported in libraries (Tavassoli and Benkovic, 2005; Tavassoli et al., 2008). The key supporting feature of such compounds is diversity found in it; greater the diversity covers broader range of biological entities (Wang et al., 2001). Diversity can be generated in many compounds including unnatural peptides by incorporating artificial genetic codes, which is more practical in today's novel anti-microbial drug-developing techniques (Xie and Schultz, 2006).

**Synthetic Polyketides**

These are natural products produced by most actinomycetes or soil-dwelling bacteria such as FK-506, epothilone and erythromycin. In synthetic approaches, strains of *E. coli* are engineered for its pathways to induce the potential of producing polyketides e.g. 6-deoxy-erythronolide B while induction of such potential in *E. coli* is achieved either by

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enzyme engineering, destructing cellular pathways or modulate production of precursor molecules (Pfeifer et al., 2002). Examples of some precursor molecules produced and directed as anti-cancer drugs include epothilone C, epothilone D (Mutka et al., 2006), ansamycin (Rude and Khosla, 2006), aclacinomycin A, doxorubicin (Lee et al., 2005) and some aromatic polyketides from bacteria (Zhang et al., 2008).

A complex enzymatic system is required and harbored by synthetic biologists to produce polyetides because a polyketide is synthesized by group of enzymes collectively called as polyketide synthases (Watanabe et al., 2003). These complexes give rise to "assembly lines" composed of modules which utilize the carbon chain in sequence; however, these modules can be separated and rejoined. Such changes are targeted and performed in *E. coli* towards the production of polyketides and, on these bases, libraries are being developed which also include polyketides with noval functions and used as anti-microbials (Menzella et al., 2005).

**Synthetic Terpenoids**

One of the diverse, major and vast classes of medicinally important compounds is terpenoids. Natural sources of terpenoids are plants such as artemisinin; an anti-malarial drug (Tan et al., 1999) and paclitaxel (taxol); an anti-cancer drug (Jennewein and Croteau, 2001). It has been common technique since decades that with the help of genetic engineering, ability of terpenoid's precursor production is engineered in *E. coli* based on the fungal mevalonate pathways (Martin et al., 2003). These terpenoid's precursors are converted into final product with the help of enzymes like modifying enzymes and terpene synthases, co-expressed with precursors. Based on this technique, Keasling lab produced artemisinic acid from manipulated *E. coli*, further, this acid is synthetically converted to artimisnin (Roth and Acton, 1989). The same group has also engineered *S. cerevisiae* for the same purpose with enhanced production abilities (Ro et al., 2006).

**Advanced Achievements in Synthetic Anti-Microbial Drugs**

List of anti-molecular drugs is large enough to cover all in this small piece of literature. The biomolecules used as drug obtained from natural sources are further manipulated to our requirements. However, some are purely unnatural and synthesized in labs such as synthetic promoters with variable constitutive strength are being developed (Hammer et al., 2006). Such promoters are not directly involved in the encounter of microorganisms but they tune the expression of various genes to produce respective targeted components like proteins and enzymes which create and regulate metabolic pathways and their products against pathogens (Alper et al., 2005). Some other techniques established by various labs across the world include "Multiplex Automated Genome Engineering (MAGE)" (Wang et al., 2009) and manipulation, compartmentalization or channeling of metabolic pathways and metabolites (Ovadi and Srere, 2000).

**Synthetic Biology and Biofuels**

Biofuel is the result of action of microorganisms upon substrate, usually waste, dead organisms or other organic wastes yielding important product like ethanol (Clomburg and Gonzalez, 2010). Its production is focused in current research studies because of the increasing demand of biofuel worldwide as well as it holds

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promising advantageous features like cost effective, quality product as well as availability of bulks of raw material from major source of waste. Somehow, limitations exist in this scenario as time-consuming and high input quantities (Alvira et al., 2010). Synthetic biology and genetic engineering are the possible solutions to this issue.

**Sources for Production of Biofuels**

The primary question for biofuel production is; "what will be the sources as input for biofuel production?" The biggest source in this regard is "waste matter". This category of waste include house-hold, agricultural, industrial as well as deposited bio-degradable waste which contain organic components as a major constituent (Antizar-Ladislao and Turrion-Gomez, 2008). Other largest source that has attained high attention are fossils (Yu and Chen, 2008) and the renewable energy resources (Zhou et al., 2005). Renewable energy resources are the production of those compounds that are utilized for various purposes and when turned to waste are easily degradable by microorganisms. Production of such products is commonly practiced since years and this production process also involves genetic manipulation as well as the techniques of synthetic biology. For instance; polyhydroxyalkonates (PHA) are the product from engineered by incorporating genes for various pathways in *Escherichia coli* (Antizar-Ladislao and Turrion-Gomez, 2008) and *Panicumvirgatum* L. (switchgrass plant) (Somleva et al., 2008) to produce bio-degradable plastic. Similarly, through genetic engineering, isopenoids were produced in *Escherichia coli* with 8 genes from *Saccharomyces cerevisiae* (Martin et al., 2003), genes from yeast and *Klebsiella pneumonia* were combined in *E. coli* to produce 1,3-propanediol from glucose (Emptage et al., 2003) and addition of enzyme (MDD: Mevalonate Diphosphate Decarboxylase) from archaebacterium in *E. coli* to engineer pathway for producing isobutene; a precursor for rubber and plastic synthesis (Marliere, 2010). All these engineered productions in *E. coli* leads to products that are easily degraded, thus are a source for biofuel production.

