

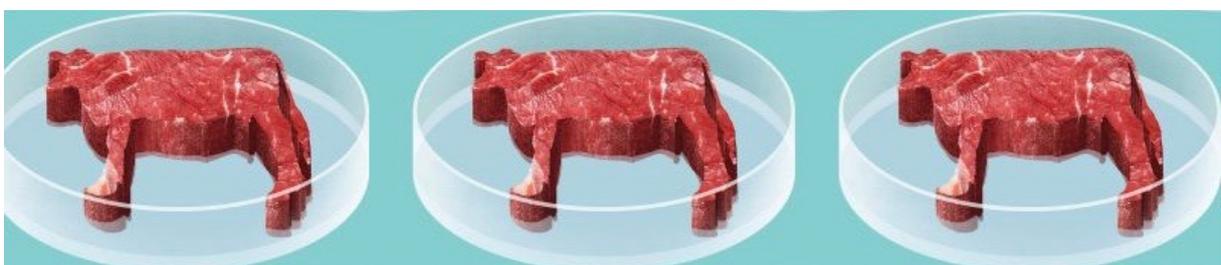


# In-Vitro Meat

Is Cultured Meat Our Future?

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# In-Vitro Meat

## Preface

From the very beginning, we agreed that our topic of our biology term paper on genetic engineering should be towards sustainability. When we then came across in-vitro meat, we agreed immediately on choosing it as our topic, because all three of us were enormously interested in such a sustainable and promising alternative to conventional meat, which contributes an underestimated share to the present climate change. All three of us have not eaten meat for years and Rosa even decided years ago to completely dispense with animal products. Our reasons for a meat-free diet are somewhat different, because Ivana and Simone are vegetarian for environmental reasons, and Rosa has become vegan for animal-ethical reasons, yet all our interests are in the subject of in-vitro meat. For us, cultured meat sounded so much more animal and environmentally friendly, which made it a very attractive subject for us all. The three of us wanted to know more about it and find out if it really is such a suitable alternative to conventional meat, or if it maybe is not as perfect as it seems. We are very active in the subject of environmental protection and we do not only pay attention to sustainability in our diet, but also in terms of our clothing, cosmetics, our means of transport and much more. Therefore, we are particularly interested in the actual sustainability of cultured meat and the animal ethics and welfare behind it. We want to find out if in-vitro meat might also be an option for us and if it really is a possibility to counter climate change in the long term. In this work, we specialize especially in cultured beef, as most research is done on it and because in-vitro beef has the greatest sustainability effect, as beef production by far requires the most resources, and is therefore the most interesting for us.

Our questions:

- How is in-vitro meat produced and what resources does it require?
- What are the Pros and Cons of in-vitro meat?
- When is in-vitro meat going to be on our plate?
- Is in-vitro meat really going to replace conventional meat?
- Is in-vitro meat an option for us?
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## Introduction Lab Grown Meat

Each day about two hundred species go extinct. Each day we release enormous amounts of greenhouse gases into our atmosphere. Each day over 150 million animals are killed, just so that we humans can enjoy our hotdogs.

It has long been scientifically proven, that one can save a very high amount of gases such as CO<sub>2</sub> and methane, only by giving up on eating meat and other animal products. Some scientists are even saying that only leaving out beef from our diet has a bigger impact than giving up on cars. But it's not only the carbon footprint that would be reduced. One could also save huge amounts of water, space and soy that could then be used for us humans.

But what if there were another solution than simply not eating meat? What if there was a way to still enjoy the taste of a good hamburger without killing animals or endangering the environment? What sounds impossible is on its way to our supermarkets: lab grown meat.

The idea of cultured meat is actually older than one would think. Winston Churchill first suggested it in 1931 when he said "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium." However, the technique didn't take off until the early 21<sup>st</sup> century.

In 2013 the first ever lab-grown meat, a burger, was eaten. It proved that it was completely possible to use the in vitro cultivation of animal cells to produce a cruelty free and environmentally friendly burger. However, to produce that one single patty, there was a cost of around 300'000 dollars.

In January 2016, a company called Memphis Meats produced a cultured meatball for 1000 \$, which obviously was already a big improvement. Mark Post, the man behind the 300'000 \$ burger is predicting that it will be possible to produce patties for about 10 \$ in the near future.

At the moment, most scientists are mostly focused on growing processed meat products, as their texture and taste are easier to achieve. That unprocessed meat is also achievable is shown by Memphis Meats, who produced the world's first cell-based poultry in March 2017.

