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Anne-Laure Mention
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From Research to Innovation: Exploring the Translation Journey with OpenInnoTrain

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 823971

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Mention, A.-L., Menichinelli, M. (Eds.), 2021. From Research to Innovation: Exploring the Translation Journey with OpenInnoTrain, 1st ed. RMIT University Press, Melbourne (Victoria), Australia. https://doi.org/10.5281/zenodo.5536932

Edited by Anne-Laure Mention & Massimo Menichinelli
Published by RMIT University Press, Melbourne (Victoria), Australia (2021)
ISBN (print version / PDF): 978-1-922016-75-1
ISBN (digital version): 978-1-922016-76-8
DOI: 10.5281/zenodo.5536932
https://doi.org/10.5281/zenodo.5536932
https://www.openinnotrain.eu/

This research has received funding from the Horizon 2020 Programme of the European Union within the OpenInnoTrain project under grant agreement n° 823971. The content of this publication does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the publication lies entirely with the author(s).

https://www.openinnotrain.eu/
https://cordis.europa.eu/project/id/823971

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10 Approaching FoodTech: some preliminary considerations

Elena Casprini, Antje Gonera, Carsten Nico Hjortsø

1 Introduction

In this chapter, we aim to introduce and characterize the concept of FoodTech and discuss this practice field in relation to knowledge translation. Today, ensuring effective knowledge translation in relation to the FoodTech sector is an important issue because food production and consumption is estimated to contribute between 20 and 40 percent of CO_2 emissions (Vermeulen et al. 2021). Changes in food consumption patterns are important to reduce this level, but FoodTech solutions will also play a significant role in contributing to make the food sector more sustainable by reducing environmental impact along the entire food supply chain (Willett et al. 2019; De Bernardi & Azucar 2020). Another important challenge is caused by a growing world population, which is estimated to result in an increase in food demand by 60 percent by 2050 (Alexandratos & Bruinsma 2012). This will put a significant pressure on the shrinking natural resources available for food production and will require a significant increase in the food sector's productivity.

The prominent role of FoodTech is highlighted in the 'A farm to fork strategy' published by The European Commission in 2020 (EC 2021). In this strategy, the importance of creating a food chain capable of satisfying both the demand and supply side requirements, while simultaneously taking care of both the climate and the environment is emphasised as a means of reaching a climate-neutral society. An additional EU initiative is the 'Food 2030', which is the European Commission's research and innovation policy to transform food systems and ensure everyone has enough affordable, nutritious food to live a healthy life (EC 2018). The Food 2030 is a policy blueprint for transforming food systems and places nutrition, resilience, reduction of carbon emissions, and public trust and involvement at the core of the transformation. These strategies and policies highlight the importance of FoodTech and place research and technology development in the food sector at the center of the EU policies and programs in the future decade. In this light, understanding how FoodTech research findings are most effectively transformed through innovation into long-term impact becomes of significant importance.

In the following, we first describe the food system and its context. We then aim to define the concept of FoodTech. This is followed by a review of recent technological developments with relevance for the food industry, and finally we highlight some recent developments in how knowledge translation occurs within the FoodTech practice field.

2 Food: from the oldest need of human beings to a locus for innovation

The role of food for society has been well documented by archaeologists (Ambrose 1998), historians of art (Riley 2014), but also humanists and by the broader literature since the first classical poems. Food scarcity has often been a reason for migration (Maharatna 2014), for war (Cribb 2019) and, consequently, an important driver of change.

Historically, people have innovated how food is produced, processed, preserved, distributed, and stored. *"The first agricultural revolution occurred when humans started farming around 12,000 years ago. The second was the reorganization of farmland from the 17th century onwards that followed the end of feudalism in Europe. And the third (also known as the green revolution) was the introduction of chemical fertilizers, pesticides and new high-yield crop breeds alongside heavy machinery in the 1950s and 1960s"* (Rose & Chivers 2020). However, only very recently, the negative impact of food production and consumption on the environment has gained attention. This is caused by deeper awareness about the pollution associated with food production (Sutton et al. 2013) as well as the importance of not losing biodiversity (Tscharntke et al. 2012). Additionally, climate changes have also urged policy makers and food producers to consider how to prevent food scarcity.