**New Generation Biofuel Production**

In previous generation, biofuel production is accomplished from the fruit and other edible sources like sugar-cane and maize which led criticism as the food is limited enough to be eaten rather than being utilized as fuel as well as the fuel produced from edible sources also contained unwanted chemical attributes (Lee et al., 2008). Extensive research introduced new generation for biofuel production which utilizes non-edible sources like microalgae, specific grasses and plants or its parts rich in lignocelluloses (Robertson et al., 2011; Wijffels and Barbosa, 2010; Regalbuto, 2009; Somerville et al., 2010). Other outcomes from new generation strategies allowed producing a variety of biofuels including ethanol which contains synthetic hydrocarbons and yields high energy such that it can be utilized by avionics (Lee et al., 2008; McEwen and Atsumi, 2012). This generation also helped to engineer hydrogen-producing microbial strains (Kruse and Hankamer, 2012). All these accomplishments are the product of broad range of synthetic biology techniques, few of them are discussed below.

**Biofuel Production from Sugar**

Many genes from different origins have been incorporated in *E. coli* or in other

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ways genes have been excised from host genome to program pathways for the production of butanol (Bond-Watts et al., 2011; Atsumi et al., 2008; Shen et al., 2011) and higher alcohols with branched chain (Atsumi et al., 2008) from sugar. The optimized enzymatic complexes are incorporated for the development of pathways of our own interest with the help of synthetic biology aided with computational modeling (Bond-Watts et al., 2011; Shen et al., 2011). Such researched techniques helped to create novel pathways in various organisms like *E. coli*, microalgae and fungi to synthesize biodiesel or alkanes either by combining various genes or altering enzymatic actions (Trimbur et al., 2010). Sensor-mediated biodiesel production in *E. coli* has also been practiced which assisted in maximized yield (Zhang et al., 2012). These techniques use sugar as substrate for action, thus proves to be simple technique which do not require expensive technologies.

**Biodiesel Production from Lignocellulose**

Many pathways are manipulated or reprogrammed to produce biofuel from cellulose/hemicelluloses-containing compounds (collectively termed as lignocellulosic polysaccharides or simply lignocelluloses) obtained from non-edible plants such as cellulose degrading bacteria are manipulated in its pathway by inserting genes from different sources for production of isobutanol (Higashide et al., 2011). Other ways to accomplish such targets include the use of genes that utilize linocellulose in various microbial organisms resulting in biodiesel, butanol and hydrocarbons (Steen et al., 2010; Trimbur et al., 2011; Bokinsky et al., 2011).

**Biodiesel Production from Light, Water and $CO_2$**

The natural ability of plants and certain microorganisms include the use of fresh water and sunlight yields photosynthetic products. The same idea was implemented after being engineered in microalgae to produce biofuels (Singh et al., 2011). This technique also led the generation of novel metabolic pathways in cyanobacteria and resulted in the production of isobutyraldehyde as well as other butanol derivatives (Roessler et al., 2010). Such metabolic engineering in cyanobacteria was effective enough to produce fatty acids which are precursors for the production of biodiesel (Liu et al., 2011), alkanes (Reppas and Ridley, 2010) as well as other energy-producing compounds (Robertson et al., 2011).

On the other hand, certain genes in cyanobacteria were engineered to build specific pathway for alkane production to industrial level (Reppas and Ridley, 2010). Technically as well as economically, such techniques helped a lot to produce biofuel at industrial scale (Stephens et al., 2010).

Using the natural phenomena for the production of biofuels helps a lot in this field as the inputs are non-costly such as direct use of sunlight as well as the natural biomass is utilized and converted into more useful products. Such idea was used to incorporate genes in microbial pathways to induce pseudo-photosynthetic pathway producing more yields of biofuels (Rabaey et al., 2011). Incorporation of synthetic biology in such fields resulted in sensor-mediated pathways as well as other electronic tools were employed leading to a new technique called electrosynthesis which

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practically resulted in production of isobutanol as well as 3-methyl-1-butanol, overall can be termed as synthetic pathway constructed in *E. coli* (Atsumi et al., 2008) and *Ralstoniaeutropha* (Li et al., 2012).