When looking at our rapidly growing population it becomes clear quickly that change needs to happen! Animal products are incredibly bad for our earth, when the demand is as high as it is at the moment. There aren't many alternative options to the lab-grown meat, as many people refuse to turn to a vegan or vegetarian diet.

The in vitro cultivation of animal cells is used all over the world, with the most famous companies being the one owned by Mark Post and Memphis Meats. Even here in Switzerland the topic is becoming more talked about, as our famous meat company bell has recently invested in the production of cultured meat.

But the question still remains: Will cultured meat ever replace real meat? We will discuss this and many other topics in our paper. In our paper we will focus on beef, as it is the type of meat releasing the highest amount of greenhouse gases.

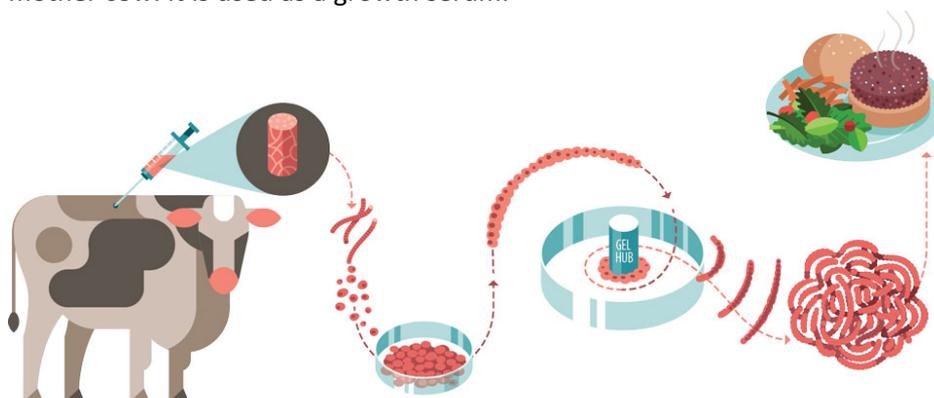
## Cultured Meat Production

To produce lab grown beef, stem cells of a cow are needed. Normally, stem cells grow when the organisms tissue gets injured to repair it. This capacity is used to produce lab grown meat. Therefore, stem cells are extracted from the muscle tissue of the cow by biopsy.

Per one biopsy, 100 stem cells are extracted. This procedure is done in the usual practice under local anaesthesia. The aim is that the cells turn into committed cells, so that they can develop into muscle cells. The stem cells turn first to myoblasts and then to myocytes, the typical muscle cell. The myocytes link to fibres and form myotubes. These myotubes are sown around a gel for final differentiation.

Differentiation is important, as differentiated cells usually produce larger amounts of the few proteins that are required for their specific function. The differentiated cells in petri dishes are put in incubators.

The petri dishes contain the needed nutrients such as sugar, minerals, vitamins and amino acids. The most important ingredient however is the blood of a calf extracted from a foetus in the womb of the mother cow. It is used as a growth serum.



To gain the growth serum, a pregnant cow is slaughtered, and the foetus is cut out of the uterus. The alive and not anesthetized calf is stung by a thick needle and blood is sucked out of the calf's heart

Picture 1: Simplified graphic of the production of in-vitro meat

until none is left and the animal dies.

The whole procedure must be performed on a living calf, because a higher amount of blood can be sucked off by the beating heart. Also, the blood does not start to clot. The foetal calf serum contains a variety of proteins, of which not all of them are known today. Among these proteins are also growth factors necessary for culturing cells.

PH value and temperature also play a big role when cells are cultured. It is important that the surrounding's conditions of the culturing cells are equal to the cow's so that the cells can grow. The next step is proliferation. The extracted cells in petri dishes are put into incubators. In order to make the product as meat-like as possible, it is important that the mass is trained like real muscles. Mechanical as well as electrical impulses are applied to the mass through which the electrical stimulation of the actual nerve cells of the cow is imitated. It is starting to develop a mass of skeletal muscle. The muscle fibres are mixed with fat cells and additives to reproduce the texture and juiciness of a traditional hamburger. Afterwards, the fibres are shaped into a burger.

## Interview with Sarah Lucas

During our research we came across the name Mark Post, the first one to present a proof of lab-grown meat. Nowadays he is working at Maastricht University in the Netherlands. We decided to ask him for an Interview. After some days, we received an Answer. He redirected us to his working partner Sarah Lucas. She works with him in his company "Mosa Meat", which deals with the promotion of in-vitro meat. Sarah Lucas was a great interview partner. She was friendly and always answered our E-mails very quickly. We asked the following questions and received the following answers:



Picture 2: Sarah Lucas

- What is Your personal motivation on cultured meat (e.g ethical/environmental reasons)?

