A Systematic Review of Cell-Cultured Meat Acceptance

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Abstract

This review explores the current research on consumer acceptance of cell-cultured meat.[2] If it reaches price-competitiveness with conventional animal protein, cell-cultured meat is likely to cause a massive decrease in demand for farmed animal products. Gaining a more accurate view of consumer acceptance of cell-cultured meat—as well as the factors that will influence said acceptance—will allow us to better understand how we should allocate resources to effectively reduce animal suffering.[3]

This report begins with an outline and justification of our methodology, followed by a description of results, a discussion section, and some tentative conclusions. Finally, some questions for further consideration are outlined.

ANIMAL CHARITY EVALUATORS

[1] We would like to thank Kieran Grieg and Hibba Mazhary for their contributions in writing and researching this report. We would also like to thank external critics Chris Bryant, Keri Szejda, and John Sanbonmatsu for the valuable feedback and perspectives they provided for this piece. Please contact Jamie Spurgeon at jamie.spurgeon@animalcharityevaluators.org with any questions about this report.

[2] In this review, farmed animal products grown via a cell culture are referred to as cell-cultured.

[3] Another factor that would influence our allocation of resources is our understanding of the timelines for cost-competitiveness. For more on this topic, please see Animal Charity Evaluators (2017).

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Methodology

There was no formal review protocol or methodology pre-committed to for this review[4]; however, an internal planning document was used to outline objectives and some methods of analysis. This systematic review was guided by the following two central questions:

1. What are the current levels of consumer acceptance of cell-cultured meat?
2. What factors will affect those levels?

Attitudinal measures (e.g., responses to items regarding the consumption of cell-cultured meat) were the principal measures used to assess these central questions in the studies we reviewed. Attitudinal measures were dominant because cell-cultured products are not yet available on the market, so consumer acceptance data is not available. We did not limit this review to a particular population: We included studies that sample populations across the globe. This review attempts to cover all of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). PRISMA is a 27-item checklist that outlines the steps to be taken to ensure honest reporting in systematic reviews and meta-analyses. These steps include describing the rationale and objectives for the review, outlining the full electronic search strategy, and sharing the study selection process.

Literature search

Before starting this report, we were aware of previous systematic reviews that focused on consumer acceptance of cell-cultured meat, the most notable being Bryant & Barnett (2018). While this recent review successfully summarizes the results of studies that have measured consumer acceptance of cell-cultured meat, its scope is limited because it does not include (i) more recent important studies such as Macdonald & Vivalt (2017), (ii) an analysis of the results of polls, or (iii) certain gray literature[5] publications that offer valuable insights into consumer acceptance.

To identify all of the studies pertaining to our research question, in June 2018 we conducted a literature search of Google Scholar, the Animal Charity Evaluators Research Library (ACE RL), and the Faunalytics Bibliography for Cultured Meat Research. This literature search involved the use of search

[4] As a result, we did not pre-commit to:

- Any methods of handling data and combining results from different studies.
- Any methods of additional analyses.
- Any specific forms of data extraction.

[5] For more on gray literature, see Wikipedia (n.d.).

terms such as "acceptance," "attitudes," and "consumers" with regards to cell-cultured meat (e.g., "cultured meat attitudes"). We read other previous systematic reviews by Bryant & Barnett (2018) and Hartmann & Siegrist (2017) to help ensure no relevant studies were missed by the literature search. To find gray literature, we searched Google for pdf files with relevant search terms. As there are multiple terms employed to describe cell-cultured meat, our search methodology took this into account by including multiple variations.[6] Through various contacts, we obtained unpublished data and studies such as Anderson & Bryant (2018), the Good Food Institute (2016), and a forthcoming study by Castelo funded by ACE's Animal Advocacy Research Fund. We made a judgment call at this stage to stop searching for specific search terms when new relevant studies were no longer appearing.[7]

Articles were prioritized as high, medium, or low priority. Studies published most recently and with relatively large sample sizes (above 100) were deemed high priority. Quantitative studies were prioritized over qualitative ones because they tended to have larger sample sizes and offer numeric results/outcomes that were easier to compile and therefore most useful in testing and validating theories. Peer-reviewed articles or studies conducted by reputable organizations were deemed high priority, while bachelor's and master's theses were considered lower priority. We read the high-priority articles in detail in order to summarize key findings, methodological quality, and risk of bias. We briefly read the medium-priority articles and only read the abstracts of low-priority articles. This was due to time constraints and a consequent reluctance to spend time reading studies that did not directly inform our central questions. (See the full literature search results here.)

