FreedomLab

# Cell Factories

SYNTHETHIC BIOLOGY | ETHICS | HYBRIDS

**Will our use of microbes enable a bio-based future? It is increasingly possible to use and tweak living organisms to produce food, fuel, drugs and materials. Here, we explore cell factories, or engineered microorganisms, to illustrate the ontological and ethical challenges that we will face in light of the rising numbers of hybrids created by advances in biotechnology.**

## Our observations

- Cell factories are single-celled microorganisms, or microbes, whose metabolism is synthetically optimized to produce more energy or different substances. In other words, microbes are viewed as production facilities that are engineered with biotechnology to produce for human usage. Examples include chemicals, food ingredients, biofuels, drugs, detergents, paper and textiles. Whereas modern industries manufacture products on the basis of fossil fuels, these cell factories are the building blocks of a bio-based industry.
- The advances in biotechnology to engineer microbes and create cell factories are in full speed. The question is whether and when these cell factories will be able to produce at industrial scale and economics, so as to accelerate a bio-based industry.
- One of the major promises of cell factories is the production of food ingredients, such as lab-grown protein (meat, fish, milk, eggs), lauric acid (to replace palm oil), carbohydrates (to replace flour). In the report 'Rethinking Food and Agriculture 2020-2030', the authors argue that microorganisms programmed to produce food, or cellular agriculture, are about to disrupt agriculture as we know it for the next ten years. The reason they believe this is that they have calculated that proteins produced in cellular agriculture will be five times cheaper than existing animal proteins by 2030 and ten times cheaper by 2035. Furthermore, these proteins, they believe, will also be more nutritious and healthier.
- The driver behind this is the rapid advance of precision fermentation. Fermentation farms, the vessels that facilitate the production of these programmed microorganisms, are production systems that are potentially more energy- and resource-efficient, more stable and sustainable than industrial animal agriculture. Industrial animal agriculture as a matter of fact has reached its limits in terms of scale and efficiency, while the worldwide demand for protein is only rising. This technological development will make the plant- versus meat-based diets distinction irrelevant, as food will neither come from animals nor plants, but from unicellular life.
- Among the parties working in this field, Solar Foods, whose first commercial factory will be running this year, is an example. But Big Food and chemical giants are also heavily investing (e.g. Dupont) in this area.
- In the past, advances in biotechnology have often raised fears over unforeseeable risks: are we creating little Frankenstein monsters when engineering cells, living organisms that we won't be able to fully control? We cannot entirely oversee the consequences of industrial biotechnology using cells as factories.

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# Connecting the dots

Animals and plants play a major role in our society by providing us with food and materials. For a long time, we have held animals to produce meat, milk, eggs, leather and wool, have grown plants to produce grains, vegetables, fruits and fibers. We have become incredibly adept at optimizing these animals and plants, by breeding them in such a way that they comply with our wishes. Indeed, all animals and plants we see at farms today are the result of a long chain of human interventions. The beginning of domesticating these life forms is considered a revolution in the history of humankind. Thousands of years ago, when we started to keep and breed animals and plants to optimize them according to our demands, the way we co-existed with them also drastically influenced our own lives. It meant that humans were able to quit their nomadic, hunter-gatherer lifestyles and settle in places. The agricultural revolution allowed humans to collect more food per unit area and thus the overall population multiplied exponentially.

With the advances in synthetic biology, we might witness what we could call the second domestication of life forms in history. This might again radically alter how we interact with other life forms. This time, however, the focus will not be on visible life forms, such as cows, pigs, sheep, chickens or plants, but on invisible ones: microorganisms, or microbes. Through strides made in the field of synthetic biology and the insights gained in molecular biology, microbes can now be engineered and optimized to fulfill certain tasks, such as producing certain substances. By reading and writing the genome in microbes, or cells, it is now possible to create so-called cell factories. They are a promising way to replace conventional ways of production, as they can be tweaked to produce the specific type of chemicals, food ingredients, biofuels, drugs, detergents, paper, textiles and other materials we need, considering this can be done on a large scale and with a minimum amount of input. Because there are good reasons to believe this will be possible within the next ten years, the question is: will this domestication of microbes change our relation to other life forms?

First of all, it will raise the question how we should view and treat these new life forms. In industrial livestock farming, animals have not exactly been treated as life forms of intrinsic value, raising animal welfare problems. On huge farms, animals often live and die on a production line, in a sense bred to be production units. This industrial handling of living organisms has been questioned for long. It has alienated us from our living world. The current corona pandemic has been labeled a "One Health issue", which means it is seen as an integral health problem for humans, animals and ecosystems.

We are increasingly aware that fixed categories of "human" and "animal" do not always make sense and that we are not an individual species, but that our wellbeing is determined by our relationships with and dependencies on other species. We look more holistically at our living world rather than as existing of separate categories. But if we want to treat other life forms rightfully, where do we draw the line? The claim can be made that microbes have less intrinsic value than macrobes, but since all macrobes are built on microbes (or individual cells), there is no clear line to be drawn. Indeed, the fact that we are more focused on life forms that are visible to us has led us to the macrobist bias in the philosophy of biology. But if we take microbes to have the same value as macrobes, should we grant them microbial rights? Already in 1977, this scenario was explored in a sci-fi story by Joe Patrouch, showing the consequences of full microbial rights, such as a ban on household bleaches as they kill microbes. But today, legislation for microbial life is not sci-fi anymore. The Swiss Federal Ethics Committee on Non-Human Biotechnology has declared that all living beings, including microbes, have minimal value in themselves, implying that all life forms, however small, will have "rights" to some extent.

The fact that we are intentionally interfering in microbial life forms with synthetic biology more often leads us to the second challenge. How do we see these altered life forms or hybrids? These are times when one can find ever-increasing numbers of hybrids that blur the lines between natural and artificial. Cell factories show the characteristics of life forms, such as metabolism, but are artificially engineered. Indeed, cell factories can be seen within a broader category of late modern technology that is increasingly showing signs of autonomy and agency, like AI. These technologies seem to have a "life of their own". Yet, there is no clear moral framework for these hybrids to come.

The rapid advances in cell factories lay bare the challenges that we'll have to respond to in the coming years, in order to decide what a bio-based future will look like.

# Implications

- **The rapid advance of the commercialization of cell factories will stir up debate on the moral status of smaller life forms and hybrids. This will again create fears about biotechnologies similar to those surrounding genetically modified crops.**
- **Cell factories might have important second-order effects on society. First, cell factories would decentralize production facilities, as they can be produced in vessels anywhere. For instance, fermentation farms can be located in or close to towns and cities. And second, cell factories might help to reduce the focus on chemicals we have in our daily practices – fertilizers, synthetic textiles, carbon-intensive materials and substances – and incite the turn to more microbe-based products.**

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