**My personal motivation is to reduce the terrible suffering of animals in industrialised farming, and also reduce the destruction of the environment for livestock farming. I previously worked in animal welfare, and founded an animal welfare organisation (called Action for Dolphins). Having done a lot of animal welfare advocacy, I recognise that it's very hard to get people to change their behaviour for ethical reasons (for example, to convince people to become vegetarian). When I learned about cultured meat, I was really excited, as this technology allows people to continue eating the meat they love, but takes away the harmful impacts to animals and the environment.**

- Is there an alternative to calf serum?
  - If yes: what?

**There are alternatives, yes. We can derive the useful components of FBS (such as growth factors) from other sources (e.g, it can be produced by yeast).**

- If no: Are You currently investigating an alternative?
- Is it, in your opinion, a more ethical solution (in terms of the calf serum used)?

**Yes, I think it is much more ethical to produce the cell culture medium without calf serum. For Mosa Meat, it's really important to us that no aspect of the production system requires killing or causing suffering to animals.**

- Why is cultured meat not yet on our plates/ What needs to be improved, so that cultured meat can finally be on our plates?
  - When will it be?

**We're hoping, in the best case scenario, to have a first product on the market on a very small scale in 2021. The main challenges to doing so are scaling up the production system, and going through the regulatory approval. We have worked out much of the fundamental science on lab scale, but now our engineers need to work out how to produce economically and safely at large scale. Also, we need to demonstrate to the regulatory authorities that the product is safe and nutritionally equivalent to meat in order to be able to sell the products.**

- What are further research steps for Mosa Meat?

**We have teams working on cell proliferation, differentiation, optimising serum-free media, and creating the large-scale cell and tissue production systems.**

- Do you think that once the cultured meat enters the market, it will be well received by the masses?

**I really think that this depends on whether we achieve the taste/texture of meat. This is crucial. I think if we can achieve that, and bring the price down to a competitive level, then most people will choose meat that is guilt-free.**

We are very grateful for the time Sarah Lucas has given to our interview and for the effort to answer our questions in such detail. We found it very amazing to hear that the company "Mosa Meat" has already found an alternative to the calf serum, because all other in-vitro meat companies, as far as we could find out, do not have yet found an alternative and still use such cruel methods to extract the calf serum.

## Discussion

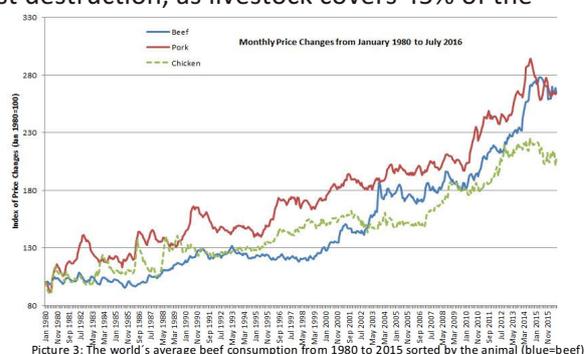
### Advantages

#### Sustainability:

Factory farming is responsible for more greenhouse gas emission than the entire transportation sectors combined. One kilogram of beef requires 6.5 kilograms of crop, 330 square meters of ground, 15'000 litres of water and produces 16.4 kilograms of carbon dioxide. In overview, the world animal agriculture is responsible for 20%-33% of all fresh water consumption, for up to 91% of the destruction of the Amazon and is a leading cause of rainforest destruction, as livestock covers 45% of the earth's total land.

One football field of rainforest is destroyed every second to raise cattle in order to produce 257 hamburgers. In 2016, the average Swiss consumed 46.3 kilograms of meat, which puts Switzerland on the 12th place in a worldwide list sorted by yearly beef consumption. Our meat consumption has drastically increased in the past years and continues going up (see picture 3).

Additionally, fertilizer used for feed-crops for the animals cause the pollution of soil, water and air by nitrogen and phosphorus. There is also a huge loss of biodiversity due to eutrophication, acidification, pesticides and herbicides used for feed-crops and due to livestock-related habitat destruction.



Producing Cultured Beef could use as much as 99% less space, 7 to 45% less energy, 78% to 96% lower greenhouse emissions and about 90% less water. This suggests that the environmental consequences of switching from the familiar factory farming to lab-grown cultured meat can have a long-term positive impact on the world's climate and environment by reducing these emissions by up to 96%.