This project faced some delays due to staff transitions, and upon resuming its completion in 2019, several new studies were added that had been published since the original literature search.

Assessing bias

It is important to evaluate the risk of bias present in research, as biases can skew results and undermine internal and external validity. We did not pre-specify the criteria that would be used to assess the risk of bias in the studies included in this report; during the risk of bias assessment process, we were not blinded to the names of authors and institutions. However, after the completion of the literature search, we decided to use different risk of bias assessments for different methodologies. For the evaluation of

[6] For example, we used the search terms "cultured meat," "clean meat," and "in-vitro meat." See the appendix for a list of specific search terms we used.

[7] In the case of the ACE Research Library, we examined all of the search pages that appeared because they never exceeded five pages.

cross-sectional surveys, we applied an assessment from Agrawal, Guyatt, & Busse (n.d.), which judged risk of bias using five measures:

1. **Representativeness of the sample**

The study should be representative of the general population. There is a high risk of bias if a sample consists of only one demographic (e.g. students), or if convenience sampling is used. In this review, we look at studies from a variety of different geographical regions and assess the representativeness of samples based on how they compare to the wider population within their region.

2. **Adequacy of response rate**

The survey response rate should be high enough that there are unlikely to be significant differences between the respondents and the non-respondents that would affect results.[8]

3. **Missing data from completed questionnaires**

There may be bias present if there are substantial amounts of missing data from survey respondents not answering particular questions.[9]

4. **Conduct of pilot testing**

Conducting pilot assessments can reduce the risk of bias by making sure that the survey is understood by recipients as intended and that it appears to be measuring what is intended.[10]

5. **Established validity of the survey instrument**

The survey items should be measuring the theoretical concepts that the survey is based on in order to be valid.[11]

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[8] Agarwal, Guyatt, & Busse (n.d.) note that the survey response rate should be high enough "to minimize the likelihood that any systematic differences between respondents and non-respondents will influence results."

[9] Agarwal, Guyatt, & Busse (n.d.) note that "[a] survey may be completed by the majority of a study sample, but a substantial amount of missing data due to items that were not answered by survey respondents may introduce bias."

[10] Agarwal, Guyatt, & Busse (n.d.) note that "[r]isk of bias is decreased if investigators have conducted a formal assessment of the comprehensiveness, clarity and face validity of a questionnaire with a field-test in a subset (e.g., 5 to 10 individuals) drawn from the larger sample. Such "pilot" assessments may ensure survey feasibility, readability of included items and assessment of whether they are subjectively perceived by respondents as addressing what they are designed to measure."

[11] Agarwal, Guyatt, & Busse (n.d.) note that "[t]he degree to which survey items evaluate the theoretical concept(s) the survey is focused on are important considerations. A survey should produce similar responses as other established surveys evaluating related constructs."

We decided to omit the "conduct of pilot testing" measure from our risk of bias assessment as none of the studies provided information on whether or not they conducted pilot testing. As such, all of the studies were at the same level of an "unclear risk of bias" on this metric. Note that while we do not provide a weighting for these bias categories, we do not think these measures are all equally important in their effect. Notably, "established validity of the survey instrument" is likely to be the most important and "missing data from completed questionnaires" is likely to be the least.

For the experimental studies, the Cochrane Risk of Bias Assessment was used, which measured six forms of bias:

1. **Selection bias**

Selection bias is a systematic difference in the characteristics of the groups being compared in the study. This can be mitigated with randomized sampling methods.[12]

2. **Performance bias**

Performance bias refers to unintentional systematic differences in how each experimental group is treated, i.e. differences beyond the interventions being tested.[13]

3. **Detection bias**

Detection bias refers to systematic differences in how the outcomes of each experimental group are determined. This can be mitigated by blinding the outcome assessors.[14]

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[12] Section 8.4 of the Cochrane Handbook for Systematic Review of Interventions states that selection bias is present when there are "systematic differences between baseline characteristics of the groups compared. The unique strength of randomization is that, if successfully accomplished, it prevents selection bias in allocating interventions to participants. Its success in this respect depends on fulfilling several interrelated processes. A rule for allocating interventions to participants must be specified, based on some chance (random) process. We call this sequence generation."