A fourth agricultural revolution has started and is enabled by technological advancements such as precision agriculture, smart farming and cellular agriculture (Barrett et al. 2021). With advancement in technologies, attention has also been posited to how food could be transported (e.g., by drones) and produced (e.g., using fermentation, 3D printing and genetic modification) in innovative ways, both following and driven by changes in consumers' behavior and taste. Whereas food is strongly embedded in cultural traditions and practices, it is also highly affected by advancements in knowledge and technology. The two are not mutually exclusive, but rather self-reinforcing.

3 What are food systems and how may they be changed?

FoodTech is concerned with the application of technology in the food system. FAO (2018, p. 1) defines the food system as encompassing:

> *"… the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded."*

Thus, one way to conceptualize the food system is to identify the chain and interdependencies of activities involved from input production to consumption. This chain is captured by the concept of the supply chain when the focus is on the processes of production and distribution of a product from raw material to the table and the 'bin' (e.g., from farmers to restaurants and actors who take care of food waste). The concept of value chain is used when the focus is on identifying the distribution of the value generated through the activities that constitute the supply chain.

The main activities involved in a (simplified) food supply chain typically include (Li et al. 2017; Papargyropoulou et al. 2014; Van der Vorst et al. 2001):

- Research and development
- Agriculture/Raw material production (e.g., vegetables, animals or fish)
- Food processing, manufacturing and packaging
- Storage and distribution
- Retail and sales
- Consumption
- Waste disposal, recycle, or upcycling

These activities are organised in many ways depending on, for example, the geographical extension of the specific food supply chain or the desired characteristics of the marketed food products. Today, many food products involve a global supply chain, where input materials are sourced from low production cost regions with favorable growing conditions such as Africa and Asia, processed through several steps in various locations, and eventually marketed in European and North American supermarkets. The evolution of global supply chains is closely linked with increasing globalisation during the last fifty years. Globalisation and widespread market liberalisation have created a food sector dominated by multinational enterprises, with an emphasis on standardisation, globalised supply chains and low-cost mass production (McMichael 2009; van Otterloo 2012). The dominant governance model at a given time is referred to as a 'food regime', which is defined as "a rule governed structure of production and consumption of food on a world scale" (Friedmann 1993, p 30). The present dominant food system is characterised as the *corporate food regime* (Friedmann 2005).

The corporate food regime has had a negative impact on the livelihood of rural smallholders as well as the environment, for example, through concentration of land ownership and a shrinking natural resource base (Holt-Gimenez & Shattuck 2011). As a reaction to this development, several movements have emerged that challenge the present dominant regime. One significant social movement is the *food sovereignty paradigm* that proposes restoration for national autonomy over food policy, territorial understanding of food security, and encourages ecosystem stewardship through a central ethic which would be 'food as a right, not a commodity' (McMichael 2013, p. 6). This movement also emphasizes the need to recognize the role of agriculture and farmers in the daily life of people, to give preference to family-based production rather than intensive export-oriented industry production, and to produce safe and healthy food, promote community, culture and the care for the environment as well as the preservation of local and traditional knowledge (Carrasco & Tejada 2008). The case of *Slow Food* is emblematic of this new paradigm of localised consumption and offering of geographically typical food products (Nosi & Zanni 2004). Another important example is the *geographical indicator* (GI) and *appellation of origin* (AO) labelling systems which are internationally defined and legally protected, as for example in the case of the wine industry where products have been protected and regulated by an AO system for several decades. In general, there seems to be a consumer trend, at least in the affluent western markets, towards willingness to pay an added value for preservation, protection and valorisation of food specificities.

