

Question: How does synthetic biology use novel organisms and engineering biological systems to lead to new energy sources, materials, and medicines.

Abstract:

This research paper focuses on the effects of synthetic biology and how it can be used for various purposes. Some of the most notable uses of synthetic biology is the utilization to make new energy sources, materials, and medicines. The research paper constructs an introduction to the idea of synthetic biology, followed by a literature review of the sources. Then, it contains a methodology where the steps taken are discussed then the results/data analysis is shown. Lastly, a conclusion of the studies and the sources are listed. This paper goes over how synthetic biology leads to new energy sources, materials, and medicines in great detail.

Introduction:

Synthetic biology is a growing specialty which can be organized into two categories. The first category is that it specializes in using unnatural molecules to reproduce behaviors emergent from natural biology, with the goal of creating artificial life. The second category is seeking interchangeable parts from natural biology to build into systems that act unnaturally (Benner & Sismour, 2005). Both categories of synthetic biology are important as it allows us to make new innovations that have not been seen before. Synthetic Biology mainly aims to use modular, well characterized biological parts to construct genetic devices and complex cell based systems to follow genetic engineering principles (Endy, 2005). This concept is important because it can be used to create novel organisms. Novel organisms are Novel organisms are artificially created or newly discovered organisms. These novel organisms can then be used to make new energy sources, materials, and medicines. New energy sources are important to make because the energy

sources that are currently being used lead to several problems such as global warming being one of the biggest issues. The current means of energy sources include fossil fuels which releases a vast amount of carbon dioxide into the air, the carbon dioxide then traps the heat coming from the sun into the atmosphere. New materials also can be found to help use more items that are easier to use as well as obtain. Finding new medicines is what novel organisms are being used heavily for. These novel organisms are helping to drastically improve and accelerate the current research process. They are being used to find cures for many diseases and illnesses that are still considered incurable, cancer being a prime example of a disease novel organisms are helping to find a cure for.

Literature Review:

Synthetic biology is a phenomenon that is newly emerging and could greatly benefit the medical field. It allows for the construction of novel organisms in order to make scientific advances. Advances in new energy sources, materials, and medicines are being studied in order to study the positive effects of synthetic biology.

Synthetic biology allows for the finding of new resources and materials. The use of the novel organisms allows for using techniques that have not been tried before. So it in return allows for new ideas and experiments, allowing for people to be able to test new theories to see what works best and try to help make advancements. Regarding this scenario, Kolja Brockman, a Senior Researcher in SIPRI's Dual-Use and Arms Trade Control Programme, describes how it is “Easier access to the knowledge, tools and components for creating living organisms” (Brockmann 2019). The easier access of knowledge, tools, and other components helps to advance and speed up the research process allowing for more innovations to occur due to the new ideas and methods being put out into the world. Brockman also describes how bio

technology allows for the “Convergence with other areas of science and technology (e.g. chemistry, engineering, computer science)” (Brockmann 2019). The more fields that biotechnology is able to connect to the more the advancements can occur for making tools to better these fields as well. As the other fields connect to biotechnology it can help them find problems in their own fields and see what can be done to fix them. They in return, can use the innovations of tools from biotechnology and further innovate on them to make tools to better their fields.

Synthetic biology helps to find new energy sources. It allows for the development of materials to help perform new tasks as well as overcome any new limitations and problems that may occur with the emergence of new ideas and experiments. This can be seen by David Kirk, an employee of Labiotech, claims that “Researchers in Germany and France have combined synthetic biology with microfluidics to create artificial photosynthetic droplets, which could lead to the production of organic chemicals and clean fuels that is more efficient than nature can achieve alone” (Kirk 2020). Kirk’s claim is describing how these synthetic (fake) biological components are able to do more to help come up with new energy sources than nature alone. Synthetic biology is able to produce organic chemicals and clean fuels in a more efficient manner than previously done. These new fuels can be very impactful to the world as these energy sources can be easier to obtain. It is also a better alternative to an energy source other than fossil fuels which are non renewable and can cause great damage to the environment (Harvard 2019). These fossil fuels can include many different gases, carbon dioxide being one of them, and can have a great impact on global warming. These greenhouse gases are able to absorb the heat produced by the sun and trap it in the atmosphere. This leads to the air around the Earth’s atmosphere to increase in temperature over the years. If a stop is not put to this it can continue to increase the

temperature in the Earth's atmosphere until it is to a point where it is uninhabitable by humans. These new synthetic organisms help to find and produce new energy sources where there is not a heavy reliance on damaging gasses such as greenhouse gasses. Synthetic biology plays an important role in energy sources that do not require as much carbon (Shears 2019).