[13] Section 8.4 of the Cochrane Handbook for Systematic Review of Interventions states that "[p]erformance bias refers to systematic differences between groups in the care that is provided, or in exposure to factors other than the interventions of interest. After enrolment into the study, blinding (or masking) of study participants and personnel may reduce the risk that knowledge of which intervention was received, rather than the intervention itself, affects outcomes. Effective blinding can also ensure that the compared groups receive a similar amount of attention, ancillary treatment, and diagnostic investigations."

[14] Section 8.4 of the Cochrane Handbook for Systematic Review of Interventions states that "[d]etection bias refers to systematic differences between groups in how outcomes are determined. Blinding (or masking) of outcome assessors may reduce the risk that knowledge of which intervention was received, rather than the intervention itself, affects outcome measurement. Blinding of outcome assessors can be especially important for assessment of subjective outcomes, such as degree of postoperative pain."

4. **Attrition bias**

Attrition bias refers to systematic differences between experimental groups due to individuals withdrawing from the study.[15]

5. **Reporting bias**

Reporting bias is the tendency of a study to be more likely to report statistically significant results rather than results that are not significant.[16]

6. **Other bias**

This includes any other observed sources of bias in the study, such as funding sources.

We decided to omit "performance bias" and "detection bias" because they seemed less relevant out of the context of a clinical trial; most of the studies were information interventions and thus all treatment groups were treated the same apart from receiving different information. Each measure was given a score of either high, unclear, or low risk of bias. We applied these response options to the Agrawal, Guyatt, & Busse (n.d.) measures as we found them to be more useful. Agrawal, Guyatt, & Busse's response options were: definitely yes (low risk of bias), probably yes (low risk of bias), probably no (high risk of bias), and definitely no (high risk of bias). The quality of the three systematic reviews included in this review was more informally assessed by using the PRISMA guidelines, a checklist of preferred reporting items for systematic reviews.

We did not pre-specify any assessments for publication bias. Selective reporting within studies ("reporting bias") was measured within the Cochrane Risk of Bias Assessment tool that was used to evaluate each experimental study. However, this was difficult to comment on as most studies lacked pre-analysis plans.

We must also acknowledge our own biases. One of the authors of this report was involved in writing a blog post included in the review. Moreover, the internal primary critic responsible for reviewing this report conducted a study included in the review. Two studies were carried out by the Good Food Institute,

[15] Section 8.4 of the Cochrane Handbook for Systematic Review of Interventions states that "[a]ttrition bias refers to systematic differences between groups in withdrawals from a study. Withdrawals from the study lead to incomplete outcome data. There are two reasons for withdrawals or incomplete outcome data in clinical trials. Exclusions refer to situations in which some participants are omitted from reports of analyses, despite outcome data being available to the trialists. Attrition refers to situations in which outcome data are not available."

[16] Section 8.4 of the Cochrane Handbook for Systematic Review of Interventions states that "[r]eporting bias refers to systematic differences between reported and unreported findings. Within a published report those analyses with statistically significant differences between intervention groups are more likely to be reported than non-significant differences. This sort of 'within-study publication bias' is usually known as outcome reporting bias or selective reporting bias, and may be one of the most substantial biases affecting results from individual studies (Chan 2005)."

which Animal Charity Evaluators (ACE) promotes and towards which it directs funding. One of the main sources used in the literature search for this review was a bibliography from Faunalytics, an organization that ACE similarly supports. Both Macdonald & Vivalt (2017) and Vivalt & Macdonald (2017) were funded by ACE's Animal Advocacy Research Fund. Kristopher Gasteratos (author of one study included in the review) works at the Cellular Agriculture Society, a charity that ACE evaluated in 2018. Moreover, Jacy Reese, the author of the Sentience Institute survey, was previously employed by ACE.[17]