Recently, non-conventional production approaches have gained ground in the food sector including hydroponics, vertical agriculture, intelligent farming, cropping, agro-ecology, permaculture, organic farming, and urban farming (De Bernardi & Azucar 2020). Many of these approaches are enabled by recent technological developments and explicitly address the above-mentioned challenges. Another contemporary development is the circular economy, which has also raised significant interest within the food sector. Circular economy constitutes a significant challenge because it may in many cases imply a total redesign of the existing supply chains in the food system and FoodTech is envisioned to play a central role in accommodating such fundamental transitions. These alternative approaches are claimed to contribute to alleviate some of the corporate food regime's negative social, economic and environmental impacts, but many of the associated technologies are still in an initial stage. This places a significant challenge on FoodTech and the sectors' ability to translate research findings into impact. Ramirez-Portilla et al. (2016, cited from De Bernardi & Azucar (2020, p. 111)) provide an overview of trends, and a breakdown of associated areas in the current food systems in need of further research and development:

- Fresh, local, and convenient:
    - New ingredients
    - Emerging regulations
    - Foods on the go
    - Proximity to customers
- Automated solutions:
    - Food bots
    - Advanced processing
    - Waste and resource minimisation

- Safety and quality:
    - Food authenticity and traceability
    - Quality management across the supply chain
    - Sanitation
- Supply chains:
    - Short product life cycles
    - Intelligent packaging
    - Sustainable sourcing

The above list combined with the diverse structures of contemporary food supply chains illustrate the multi-actor, multi-function, and multi-factor nature that characterizes food systems, and thus the potential field of application of FoodTech solutions. In the next section, we will zoom in on the notion of FoodTech with the aim of understanding how it may be defined in different contexts.

Food system transition builds on the theory of systemic innovation as a process of renewal of a system (Elzen et al. 2004). Transitions come about because of interaction between different analytical levels and the theoretical model developed by Geels (2011) shown in Figure 1. These levels include *innovative niches*, the *socio-technical regime*, and the *socio-technical landscape*.

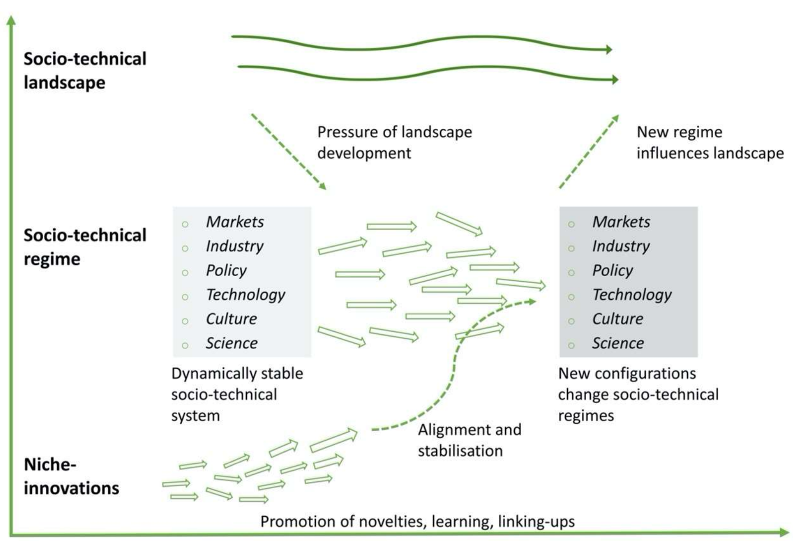

Figure 1 Transition to sustainability (modified by the authors from Geels (2011))

The socio-technical regime is the core concept. The regime is understood as relatively durable, stable and difficult to change. In the food industry context, the regime corresponds to what we know as the mainstream *corporate food regime*. Regime change - or systemic change - is slow and difficult because the regime is constantly reproduced and held together by what is known as lock-in mechanisms. There are material lock-in mechanisms such as artifacts, instruments and infrastructure, or economic lock-in mechanisms such as sunk cost investments, economies of scale and favorable price-performance relations, and vested interests that exclude novelty.

In this model, it is argued that innovation happens in *niches* – protected and 'away' from the dominant or ongoing everyday business of the regime. Examples include alternative food networks (Randelli & Rocchi 2017) and organic farming (Smith 2006). Other examples of innovative food niches include new technologies in genetics and preventive health, precision farming, in vitro/cellular farming, social innovation, and organisational changes. The idea of alternative food networks started in the 1970's as a reaction to concerns about globalised and industrialised food production. In much of the literature about alternative food networks, environmental sustainability is associated with organic farming (Randelli & Rocchi 2017). Alternative food networks often evoke a sense of place, a social connection to the food or social embeddedness.

