ARE we fast moving towards a synthetic world? Synthetic meat products and transgenic food and pharmaceutical products are slowly being accepted by the common man. Scientists have also successfully developed organs using stem cells. Life or more specifically human life today is like an automobile manufacturing unit where every part is produced separately and joined together. Scientists can now regenerate any damaged body parts.

Scientists know very well that every species has a time frame and after that it has to become extinct. But we don’t want to lose our species and so we have successfully developed techniques that could recreate species.

In the spring of 2010, Craig Venter – he has been called the “richest and most powerful man in biotechnology” – announced the creation of a new life form from a synthetic DNA. The synthetic DNA contained sequences specified by scientists and the bacterium even replicated, showing that Homo sapiens can even act as a creator. Has the time arrived to rewrite the evolutionary concepts and beliefs long held by humans?

Evolution from Biology to Synthetic Biology

It is the series of lectures entitled, “What is Life?” given by Austrian physicist Erwin Schrödinger in Dublin in 1943 that gave birth to modern biology. Schrödinger suggested that chromosomes were a kind of “code script”, which might be as simple as the Morse code.

Canadian and American scientists Oswald Avery, Colin MacLeod and Maclyn McCarty in 1944 proved that DNA, and not proteins, was the hereditary material of cells. American biologist James Watson and his British colleague Francis Crick discovered the structure of DNA, building on work by Rosalind Franklin and Maurice Wilkins in 1953. Huge advances in the understanding of DNA and recombinant DNA technology were made in the 1960s and 1970s. Building on these foundations, the first draft sequence of the human genome was published in 2000 by Venter’s group and the publicly funded Human Genome Project.

The entire human genome has been decoded by now. Nobody can clearly explain how a living human being develops from DNA molecules—a human being that can breathe, eat, walk, study, love, award Nobel Prizes and receive them. There is no absolute clarity even for the development of single-cell organisms. Even the simplest bacteria possess genes that have no apparent function and which are not essential for life.

Many genes which might have been useful at some point but were rendered useless by mutations have turned into ‘genetic waste’ during evolution. Some genetic components were in fact smuggled into the genome by viruses; others were created by accidental duplications of genetic segments. Evolution is made possible in the first place by numerous molecular mechanisms which result in many genetic variations. But over time,

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Perhaps, in the not so distant future, organisms designed from scratch could convert waste into fuel or enter people’s bodies to kill cancer. Even though the prospects of possible mishaps and concerns about tinkering with life are there, many scientists see synthetic biology as the best bet to tackle some of the world’s most urgent problems that affect human life.

Though it’s difficult to predict the areas where synthetic biology is going to have an immediate impact, it is projected to help human species in areas of medicine, energy, food, and environmental remediation.

**Medicine:** The most significant contribution in the field of synthetic biology has occurred in the field of medicine. Scientists hope that they would be able to precisely detect and kill cancer cells in the immediate future. Tinkering with the organisms for developing drugs and manufacturing of human organs has become a routine practice in research labs.

The technology of 3-D printing is revolutionizing the field of synthetic biology. During 2014, scientists have successfully developed heart and even brain tissue using this technology for finding cures for trauma patients. Stephen Power, from Cardiff, is thought to be one of the first trauma patients in the world to have 3-D printing successfully used. Doctors at Morriston Hospital, Swansea, had to break his cheekbones again before rebuilding his face.

**Synthetic Biology**

Since the turn of the 21st century, it has been difficult to clearly define synthetic biology. The aim of engineering biology to control living systems and the practice of assembling a synthetic system from component parts represents its heart. However, the boundaries of synthetic biology as a discipline lie in a grey area. Until one examines its manifestations in other fields, it is difficult to gauge its success. Although not commonly labelled as such, the fields of protein engineering, optogenetics, and genome editing all come in the purview of synthetic biology.

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**Food:** Genetically modified plants and their produce have already gained entry in the market. Today technology is available to design better and healthier proteins and flavours than what we get from nature. Synthetic biology companies are selling orange and grapefruit flavorings produced by yeast. One company Evolva makes yeast-generated artificial vanilla flavoring. Meat today need not be produced by culling animals. Using cell culture techniques one could produce synthetic meat that tastes similar to the natural meat.
How scientists created the first artificial life

1. Decode DNA from a bacterium (single-celled organism) in this case *Mycoplasma mycoides*
2. Synthetically create the DNA of the bacterium in the lab and add a “watermark” to distinguish it from real DNA
3. Transplant the artificial DNA into a living bacterium (in this case *Mycoplasma capricolum*) with its own authentic DNA
4. Allow the bacterium which now contains artificial and authentic DNA to divide and create “daughter” bacteria, some of which contain artificial DNA and others that contain authentic DNA
5. Add an antibiotic that kills the bacteria with authentic DNA but not the bacteria with artificial DNA
6. Allow the artificial bacteria to produce proteins

RESULT: The artificial DNA produced proteins from the original bacterium, the *Mycoplasma mycoides* qualifying as the world’s first artificial cell

In the history of science every new development has been met with stiff opposition. During the 1970s when genetic engineering evolved many were critical of the technology. But today everyone is reaping the benefits of this technology and one cannot think of a substitute for recombinant insulin which is a life saver for thousands of people suffering from diabetes.

Energy and environment: One major area of human concern is finding alternatives to fossil fuels and abetting environmental pollution. While fossil fuel is depleting, pollution is continuously increasing. Synthetic biology is working towards finding a solution to these problems. It has already shown tremendous results. Living cells have been programmed to produce usable fuel from non-edible living sources like algae and the technique is in the process of commercialization. Genetically Modified Organisms (plants and microbes) that can mop up toxic waste have already been developed.