Results

A number of polls on consumer acceptance of cell-cultured meat have been completed. These informal polls include: The Guardian (2012), The Guardian (2013), The Guardian (2014), Jaeger (2016), McCrum (2016), Harris (2016), Reeve (2017), Jha (2017), Consumer Reports (2018), Charleston|Orwig (2018), and Surveygoo (2018). These polls may have methodological flaws (such as unrepresentative samples or the possibility of the same individual voting numerous times) that should be taken into account during interpretation. More formal polls and surveys on the subject have also been completed by market research firms, non-partisan think tanks, and social scientists. These polls and surveys from more reputable sources include: European Commision (2005), YouGov (2012), Flycatcher (2013), Smith (2014), Hocquette et al. (2015), Verbeke, Sans, & Van Loo (2015), Harris Interactive (2016), and Wilks & Phillips (2017). Only some of those more formal polls and surveys provide an explanation of what cell-cultured products are. The polls and surveys which do not provide this information may poorly estimate expected consumer acceptance levels of cell-cultured animal products. It seems likely that most future consumers will become somewhat informed about cell-cultured products via sources like popular media reports, advertisements, or the products' packaging, and that this additional information will likely affect consumer acceptance. Since we are more interested in the polls and surveys that we think more accurately reflect the consumer attitudes that we should expect in the future, this review prioritizes research that both seemed to provide an adequate explanation of cell-cultured products and seemed relatively unlikely to have large methodological flaws. It is important to note, however, that different explanations of cell-cultured meat products may themselves prime and frame in various ways, to which we are attentive in the discussion section.

[17] Additionally, some ACE staff members maintain friendships with some staff members at Sentience Institute. While we do not think that these associations have impacted our impartiality on this particular piece, we would like to note the potential for a conflict of interest.

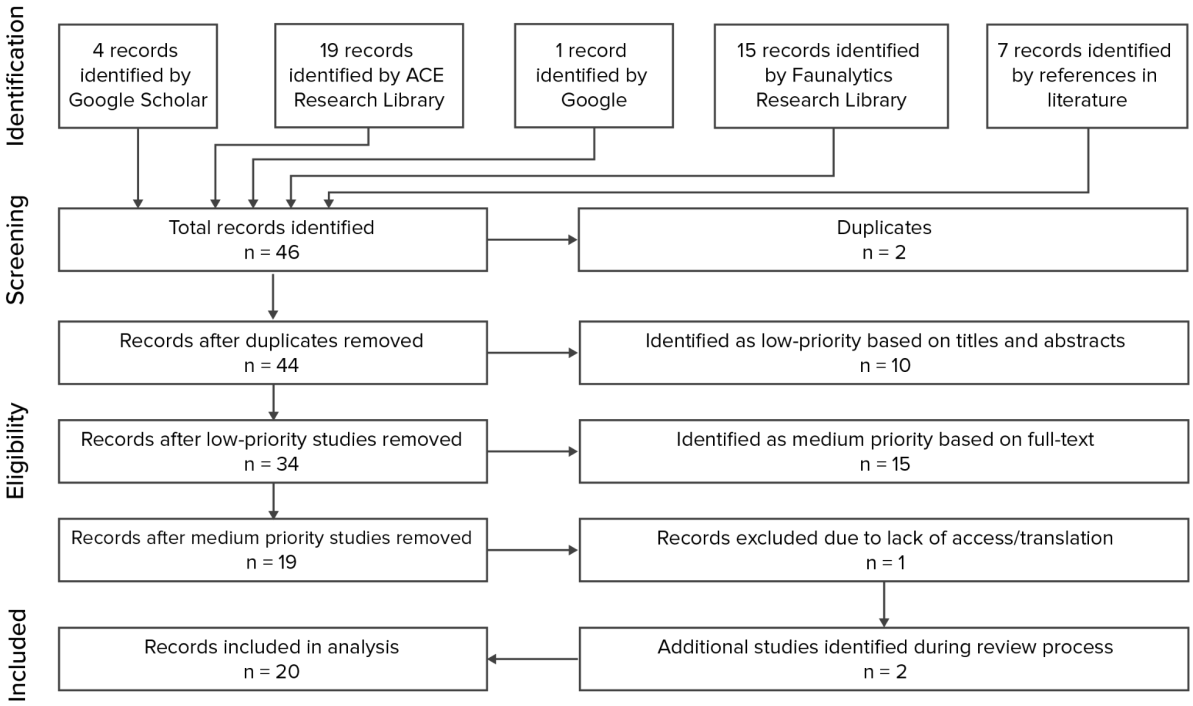

Figure 1: Stages of identification and exclusion of studies based on Moher et al.'s (2009) phases of a systematic review diagram

First, we will examine the cross-sectional surveys, followed by experiments and previous systematic reviews. Lastly, we will offer a synthesis of these results.