Synthetic biology also allows for the finding of new medicines in the medical field. It is able to test a wider theory of human life and biology allowing for more advancements. In fact, there are many reviews and journal articles that reference the potential of synthetic biology to impact drug discovery and produce new medicines (David 2021). There has already been many discussions on further steps as well as the acceptance that synthetic biology can be used to produce new medicines. Since, the theory and idea that synthetic biology can be used for medicinal purposes has already been proposed and confirmed, there have been efforts to try and make this theory a new reality. Since then, there have been many projects that include synthetic biology to improve the medical field. For example, one of the most notable synthetic biology medical advancements is CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats). CRISPR-Cas9 is an innovative genome editing technology. CRISPR-Cas9 works by binding to the DNA (Deoxyribonucleic acid), and then cutting it to shut off the targeted genome (2014). It is important because not only does it show how synthetic biology can produce real efficient products, but it is also able to treat diseases by permanently, precisely cutting and erasing base mutations or disrupting disease causing genes (Li et al., 2023). CRISPR-Cas9 is one of the most important advancements in synthetic biology because it started the acceleration of using synthetic biology and research for other diseases that were seen as incurable; cancer. It has also greatly improved cancer research across the board and led to new developments in the

implementation of treatments (David 2021). Synthetic biology is crucial in the medical field as it has led to many developments in new medical practices and medicines.

Methods:

When researching a topic it is important to get background information on the topic so there is background knowledge to help the writer and the reader learn more about the topic. It is important to include the background information in the introduction and in the literature review to help the reader understand the topic and define key terms so the reader understands what is going on and being discussed in the paper and help them to understand the concepts better. Then, moving onto the Literature Review, it is important to gather all the sources and organize them. For example, put the sources that discuss the same effects in one section and the sources that discuss other effects in another section. Or, how this research paper was written is that for the literature review it focussed on the previous attempts of synthetic biology and previous theories that were also made. So, the information in the sources was organized into sections such as synthetic biology contributing to new energy sources, materials, and medicinal purposes. Then, these topics can be narrowed down even further by separating processes as well. An important tip to keep in mind while writing the literature review is how the sources should move in a conversation with each other and connect with one another. These sources being put in a paragraph together should discuss the same concepts and build upon one another. It will help the reader as well as the writer understand the different perspectives regarding the topic and how they connect with one another. Then, it is important to move onto the results section and properly organize them. The results can be obtained from other studies and papers and put together, but should give credit to whichever paper it was taken from and should have an in text citation near

the image, and should be a full citation in the bibliography. There should also be a brief description for each result so the reader knows what is going on in the data, because, if an image is given it will be hard for the reader who has no clue about the topic to understand the image. It should not be assumed that the reader is already acknowledged on the topic as much as the author. Once the data/results are gathered they can be organized to come to an understanding in the discussion section. Lastly the results should be discussed in the discussion section of the paper. Most if not all of the results should be written and the discussion and referenced to make it easier to understand which image is being discussed. Lastly, the understanding should be put in the conclusion section and explained further to discuss future effects and implications of the paper. Since this paper was a science/biology based research paper it is important when citing to use APA format. Lastly, this study used qualitative data over quantitative data because qualitative data is able to study the impacts synthetic biology has in more detail. It also helps the reader understand the impacts of synthetic biology better because numerical data does not fully show the impacts of synthetic biology in a more in depth understanding.

Existing Data:

The research method approach that was used in this study was researching already existing data. For example, any peer reviewed journals or online published research papers were used in this study. This way was the most efficient way to get data as it might be difficult to conduct studies with synthetically produced biological organisms to see the impacts it had. So, researching already existing data made it easy to obtain information and past research attempts and combine it into one. The information from previously published sources help to inform not only the writer but the reader as well.

Thematic Analysis:

After the research is completed, the data collected will be organized into relationships present to study the impacts of synthetic biology. For example, all the data and sources discussing how synthetic biology leads to

After the surveys are completed and all the data is collected the relationships present between the data will be studied further. It is important to move on to the Thematic analysis where the relationships present in the data are further observed. This can be done by organizing the data into sections of similarities and differences. To come to a proper understanding and conclusion.

Limitations:

Though measures were taken to reduce certain limitations there were still some that occurred. The biggest limitation found was not being able to verify if the information was fully accurate. So, to reduce this limitation it was made sure that peer reviewed journal articles, trusted online databases, and trusted online articles were used to obtain data in this research paper. Making sure the sources are trustworthy reduces the risk of listing inaccurate data in this research paper. Another limitation that occurred was the finding of sources that correlated to my research topic. For example, there were not many sources that can be found in certain online databases that correlate directly to my topic. So, keywords were used to research in the data bases, and if some key words did not work, different keywords were used. There were different combinations of keywords used to try and find as many sources as possible to match the research topic of this paper. This ended up giving some more results to find potential sources that could be used in the research paper.

