Chapter 8
State of the Field and Future Prospects

Abstract Biofuel production has the potential to have a great and lasting impact on the society and is a focal point of biological and metabolic engineering research. There have been great advances in the ability to engineer biological systems, and it can be seen that there lies many possibilities to expand the use of biology in producing a variety of chemicals, not just biofuels.

The chemical field has started taking advantage of biological systems to make commodity chemicals as well as fine chemicals due to their much lower processing costs. So far the number of chemicals made by biological means is limited mostly to existing metabolites that are more easily purified and to a few fine chemicals that have been the subject of extensive research.

We are really just seeing the beginning of chemistry and synthetic biology coming together in a mutually beneficial way that will provide a sustainable future for many different industries. Chemists are realizing that using organisms as factories that require few inputs such as sugars or sunlight provides a much more cost-effective process that reduces the hazards involved with disposing of mass quantities of chemical waste and leaving a much larger carbon footprint.

Chemists are starting to see that the way in which organisms have evolved has great significance and generally exposes the most energy-efficient route to producing chemicals.

Elucidating the pathways to producing an unlimited variety of chemicals using organisms lies in the computational framework being established. Once there is a complete database of enzymes and how they affect any different chemical, it will be possible to use any combination of enzymes to produce an endless number of chemicals. While these enzymes could work outside of the organism, it may prove to be more beneficial to incorporate the process in the organism. To choose which organism would be most suited for the process, data as to which enzymes are in each organism, and at what efficiency recombinant enzymes work would need to be included in the database. The alternative to this method would be the success of a "minimal cell" that could accept all of the genetic information needed to carry out the production of a desired chemical.

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In order for biofuels to be integrated into our current infrastructure and lifestyle, there will need to be a transition period where different combinations of biofuels fulfill the supply. A biofuel that can be blended into gasoline or easily implemented at existing gas stations that can work in our current engines would be the easiest transition but blending anything other than ethanol at this point is not cost-effective.

Algal biodiesel seems to be a solution that would work well in terms of production, greenhouse gas emissions, and sustainability, but this would require people to have diesel engines and they are not currently popular in personal vehicles. Once the price of algal biodiesel is low enough to compete with gasoline, the benefits of it should outweigh gasoline enough to where people start transitioning to diesel engines to accommodate this and other biofuels which work better in diesel engines.

Ethanol as a main biofuel has already been implemented in Brazil where they use almost a quarter of the world's ethanol fuel supply. Ethanol is already being blended into gasoline here in the US by up to 10 % ethanol, but there is still some debate as to whether or not ethanol is harming our current gasoline engines. Modifications can be made to existing engines that would allow for pure ethanol usage in personal automobile engines or they are already manufacturing flex-fuel vehicles that are already designed to run with high levels of ethanol. As of now most ethanol in the US is being produced from corn, but it will only succeed as a major contributor to our future in biofuels if we can produce ethanol in cost-efficient ways that do not take up arable land and which reduce greenhouse gas emissions. Producing ethanol from cellulosic feedstock or cyanobacteria would be the best routes if ethanol is to become a mainstay in biofuels in the US, but producing propanol or butanol may prove to be a better option.

Propanol or butanol production from cellulosic feedstock or a photosynthetic organism would be a much better option in terms of fuel efficiency but there is much research to be done to develop a process that is efficient enough to become cost-effective when run on a large scale. Most likely these types of fuels will not be able to stand on their own and will be blended with ethanol, gasoline, or another type of fuel to provide energy efficiency and water resistance without raising the cost of the fuel too much.The future of sustainable biofuels will be a blend of many techniques initially and may never be reduced to one single biofuel that shines above the rest in terms of cost, efficiency, sustainability, and availability.

The application of new knowledge and techniques derived from systems biology and synthetic biology is leading to new approaches to biological engineering. The advances make it possible for engineering design approaches to be taken in a biological setting where the individual steps of the design-build-test paradigm can be treated somewhat independently. This allows for a new degree of intellectual freedom where design is constrained by creative limitations, not logistical construction limitations. Moving forward, as the possibilities for biological engineering broaden, more prospective thought must be given to macroscopic decision making to help to identify promising avenues of research priority.