Cross-sectional surveys

We reviewed eight cross-sectional surveys. (See Table 1a.)

Table 1a: Some key features and findings of the cross-sectional surveys

Study	YouGov (2012)
Context	A survey of U.K. adults assessing willingness to try cell-cultured meat Publication type: Gray literature (survey) Location: U.K. Sample size: 1,729
Description of Methodology	One question regarding cell-cultured meat was posed: "Scientists are currently developing artificial meat that can be grown in a laboratory. Imagine artificial meat was available

	commercially, do you think you would eat it?"
Key Findings	- 19% of the sample said they would try cell-cultured meat while 62% said they would not. - Men were more likely to eat cell-cultured meat (28%) than women (11%), as were younger people than older people. - Vegetarians and vegans were less likely than non-vegetarians/vegans to eat cell-cultured meat (14% versus 20%).
Key Limitations	Little to no methodological data was provided.

Study	Flycatcher (2013); update (2018)
Context	A survey of Dutch consumers assessing attitudes towards cell-cultured meat Publication type: Gray literature (survey) Location: Internet survey, the Netherlands Sample size: 1,296
Description of Methodology	- All members of the Flycatcher panel (14,765 people) were approached via email to complete a 15-question survey. Flycatcher received 7,703 valid responses and selected 1,296 of them to create a representative sample of the Dutch population in terms of gender, age (over 18), region, and education. - After the first question regarding whether respondents had previously heard about cell-cultured meat was asked, a description was provided. - The description framed cell-cultured meat as a solution to the growing world food issues. It mentioned Mark Post, M.D./Ph.D., working to create meat with the properties of traditional meat, but made in a laboratory using animal tissue. The description also listed possible positive and negative effects. Positive effects included: reduced animal suffering, reduced farming-related diseases, contribution to solution of world food scarcity, less waste produced, less deforestation. Negative effects included: bankruptcy of those employed within the animal agriculture industry and uncertainty about whether cell-cultured meat has the same mouthfeel and taste as traditional meat.
Key Findings	- 21% of respondents had heard about cell-cultured meat ("kweekvlees" in Dutch) in 2013. *This number has risen to 53% in 2018.* - 37% of respondents were against the production of cell-cultured meat. - 52% of respondents noted they would buy cell-cultured meat if it were available. 11% stated

	they would be willing to pay 20%–30% more for cell-cultured meat. *In 2018, 57% stated they would buy cell-cultured meat. Almost 20% stated they would be willing to pay 20%–50% more.* - Genetic manipulation, health, and taste were the main reasons for not wanting to try cell-cultured meat. *In 2018, genetic manipulation was still the main reason.* - Reduced animal suffering and a solution to the world food problem were the main stated reasons for wanting to buy cell-cultured meat. *In 2018, reduced animal suffering was still the main reason.* - If taste, structure, and nutrition of cell-cultured meat were the same as traditional meat, 71% stated they would buy it again. *In 2018, this figure had risen to 78%.* - The most common associations (in an open question) with cell-cultured meat were: fake, unnatural, laboratory, manipulated, gross.
Key Limitations	- Only 21% of respondents had heard about cell-cultured meat before the survey, meaning the attitudes of most respondents were based solely on the short description that was provided. - For attitude questions, multiple choice answers were provided (e.g. "Most important reason to buy cell-cultured meat: animal suffering; world food problem; [...])," though an open-ended option to give other responses was also available. Because most respondents had not heard of cell-cultured meat before, the results could be skewed towards representing how respondents rated the relative importance of these issues, rather than how they related to cell-cultured meat; respondents may have associated these issues with cell-cultured meat only because they were mentioned in the survey. - Providing choices for possible answers influences and skews responses. (Personal health, environment, and antibiotic resistance could potentially be options for people to prefer cell-cultured meat over traditional meat, but these options were not included in the question of why people would buy cell-cultured meat.) - For the 2018 update, no report is available, and the source is a press release about the report.