Results:

Figure 1:

The figure shown below depicts the scheme of the principle of split-Cas9 and the logic gate. These synthetic circuits focus on the split of the Cas9 to detect cellular events to see what is happening in the body (Czapiński 2023).

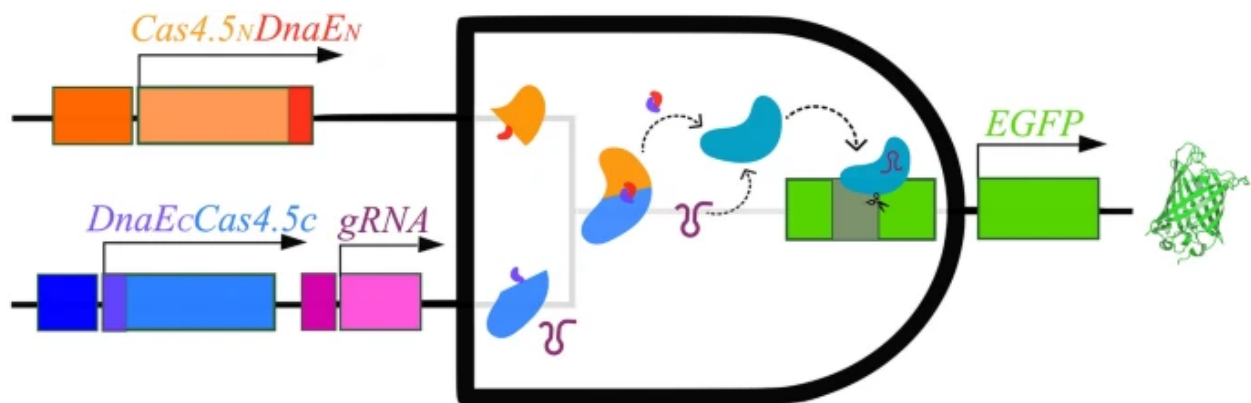


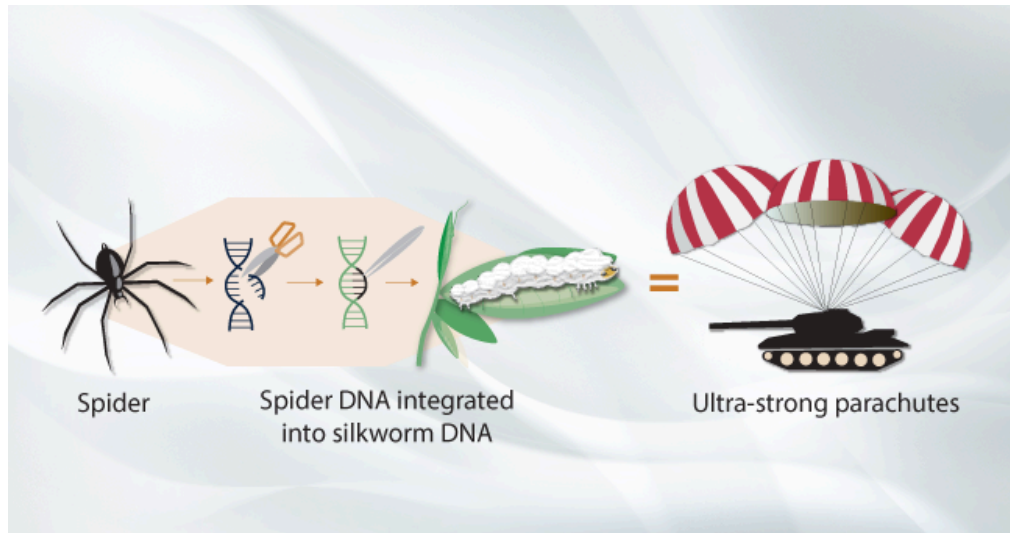
Figure 2:

This image below depicts Calyno oil being taken from the soil of the plants. It was used as a replacement for Soybean oil because Soybean oil does not have a long shelf life because it is high in linoleic acid and degrades quickly in the fryer (Voigt, 2020).



Figure 3:

The figure shown below shows a simplified version of how synthetic biology can work to produce new materials. The image below is important because of how they are able to combine the DNA of two different species to produce a useful material (Scientific Literature).