## Social and Economic Impact Biofuel Production with the Help of Synthetic Biology

All the biofuel productions are interconnected processes, especially the new-generation biofuels production are linked to various processes like photosynthesis, as well as if affects the environmental components like green-house gases emissions (GHGs). It is estimated that 80% of energy needs can be fulfilled with the help of biofuel productions by changing the naturally occurring processes with the help of sophisticated natural phenomena (IEA, 2008). Alternatively, they also helps in minimized input requirements, land requirements as well as less food consumption as in production of first generation biofuel.

In first generation biofuels production, the focused material used as input was edible food like corn or sugarcane which also required maximum area for its production followed by its utilization. However, in next generation biofuel production, advantages include all these high input requirements are avoided or minimized as the renewable energy resources are produced and utilized which are fulfilled with only the use of bioreactors, they do not require vast area of lands for productions, less fertilizer's input, as well as they have minimized harmful effects on GHGs emissions, minimized pollution spread and less effects on biodiversity as compared to first generation biofuel production and they require less fertilizers (Fargione et al., 2008; UNEP, 2009; Ribeiro et al., 2009). Thus overall, they help in the economic and social benefits worldwide.

Some other benefits of next generation biofuel production also include that it will help people to avoid displacement from areas due to cultivation of bulk quantities requirements as in first generation biofuel production as well as it avoids misuse of sources, land and fertilizers, however, it would adversely affect the livelihoods of people depending upon those cultivations (Wijffels and Barbosa, 2010; Mata et al., 2010).

### Conclusion and Future Perspectives

Newer techniques arise by merging existing techniques which supports each other and in return enhances the advancements in both fields. Same is the case with genetic engineering and electronic engineering, as genetic engineering is biological solution to various problems while electronic engineering yields efficient and easy to handle methods for problem solving. Coupling of genetic engineering with electronic engineering resulted in synthetic biology. Synthetic biology when applied to drug development, vaccine production and biofuel production with the support of genetic engineering yielded very fruitful results, yet, much more has to be investigated in this field. The electronics part of synthetic biology helped in identification and monitoring of components within or after the completion of metabolic pathways which resulted in helpful devices like biosensors.

In case of drug development, synthetic biology has served a lot especially in identification as well as helping genetic engineering to boost for producing effective anti-microbial drugs. Current problems arose in dealing with drug development has

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shown that besides the production of anti-microbial drugs, the major concern is to optimize drugs in such a way that it can be administered in effective manner with targeted drug delivery and minimized side effects. Future of synthetic biology shows a hope to accomplish the production, optimization, administration and targeted action of anti-microbial drugs.

The field of synthetic biology is very promising in various perspectives of life sciences. Due to serious health concerns such as; life-threatening cancer, AIDS (Acquired Immune Deficiency Syndrome), Alzheimer's disease and many more, the importance of synthetic biology is quite obvious because it can the solution to control and cure such diseases. However in pathogen-induced infectious diseases, the best optimum solution is administration of vaccines. Due to highly variable genomic or proteomic attribute of pathogens, the conventional technique for development of vaccines becomes limited. Due to this reason, help of more advanced technologies like genetic engineering as well as synthetic biology have been incorporated which has yielded very fruitful results since decades.

Employment of such sophisticated and advanced techniques made the field of vaccine development to gain speed in producing vaccines for more dangerous infectious diseases. They have helped in building and improving immune system against such pathogens which were being very difficult to be controlled such as SARS, Anthrax, Anti-malarial drugs etc.

In spite of such breakthrough and achievements as well as after being extensively researched by various scientific communities around the sphere, yet more has to be unveiled. Question arises like will the field of synthetic biology be enough to control all the infectious diseases by producing targeted vaccines? Will the synthetic biology program the vaccines and drugs for targeted delivery? What sort of other opportunities can be promised and expected by synthetic biology for the production of vaccines?

The possible answers to these questions may be narrated as if the advancements in the past are being researched and studied the future can be foresighted. Not only restricted to production of vaccines, drugs or biofuels, it has always minimized the barriers faced by genomic and proteomic studies and their manipulations. As they helps in eliminating barriers like interspecies barriers plus their run-time abilities to check, mediate and optimize the biological process can led to the answer various questions. From the futuristic point of view, they can be a sole method of pharmaceuticals, vaccine and biofuel productions because of their high level of integration in biological system supported by computational studies and techniques with engineering principles.

In short, it is quite obvious that synthetic biology is a tested solution as well as a hope to overcome limitations faced by many other biological techniques commonly employed for the production of drugs, vaccines and biofuels and it is synthetic biology that can lead to develop more and newer opportunities in all biological fields.

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