The third analytical level in a transition perspective, is the notion of a *landscape*. The landscape in which a system operates includes the economic environment and the sociotechnical environment. Landscape level changes are caused by external shocks or long-term trends. Examples include the financial crisis, and demographic trends. In terms of the food system, landscape factors include the ongoing discourse about climate change, increasing awareness of animal welfare issues, and public health concerns. For example, in the mid-1990's consumers were faced with the debate on genetically modified organisms (GMOs) and a series of livestock disasters such as BSE/Creuzfeld-Jacobs. Events that triggered new interest in alternative foods and a new skepticism about the intensification of the livestock industry (Van Otterloo 2012). The COVID-19 pandemic is one such shock to the food system that triggered innovations and technology disruptions towards a food system change (Galanakis et al. 2021).

4 What is FoodTech?

The notion of FoodTech may be defined more or less broadly. Some very closely related concepts include AgriTech (Krishnan et al. 2020) and Agriculture 4.0 (Kovács & Husti 2018; Liu et al. 2021) which are related terms that may emphasize a focus on a particular node or segment of the food value chain, in this case the upstream segment. These terms are often used interchangeably and in this chapter, we adopt an inclusive definition of FoodTech, considering AgriTech and Agriculture 4.0 as part hereof.

No unanimous definition of the term FoodTech exists, but FoodTech is closely linked to the broader discipline of food science. This relation is recognised in Wikipedia's definition of FoodTech:

> *"Food technology as a scientific field is a branch of food science that deals with the principles and processes involved in production,*

> *preservation, quality control, distribution, and research and development of the food products" (Wikipedia n.d.).*

Institute of Food Technologists, a professional organisation for food technologists and scientists helps us place FoodTech in a disciplinary context:

> *"Food technology is the application of food science to the selection, preservation, processing, packaging, distribution, and use of safe food. Related fields include analytical chemistry, biotechnology, engineering, nutrition, quality control, and food safety management" (IFT n.d.).*

The consulting firm Forward Fooding highlights the link between technology, efficiency, and sustainability:

> *"At Forward Fooding we define Food Tech as 'the emerging sector exploring how technology can be leveraged to create efficiency and sustainability in designing, producing, choosing, delivering and enjoying food." (Forward Fooding n.d.)*

Finally, in the last example, we highlight the educational perspective, drawing on the Technical University of Denmark's description of its FoodTech MSc program:

> *"Food technology is an innovative, exciting, and highly interdisciplinary field of study; meeting the challenges related to global market requirements, changing consumer demands, sustainability, social responsibility, and competitiveness requires knowledge in a wide range of areas." (DTU n.d.)*

This description emphasizes the social, systemic, and market-oriented context and recognizes the current focus on sustainability. Moreover, the interdisciplinary nature of FoodTech is highlighted.

These four definitions drawn from the sectors of science, the professional community, consulting, and education, illustrate the inherent complexity involved in the FoodTech domain. Considering the above-mentioned R&D needs in the current food systems for which FoodTech can provide technological solutions, FoodTech emerges as a very broad and multi-disciplinary discipline or practice area. In this context, we have a special interest in the developments driven by Industry 4.0. Next, we will identify what characterizes contemporary technology development in relation to FoodTech.

5 What characterises the contemporary technological development?

The World Economic Forum (2018), in its report 'Innovation with a purpose: The role of technology innovation in accelerating food systems transformation' identified three areas of emerging Industry 4.0 technologies with a potential for rapid and large-scale change in food systems:

- *Digital building blocks*; for example, new computing technologies, big data and advanced analytics, Internet of Things, artificial intelligence and machine learning, blockchain, virtual reality and augmented reality.
- *New physical systems*; for example, next-generation biotechnologies and genomics, energy creation, capture, storage and transmission.
- *Advances in science*; for example, autonomous and near-autonomous vehicles, advanced, smart robotics, additive manufacturing and multidimensional printing, advanced materials and nanotechnologies.

Figure 2 summarizes the main established and emerging technology themes across the agri-food supply chain.