Source: GAO analysis (scientific literature). | GAO-23-106648

Figure 4:

The image shown below shows the different effects of synthetic biology in food science. For example, it shows how it can produce more sustainable, safer, more nutritious, and better tasting food through the incorporation of synthetic biology. It also shows how the incorporation of synthetic biology in food science can lead to a change in food production systems, fermentation technologies, and add new functions to food (Xueqin Lv a b et al., 2021).

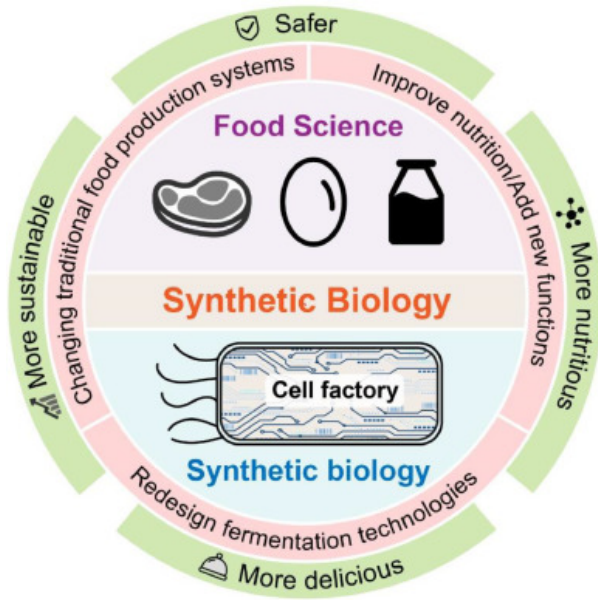


Figure 5:

The image shown below shows how synthetic biology can take a virus and take the genetic material of the virus and put it into a carrier to produce a new vaccine to improve human health. Vaccines can use the modification of a virus and the use of synthetic genetic material to help the health of humans. This concept uses these ideas to make new vaccines to try and help the human population be healthy (Office).

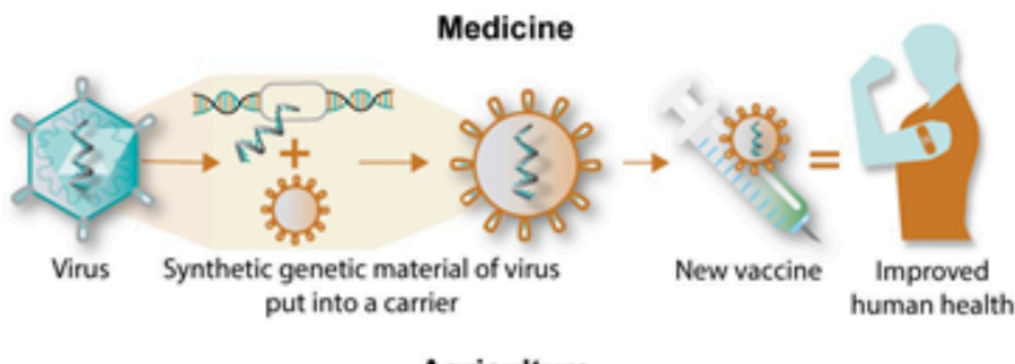
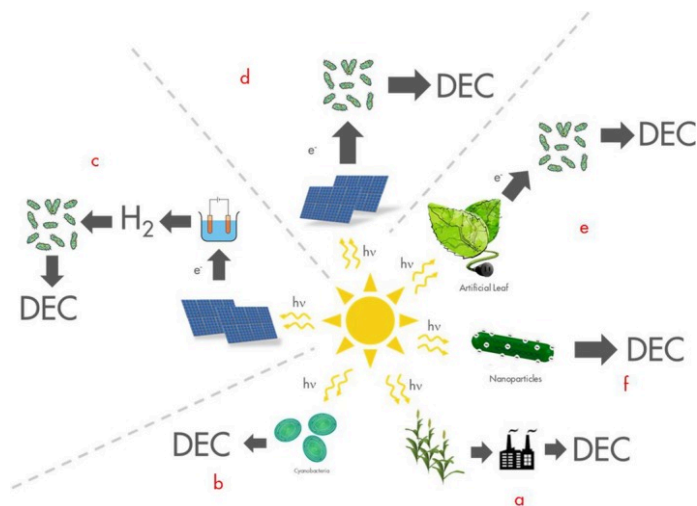


Figure 6:

The image shown below shows how synthetic biology can use the sun to produce new energy sources such as DEC (Shears, 2019).



Discussion:

Synthetic biology is important when creating new ideas and innovations. For a while many people did not believe that it was possible. However, in recent years there has been significant development in energy sources, materials, and medicine. A large part of these advancements is due to the contribution of synthetic biology.