Study	Hocquette et al. (2015)
Context	An exploration of educated consumers' (predominantly scientists and students) attitudes towards the environmental, ethical, and health promise of cell-cultured meat Publication type: Peer-reviewed journal Location: Internet survey in English: Global, Internet survey in French: France, Paper survey:

	France Sample size: 1,890
Description of Methodology	- 817 people (located all over the world) responded to an internet-based survey in English after reading a written text about cell-cultured meat. - 865 people (located in France) responded to an internet-based survey in French after reading a written text about cell-cultured meat. - 208 people (located in France) responded to a paper-based survey in French and English after attending an oral presentation about cell-cultured meat. - The questions in the survey asked respondents about the feasibility of cell-cultured meat and whether they thought cell-cultured meat would address the environmental and ethical problems of conventional meat production.
Key Findings	- Over 50% of respondents believed that cell-cultured meat was feasible. - 5%–11% of participants said they would accept cell-cultured meat over conventional meat. - While most respondents thought that consumers would not accept cell-cultured meat, they believed that further research into cell-cultured meat should be supported. - Most respondents did not believe that cell-cultured meat would be healthy or tasty. - More respondents believed that cell-cultured meat could be healthy and tasty in the paper survey than in the internet surveys. This could be owing to the fact that the oral presentations were more convincing in outlining the benefits of cell-cultured meat than the written explanations in the internet surveys, which respondents may not have had the time or attention to read and understand.
Key Limitations	The sample was not representative: It was composed of 40.4% scientists and 9.3% meat sector employees.

Study	Harris Interactive (2016)
Context	A survey of consumers assessing attitudes towards cell-cultured meat Publication type: Gray literature (survey) Location: U.K. Sample size: 2,082
Description of Methodology	Participants were asked whether or not they would try cell-cultured meat, whether or not they had heard of cell-cultured meat, and whether or not cell-cultured meat was a good thing

	(using a 5-point Likert scale from “Strongly Agree” to “Strongly Disagree”).
Key Findings	- More than 50% of respondents stated they would not buy cell-cultured meat. Men were more likely than women to be receptive to cell-cultured meat, while those over the age of 55 were the least likely to buy cell-cultured meat. - In response to the question, “What, if anything, would put you off from buying ‘cultured meat’? Please select all that apply,” over 50% of respondents worried about chemicals in cell-cultured meat, 49% were concerned with long-term side effects, and 48% were worried about the “unnaturalness” of cell-cultured meat.
Key Limitations	Little to no methodological data was provided.

Study	Wilks & Phillips (2017)
Context	An investigation of perceptions of cell-cultured meat and the potential barriers that might prevent engagement Publication type: Peer-reviewed journal Location: U.S. Sample size: 673
Description of Methodology	- Participants were asked to imagine that cell-cultured meat was commercially available and whether they would be willing to try it, using a Likert-type scale from 1 (“Definitely Yes”) to 5 (“Definitely No”). If participants selected options from 1–4, they were asked a number of follow-up questions examining their willingness to try the product and how much they would be willing to pay. - All respondents were then given a multiresponse option investigating the conditions under which they would be unwilling to eat cell-cultured meat. This question also had an open-ended response option. - Respondents were also asked to rate how much they agreed with a number of statements that outline positive or negative potential outcomes of cell-cultured meat production, from 1 (“Strongly Agree”) to 5 (“Strongly Disagree”).
Key Findings	- 65.3% of the sample stated they would be willing to try cell-cultured meat. - One-third of respondents stated they were willing to consume cell-cultured meat regularly or as a replacement for conventional meat. - Men were more willing than women to try cell-cultured meat.

	- Politically liberal respondents were more likely than conservative ones to try cell-cultured meat. - The main concerns around cell-cultured meat included: anticipated high price, limited taste and appeal, and a perception that the product was unnatural.
Key Limitations	The sample diverges from the U.S. general population in age, income, and education (not fully representative of the U.S. population).