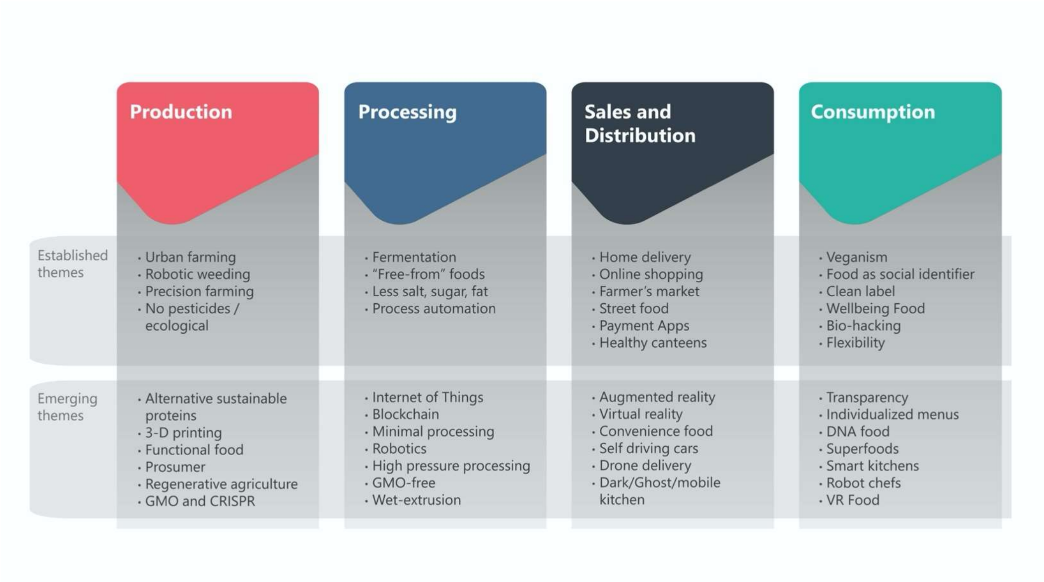

Figure 2 Illustration of FoodTech Trends (modified by the authors from the GDI Food Trend Map (2021)).

In the following, we provide a brief overview of the main technologies associated with the Industry 4.0 development and give examples of how these technologies may be applied in the food sector in the future.

- *Big data and advanced analytics*. Big data analytics help managers to make decisions and enable predictive analytics. Wolfert et al. (2017) provide a review on big data in smart farming, noticing that there are several activities constituting the "data chain", that can be analysed from a technical and a business layer and along four main stages (raw material, processing, transport and marketing).

- *The Internet of Things (IoT)*. IoT technologies are diverse and include the adoption of QR codes, radio-frequency identification (RFID) technologies, sensors, and cyber-physical systems (CPS), for example, in order to trace food products along the whole supply chain (Li et al. 2017). Sensors are also used for monitoring soil humidity and the health of plants (e.g., through dendrometry). IoT technologies can be applied to several products and at different stages in the supply chain, for example, in white appliances, where companies are developing 'smart fridges'.
- *Artificial Intelligence (AI) and machine learning*. A recent article on Forbes notices that AI is crucial for the safety of the food. For example, some companies are using AI-based models for identifying the steps to be followed for washing hands and monitoring employees' hand washing or for identifying unsuitable food items through the use of e-noses (Koksal 2021).
- *Blockchain*. Blockchain is used in tracing the origin (and the development) of products - from soil to table. Feng et al. (2020, pp. 3-4) define a blockchain as "*a shared, distributed and tamper proof digital ledger that consists of immutable digital record data [...]; an innovative application of distributed data, peer-to-peer transmission, consensus mechanism, encryption algorithm, and other information technologies*", and provide several examples, including for the traceability of poultry products.
- *Virtual and augmented reality*. These technologies are particularly important for consumers since they enable the creation of new experiences as well as helping people change consumption habits and shifting preferences towards healthy food.
- *Next generation biotechnology and genomics*. Omics[1] and gene editing technologies such as CRISPR are used to engineer probiotic cultures and to enhance yield, drought tolerance and nutritional value in crops. An emerging biotechnology is cellular agriculture, which is used for production of enzymes or lab grown meat, fish and seafood.
- *Autonomous (unmanned aerial vehicles - UAVs) and near-autonomous vehicles*. These technologies help improve production efficiency as in the case of tractors equipped with radars and GPSs that help farmers to remotely monitor and control sowing, fertilizing, spraying and harvesting (Parker 2016).
- *Robots*. Robots can be introduced in several processes. For example, in food manufacturing the use of robots may happen from cooking to palletizing.
- *Additive manufacturing and multidimensional printing*. 3D printing; that is applied in food design.

