# Decoding cultured meat production

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# IMPACT

Production of livestock to satisfy the growing demand for meat comes with great cost for the environment, accounting for over 13.5% of global greenhouse gas emissions, 38.5% of habitable land usage and 30.2% of fresh water consumption.[1,2] Cultured meat technology offers a chance to drastically improve the environmental footprint of meat by producing muscle from stem cells using tissue engineering techniques. However, a multitude of scientific challenges must be overcome to bring this novel food technology to market.

The aim of this thesis is to use bioinformatic tools to address the biological limitations of satellite cells, one of the most promising cell types that can be used for producing cultured meat. These are stem cells that have the ability to form new muscle fibres in animals but also outside of an animal when grown as cell cultures.

## Scientific impact

Satellite cells (SCs) have traditionally been grown in cell culture using compounds derived from animals, a major obstacle for their application in cultured meat. The results of this thesis show that it is possible to remove animal components from SC cultures derived from cows, both for their growth and their differentiation, i.e. the formation of muscle structures. The development and optimisation of animal component-free media for growth and differentiation of SCs are important steps for the cultured meat field. Beyond its application in cultured meat, the underlying approach to develop and optimise animal component-free media can also be extended to medical basic research, where animal components are still in frequent use to culture mammalian cells.

Just as animals alter as they age, the behaviour of SCs is subject to change during long-term growth in culture. During this ageing process, they gradually lose the ability to divide or to differentiate, which restricts the quantity of cultured meat that can be produced. In this thesis, we analyse the changes that occur to SCs during prolonged culture on a single-cell and a population-wide level. Our findings indicate that it is possible to produce enough functional cells for commercially relevant quantities of cultured meat but further optimisation is needed to achieve this robustly. The ability to create large amounts of cell mass, and from those, maturated and complex tissues, is equally relevant for other applications in the field of tissue engineering, such as the growth of organs for patient-derived cells.

This thesis demonstrates how to use existing bioinformatic tools to understand cell behaviour during these processes and how to leverage gained insights to improve them. Although there is only limited transferability of results from cells cultured outside an animal to their natural environment, the detailed characterisation of SCs in this work can also contribute to a better understanding of skeletal muscle biology necessary for treating muscle-related syndromes such as sarcopenia or duchenne muscular dystrophy.

## Social impact

The revenue generated in the global meat market amounted to over 1.1T USD in 2021, of which meat substitutes had a share of less than 1%.[3] This creates a strong incentive for commercial parties aiming to enter the market with a food technology that promises environmental and ethical benefits over conventionally grown meat. This vast market opportunity resulted in the founding of 107 cultured meat-related startup companies by the end of 2021.[4] However, the challenges of producing cultured meat on a commercial scale are too numerous and complex to be solved by one company alone. Meanwhile, the opportunities offered by this technology outweigh mere financial interests and justify collaborative efforts beyond the boundaries of private institutions.



The realisation of cultured meat on an industrial scale may have a dramatic impact on society. If the estimations of early life cycle assessment studies hold true, it may reduce greenhouse gas emissions, land and fresh water usage, deforestation and loss of biodiversity. It may contribute to global food security by requiring fewer crops to produce equal calories of meat. It may lower the risk of animal-borne diseases and antibiotic resistance by reducing the number of animals used for food production. Just as importantly, it may reinstate the social contract between livestock animals and humans, where the harvest of animal goods is exchanged for protection from nature and disease. This social contract is out of balance in today's industrial meat production, where livestock animals are considered merely a product. In contrast, cultured meat technology presents the chance to return the rights to these animals by harvesting their cells, rather than their lives, for the production of meat.

The research presented in this thesis aims to support environmental and societal change through advancing the development of the field, but it also shows that the path to produce substantial quantities of cultured meat might be long and convoluted. In an area dominated by privately funded companies, open-access research and scientific dialogue across institutions remain key to drive innovation along the entire product chain. Therefore, the results of this thesis have not only contributed to the filling of three patents (applications pending)[5] but were shared in peer-reviewed journals,[6] open-access repositories,[7] scientific conferences,[8,9] lectures, blog posts,[10,11] social media platforms and podcasts.[12] By promoting open-access science and engaging in public education, we want to create a technology that is comprehensible, inclusive and transparent. This may pave the way for a new, sustainable and more ethical relation to our food.

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