#### Job creator:

There is an immense demand for beef globally and with our constantly increasing population and standard of living, the demand for beef has not reached its peak. With cultured meat there will be an immense number of new business sectors created, new employment generated and will start the production of not only in-vitro meat but also other cultured foods.

#### Health:

Human ingest meat mostly from animals that have been injected with antibiotics, which is a source of antibiotic-resistant bacteria that can harm us and cause serious health issues. If you eat undercooked meat where those antibiotic-resistant bacteria are present, you could get sick because of bacteria that an antibiotic can't treat.

Around two million Americans get infected with antibiotic resistant bacteria every year and at least 23 thousand Americans die from those infections. We are using 15 million kilograms of antibiotics in food animal production every year, which is four times as many antibiotics as we are using in human medicine.

Perspicuous cultured meat does not require the use of any antibiotics, so there is no development of antibiotic-resistant bacteria, which is a major progress for human health. Cultured meat also minimizes or entirely keeps off animal-borne pathogens and bacteria, like salmonella that could cause further diseases.

#### Ethics:

Modern and therefore almost all high-pressure agriculture keeps the animals like cows, pigs, calves, chickens, ducks and other animals in horrible conditions, where they are not treated like living beings but like objects that do not deserve to be happy. They are commonly kept in overcrowded, dusty and undersized cages, stalls, crates or sheds where they are often unable to take a single step. Even in our "cow-friendly" Basel you can observe farms and realize that often the cows are most of the time kept in small cabins where they are not even able to turn. Deprived of proper or even no veterinary care, exercise, sunlight these feeling beings suffer and die at the rate of millions per day just to land on our plate. Cows and pigs are so intelligent and their senses are so much like our own. The only difference between pigs and dogs is our perception and traditions. Pigs are even a lot smarter than dogs, the only difference is that they might not look as cute and do not have such a fluffy fur. Pigs, cows and even chickens are all individuals with feelings – they experience happiness, love, loneliness and fear, just as cats, dogs and people do. More than 25 billion animals (, from which 300 million are cows and 1.4 billion pigs) are killed by the meat industry every year in horrible ways that we could not even imagine. Lap-grown meat does not require slaughter and all this cruel process of raising an animal under horrible conditions and is therefore way more ethically acceptable. Faster production: In-vitro meat only takes several weeks to culture and harvest and is therefore much faster than conventional meat. With that advantage the industry can react and act much faster to current changes in the demand of the consumers.



Picture 4: Factory farming of cows in order to produce beef

#### Faster production:

In-vitro meat only takes weeks to culture and harvest and is therefore much faster than conventional meat. With that advantage the industry can react and act much faster to current changes in the demand of the consumers.

## Disadvantages

### Health:

The World Health Organization classifies red and processed meat as known carcinogens, which means that there is a significant evidence that they increase the risk of certain types of cancer. Cooking skeletal muscle produces carcinogens. This is independent of whether it is organic or where it is from.

A sugar found in animal meat has been shown to trigger inflammation in the body, which can cause arthritis, tumors or cardiovascular disease. Meat is high in saturated fat and cholesterol, which will increase the risk of heart disease and can cause other serious health problems like diabetes. It contains a lot of animal protein which is very acidic for the human body and has been linked to kidney disease, cancer and osteoporosis.

Cultured meat unfortunately does not solve these problems, but there are some improvements that can be reformed concerning the saturated fats and nutrients in cultured meat (We are going to discuss that subsequently in the topic “Future research steps”).

### Unemployment:

Even though the in-vitro meat industry is going to be a huge job creator, the consequences for hundreds of millions of people around the world, whose jobs are connected to factory farming, could be unemployment.

### Trust:

Lab-grown meat is probably going to need a generous amount of time to be fully accepted by people as a replacement for “real” meat, as people often have a perception that it is unnatural. This might be similar to people’s concerns about genetically modified foods, like the widely disseminated transgenic maize.

### Price:

This point could even be considered as a potential Pro. Right now, there are many companies in the research and development phases of creating cultured meat and are investing high amounts of money. This means that the finished product is probably going to be costly for the consumer. However, after some time the price is going to decrease until cultured meat proves to be a relatively cheap product. This, because in-vitro meat products do not require a lot of effort, time or resources, if they are produced in large quantities.

### Remaining animal suffering:

Although animal suffering is significantly reduced, it is not completely avoided. Obtaining the correct type of muscle tissue from the animal still requires invasive techniques that do not guarantee the elimination of suffering. In addition, a nutrient medium for growing the stem cells veal serum is used, which is taken from the living fetal calf in the last third of the mother's pregnancy, in which these fetuses are already capable of feeling pain. (However, research is being done on alternatives, more on this later in the topic “Future research steps”).