[1] Omics refers to the collective technologies used to explore the roles, relationships, and actions of the various types of molecules that make up the cells of an organism (AltTox.org. n.d.).

- *Advanced materials and nanotechnologies*. Nanotechnologies, i.e. the understanding and control of matter at dimensions of roughly 1 to 100 nm (Sastry et al. 2010), are important in the agri-food sector since they can be adopted along the supply chain. These technologies are important in food safety, preservation and security.

As it appears from the above list, the FoodTech sector is highly engaged in Industry 4.0 technologies, but this does not automatically mean that society will harvest the potential fruits to the degree envisioned by institutional actors such as the EU and WEF. The impact of these technologies depends on the extent to which research findings are translated through innovation into practical solutions adopted by the food sector. In the final section, we will address the translation process as well as recent developments in research on FoodTech innovation processes.

6 How does FoodTech knowledge translation take place?

The heterogeneity of actors, technologies, and fields involved in food systems requires us to consider how knowledge is translated from research to practice and vice versa. Once created, scientific knowledge has to be transferred, translated, transformed and used in order to have an impact in society (Greenhalgh & Wieringa 2011; Rybnicek & Konigsgruber 2019). These processes happen not only within universities or corporate R&D labs, but are increasingly also the result of a broader network of relations between food system actors (Strand et al. 2003; Pigford et al. 2018).

Born in the health sector, 'research translation' (Mention et al. 2020) is an emerging concept that aims to complement the traditional knowledge transfer perspective with an increased attention to how knowledge is not only created and translated to the industry or other societal sectors, but how this knowledge is efficiently translated into societal impact through innovation resulting in new products, services, practices, policies, or business models (Woolf 2008). In the FoodTech context, we identify some important aspects that should be addressed in future research in relation to emerging research translation practices:

- The role of *translational developers*, i.e., a function or person who closes the gap between research and practice (Norman 2010). The translational developer can play an important role as a boundary spanner who facilitates the use of knowledge across organisational boundaries and knowledge domains.
- The increasing need for transdisciplinary collaboration between industry and academia driven by the introduction of industry 4.0 technologies into traditional food supply chains (EC 2018).

- New emerging forms of research such as co-creation and open innovation (Filieri 2013; Sarkar & Costa 2008), foresight (Barrett et al. 2021), and design science (Gonera & Pabst 2019).
- The role of universities in supporting entrepreneurship both among students and academic staff also constitutes an area that has been promoted significantly during the last decade, and which provides a promising venue for translating FoodTech research findings into practical use (De Bernardi & Azucar 2020).
- Finally, entrepreneurial (agrifood-)ecosystems (Hernández-Chea et al. 2021) provide an interesting empirical phenomenon and theoretical perspective which has gained increasing attention and importance as a means of understanding the contemporary context of translation processes.

7 Conclusions

In conclusion, we contend that FoodTech is a highly interdisciplinary field, which offers a significant potential for contributing to the needed transformation towards a more social, economic and environmental sustainable food system. It is widely recognised that, in order to realize the significant transformative potential offered by the new Industry 4.0 technologies, FoodTech and associated scientific disciplines cannot only rely on traditional linear knowledge transfer processes, but need to engage more deeply in the food systems transformation through new modes of university-industry collaboration to foster innovation with social impact.

We argue that FoodTech knowledge creation and use need to be seen as an integrated element of more complex knowledge and innovation systems, for example in relation to Industry 4.0 technologies. Future research should contribute to enhancing our understanding of the different functions and processes that characterize the interaction among actors throughout supply chains from 'farm to fork'. We contend that the concept of research translation can be useful for enriching our understanding of the nature of the collaboration across multiple fields of knowledge and actors needed to realize the potential impact expected from emerging developments within FoodTech.

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