Anti-malarial drugs: For a long time, Artemisinin, the most effective drug to treat malaria, had to be derived from the sweet wormwood plant *Artemisia annua* through a slow and expensive process. That changed in 2013 when artemisinin was produced at an industrial scale using synthetic biology by pharmaceutical firm Sanofi. In what is widely considered as the first large-scale drug project to use synthetic biology, the company did this by taking the plant’s genes for making artemisinic acid and putting them in yeast. This allowed them to produce the drug more quickly and efficiently. This turned out to be a major achievement.

Creating bacteria: Scientists have long been trying to alter the genetic make-up of organisms. The first success came in the 1970s when Paul Berg, Herbert Boyer and Stanley Cohen began to cut and splice DNA. From that point onwards there was no looking back. We could find consistent developments in the area every year, culminating in the creation of the first synthetic cell by researchers lead by the maverick scientist J. Craig Venter at the J. Craig Venter Institute in 2010. This was the result of a 15-year, $40 million project where they took the genetic code from one bacterial species, made it in a lab from scratch, and then put it into an entirely different species. The new species was nicknamed “Synthia”. This organism contained synthetic genome and new sequences that acted as watermarks. The work proved that a cell could survive using a synthetic DNA.

Creating yeast: Continuing the success of bacteria containing synthetic DNA, scientists tried the same trick in eukaryotic system. In 2014, a team of researchers from a consortium led by Johns Hopkins University revealed that they had synthesized an entire yeast chromosome from scratch. This chromosome functioned properly when put back into a yeast cell.

The researchers built the artificial chromosome from scratch by stitching synthetic strands of DNA together in a sequence based on the known genome of brewer’s yeast. This is truly a milestone development in synthetic biology, as it is moving closer to creating other eukaryotic organisms including *Homo sapiens.*

New additions in the DNA alphabet: Creating a new class of amino acids is a challenging task as one would have to tinker with the nucleotides. The entire spectrum of amino acids is coded by just four letters, or nucleotides: [Adenine (A), Guanine (G), Thymine (T) and Cytosine (C)]. In May 2014, researchers reported the discovery of new DNA letters called X and Y that could be successfully introduced into the *E. coli* bacterium. The incorporated DNA is known as XNAs.
CONSTRUCTING LIFE

Researchers have synthesized a fully functional chromosome from the baker’s yeast Saccharomyces cerevisiae. At272,281 base pairs long, it represents about 2.5% of the organism’s 12 million-base-pair genome.

1. Scientist writes DNA sequence on computer
2. Polymerase chain reaction is used to stitch sequences into ~750-base-pair (bp) strands
3. Yeast cell weaves several 750-bp strands into 2,000-to 4,000-bp chunks

It was observed that these bacteria were able to copy DNA containing X and Y for 24 generations (about 15 hours) using their existing molecular machinery. The next major task was to express these DNA containing new alphabets, that is, to synthesize proteins. XNAs are chemically extremely robust and, as they are not found in nature, they are not recognized by the body’s natural degrading enzymes. This property makes them an attractive candidate for long-lasting treatments that can disrupt disease-related RNA.

Creation of synthetic enzymes:
Recently, synthetic enzymes based on XNA were developed by scientists from the MRC laboratory. These enzymes were made from folded strands of XNA molecules known as “XNAzymes”.

Until recently, scientists were of the view that only DNA and RNA have the ability to store genetic information and perform various regulatory roles in the cell machinery. But the discovery of “XNAzymes” shows that there are many alternative mechanisms possible in the cell.

These XNAzymes” carry out simple enzymatic reactions like cutting and joining RNA strands in a test tube. They were also able to join XNA strands together, which represents one of the first steps in creating a replicating biological system. This technology could be developed to make drugs that can block cancer-causing genes or bind to the RNA of viruses such as Ebola or HIV.

Consequences of Synthetic Biology
In the history of science every new development has been met with stiff opposition. During the 1970s when genetic engineering evolved many were critical of the technology. But today everyone is reaping the benefits of this technology and one cannot think of a substitute for recombinant insulin which is a life saver for thousands of people suffering from diabetes.

Synthetic biology finds itself in a similar situation. The quantum of sequences generated through various sequencing projects serve as a potential database for creating a better tomorrow. Using these sequences one would be able to create totally new life forms designed for the needs of humans.

The maverick genome scientist Craig Venter’s group has already started work to create synthetic hybrid pigs using these sequences, which can produce human lungs and other organs. He has also started a crazy project to decode the extraterrestrial life and synthesize them in our labs to understand alien environment. He could probably even send the modified organisms to space, which may be of great help to proposed human settlements in space. Probably, he is looking at the business prospects once human colonization in space becomes a reality!

Going by the exponential growth of synthetic biology it seems that future scientists may be forced to rethink about the concept of evolution itself. All evolutionary concepts have been formulated based on the natural population. But recent studies carried out at the University of Glasgow revealed that even by using non-biological systems like oil droplets one could mimic evolution in the laboratory, revealing the possibility of an evolution in the event of a synthetic world.

Many such mind-boggling researches are going on in the field of synthetic biology that may reap benefits to future humanity. The selfish animal Homo sapiens is not at all concerned about the negative impacts of synthetic biology because of the vast potential economic benefits projected out of it.

Could today’s synthetic life turn out to be the natural and a better population of the future?

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