The use of synthetic biology in contributing to new energy sources can be seen by looking at **Figure 2** which depicts a person looking at plants. However, it also shows how synthetic biology can be used to contribute to new sources. Typically, soybean oil is used when frying foods, but, a problem that emerges with soybean oil is its high concentration of linoleic acid and how it degrades quickly. Linoleic acid is not good for the human body because it can disrupt healthy cellular function and can't contribute to obesity and inflammation. Also, since it

degrades quickly in the fryer it leads to a lot of waste that can accumulate rather quickly. With the use of synthetic organisms and synthetic engineering Caylen oil was able to be created. This led to a positive impact because Caylen oil does not contain high amounts of linoleic acid and it does not degrade quickly in the fryer. This makes it healthy for the human body as well as reducing the waste that comes with soybean oil. Another way synthetic biology can lead to new organisms is through **Figure 6**. **Figure 6** depicts how the energy from the sun can be modified through synthetic biological engineering to contribute to new energy sources. For example, they use an artificial leaf to produce energy. Synthetic biology can help the future as well with the development of new energy sources that can be used for various reasons and not harm the planet like previous energy sources.

The use of synthetic biology in contributing to medicinal purposes is one of the most well known uses of synthetic biology. Looking at **Figure 1**, it describes how Cas-9 (CASPR) works. The process of Cas-9 uses synthetic circuits to detect cellular events to see what is happening to the body. CASPR is one of the most notable incorporations of synthetic biology. Before CASPR it was not possible to edit genomes to help prevent illnesses. With the use of CASPR they were able to make many advancements to the medical field and in cancer research. Since cancer is a big issue that affects many people globally, synthetic biology is working out to help these people as it has greatly expedited cancer research. Not only has it expedited cancer research, but it has also expedited research for other diseases as well. A notable impact synthetic biology made in the medical field is in vaccines. Looking at **Figure 5**, it represents how synthetic biology is incorporated in the production of vaccines. A virus is taken and then the synthetic genetic material of the virus is put into a carrier. This carrier is then put into a vaccine, which is then injected in the human body. This helps the human body by building resistance to diseases. An

example of a vaccine where synthetic biology was used was the development of the Covid-19 mRNA vaccines which were developed by; Pfizer and Moderna. These vaccines helped millions of people and protected them from the vaccine (Pfeifer et al., 2023). Synthetic biology can greatly impact the medical field by contributing to many advancements. With the emergence of synthetic biology there have been many advancements in a short amount of time, then there have been in many years prior to the emergence of synthetic biology.

Synthetic biology is also used to produce new materials to contribute to various reasons. Looking at **Figure 3**, it represents how synthetic biology can combine DNA of two different species to provide stronger parachutes. It takes a great deal of effort to successfully combine DNA from two different species and not ruin the results. They have successfully used synthetic biology to make new materials. These parachutes can be used by the military in a more safe manner because it reduces the risk of parachutes breaking, which leads to several fatalities and casualties. Not only is it helping the military but synthetic biology also helps the food production. Looking at **Figure 4**, synthetic biology is used in food science to produce better results. For example, it results in redesigning of fermentation techniques, changing of food production systems, and becoming more nutritious and having new functions. These results then result in more sustainability, safer food, tastier food, and nutritious food. Since food is a vital necessity of the human body, with the growing population synthetic biology is able to make better food for humans at a faster rate. This is important for humans because there are several areas where people do not receive enough food to eat, so the use of synthetic biology is helping to reduce hunger in the world.

Conclusion:

Synthetic biology is vital for the advancements in many fields including energy sources, materials, and medical research. It has greatly catalyzed the research and performance of these fields. In energy resources, it has limited the use of fossil fuels and other damaging energy sources. It has proposed new resources that limit waste and do not harm the environment. It has also provided new materials that can help for various reasons ranging from the military to food production systems. It can produce better parachutes that decrease the risk of casualties from poor performing parachutes. It can also improve food production systems leading to more nutritious, faster produced, and safer food. This food can then be used to help humans around the world who may not be able to have a steady source of food. Lastly, the incorporation of synthetic biology in the medical field was discussed. The medical field has been incorporating synthetic biology more often lately. Due to the new research and developments in synthetic biology it can be used by the medical field. CASPR, being the most notable device made with synthetic biology, can help several people around the world by preventing them from getting certain illnesses in their genomes. It can also be used to expedite previous research for other illnesses such as cancer. It is also mainly used in vaccines, most notably being the Covid-19 mRNA vaccines produced by Moderna and Pfizer. These vaccines helped millions of people around the world by reducing their chances of getting the Covid-19 virus. Synthetic biology can lead to several developments in technology and help many people around the world.

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