Picture 5: Fetal calf serum

## Future Research Steps

The research of cultured meat is quite advanced and the goal is to bring a finished product to the market. But there are still some issues that have to be considered and rethought. If the final basic model is finished, which would include a close to reality consistence and taste, researchers have suggested that omega-3 fatty acids could be added to the in-vitro meat as a health bonus, as there is almost no omega-3 present in conventional meat.

Just as omega-3 fatty acids could be added, cultured meat could easily be supplemented with vitamins and minerals that are not found in natural meat. These could be adjusted to the specific country and its needs. “For example, here in the Netherlands, where it’s always dark, we could add vitamin D in your meat to supplement it,” explained Daan Luining, a Dutch cultured meat researcher, in an interview with “Labiotech”.

The production of cultured meat does not require techniques of genetic engineering, but there is discussion among researchers about utilizing such techniques to improve the quality and sustainability of cultured meat. This can for example play a role in the proliferation (= high growth rate) of muscle cells. The idea is to introduce myogenic (=producing muscle tissue) regulatory factors, growth factors, or other gene products into muscle cells in order to increase production past the capacity of conventional meat.

Hitherto fetal calf serum is used as culture media but researchers are working on a more sustainable and animal free alternative, which turned out to be quite difficult. For example, the use of photosynthetic algae and cyanobacteria has been proposed to produce the main ingredients for the culture media but it is not well elaborated yet.

Another future research direction is the production of exotic meat. Cultured meat offers the possibility of producing exotic meat from animals that are endangered or even extinct, because it requires only a sample of the animal cell.

## Progress made with Cultured Meat

Cultured meat has already undergone huge development and progress. There are plenty of companies working on the development and production of different types of meat including beef, which is the most interesting as it would bring the highest sustainability effect. But there is also a big research around in-vitro pork, poultry and seafood.

There are several companies like Memphis Meat (San Francisco, California), Super Meat (Israel) or Mosa Meat (the Netherlands) working on an in-vitro ground beef burger. They predict to serve the clean in vitro meat to society within the next 4 years. Mosa Meat generated the first lab-grown ground beef burger in 2013, which was a time consuming and labor-intensive process. It is estimated that this first burger cost around \$300,000, if labor-cost of all scientists and technicians are included.



Picture 6: Mosa Meat's first lab grown beef burger

Feedback on Mosa Meat’s original burger was that it successfully recreated the structure and texture of the muscle but lacked moisture and flavor that typically comes from fat content. Since then they have been trying to produce fat tissue to complement the structure of the first burger. Mosa Meats is currently scaling up their manufacturing processes to bring costs down to a commercially viable level.

In our prior interview, Sarah Lucas mentioned that Mosa Meat is planning to have a commercial product, focusing initially on “soft” meats like the original burger, on the market in the next one or two years with which they would be the first company and contributing a lot to bringing the in-vitro industry forward. The technology behind cultured meat is improving rapidly and the hope is that affordable options will be commercially available within the next few years.

## Summary

In our paper, we discussed various aspects of the production of in-vitro meat. We looked at its production through the cultivation of stem cells using calf serum as a growth medium and found out about alternatives to the serum such as yeast. We discussed that the “fake” meat has many benefits, like using less resources than conventional meat or not requiring the killing of animals. However, we also found out about its negative aspects, such as many people working in livestock farming, losing their job.

We interviewed Sarah Lucas from the company Mosa Meat, from whom we received many interesting facts. For example, it will take about two years until Mosa Meat’s cultured meat will land on our plates. In our preface, we asked ourselves whether in-vitro meat is an option for us personally.

Ivana and Simone can affirm that, because they are cocksure of the huge sustainability advantage and if the taste is convincing, they would definitely give the cultured meat a chance and reintegrate it into their diet.

On the other hand, after she found out about the production and way of the research, Rosa rejects cultured meat. She represents an animal experiment free lifestyle and, even if at the end for the specific piece of meat on our plate no animal was killed, animals were still tortured and exploited during the process of getting to the end product.

All three of us are very convinced that, if the taste convinces the consumers, then lab grown meat is a very realistic opportunity to replace conventional meat and thus a great possibility to counteract climate change. In conclusion, we can say that we support this new turn, which the meat industry is taking, as long as the production process eventually will be ethically correct.

We found the work on our project very interesting, as all three of us have a personal relation to our chosen topic and hope you enjoyed reading our paper.

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