Study	Sentience Institute (2017)
Context	A survey of adults assessing attitudes towards animal farming and animal-free meat Publication type: Gray literature (blog post) Location: U.S.
Description of Methodology	After a brief description of cell-cultured meat, participants were asked to respond to the following statements with a level of agreement from "Strongly Agree" to "Strongly Disagree": - "When these foods [cell-cultured meat] are the same price as animal-based foods, people should eat more of these foods and fewer animal-based foods." - "When these foods [cell-cultured meat] are the same price as animal-based foods, I would prefer to eat more of these foods and fewer animal-based foods."
Key Findings	- 63.4% agreed (selecting "Strongly Agree," "Agree," or "Somewhat Agree") with the statement: "People should eat more of these [cell-cultured] foods and fewer animal foods." - 56.2% agreed (selecting "Strongly Agree," "Agree," or "Somewhat Agree") with the statement: "I would prefer to eat more of these [cell-cultured] foods and fewer animal foods."
Key Limitations	- There was a substantial amount of missing data within questionnaires due to unanswered questions. (While there were 486 questionnaires with at least one question excluded from the analysis—making the sample size just 608 instead of 1,094—the authors did a robustness check. They conducted a regression in two ways, the first with the 486 incomplete questionnaires excluded and the second using multiple imputation to predict missing data. The two regressions produced similar values, and therefore the missing data presents low risk of bias.)

Study	Wilks et al. (2019)
Context	A study testing potential psychological predictors of attitudes towards cell-cultured meat Publication type: Peer-reviewed journal Location: U.S. Sample size: 1,193
Description of Methodology	- The study used an attitude roots model to explore the psychological mechanisms that may contribute to attitudes towards cell-cultured meat. - The psychological mechanisms measured were conspiratorial ideation, fears and phobias, food neophobia, disgust sensitivity, worldviews, political conservatism, naturalness bias, speciesism, social dominance orientation, and distrust in science. (See the study's full text for information about what measurement scales were used.) - Willingness to eat cell-cultured meat was then analyzed using a hierarchical linear regression analysis.
Key Findings	- Regarding negative attitudes towards cell-cultured meat, the strongest predictors were food neophobia, political conservatism, and distrust of food scientists. - For those who believe cell-cultured meat should never be allowed, the strongest predictors were food and hygiene disgust, food neophobia, and conspiratorial ideation. - Social dominance orientation, speciesism, and naturalness bias were not found to influence attitudes towards cell-cultured meat.
Key Limitations	- The sample was older, more highly educated, and slightly more male than the U.S. average. However, demographic differences were controlled for in the analysis. - The measurement of naturalness bias was not in relation to naturalness of cell-cultured meat, but naturalness concerns more generally. Additionally, the measure was developed specifically for the study and does not have external validity. These points may explain the disparity between these findings and those of other studies.

Study	Bryant et al. (2019)
Context	A survey of consumer perceptions of plant-based and cell-cultured meat in the U.S., India, and China Publication type: Peer-reviewed journal Location: U.S., India, China

	Sample size: 3,030
Description of Methodology	- The authors aimed to recruit representative samples of 1,000 participants per country. The sample ended up being skewed towards higher income and urban groups in India and China. - Participants completed the Food Neophobia Scale and the Meat Attachment Questionnaire, rating their attitude towards various aspects of conventional meat. - Participants were then asked about their familiarity with, attitudes towards, and intentions towards plant-based and "clean" (cell-cultured) meat. They were also asked preference questions in a hypothetical scenario in which each meat group was widely available. Finally, they were asked to provide demographic information.
Key Findings	Familiarity and acceptance of cell-cultured meat were both higher in India and China than in the U.S: - 42.7% of U.S. participants had some level (from "Slightly" to "Extremely") of familiarity with "clean meat" compared with 64.5% in China and 74.5% in India. - In the U.S., 29.8% of participants were "Very/Extremely" likely to try "clean meat" compared with 59.3% in China and 48.7% in India. - A statistical analysis (ANOVA) showed a significantly higher likelihood of purchasing "clean meat" in India and China than in the U.S.
Key Limitations	- The samples for India and China were skewed towards higher income and urban groups. While this may be advantageous—as these are the groups most likely to be able to purchase cell-cultured meat—the effect this had on the between-country comparisons is unclear. - It is also not clear how internally reliable the food neophobia scale is in India and China.

Across all eight studies**,** there were a total of 12,987 participants in the cross-sectional surveys (with questionnaire responses with missing data excluded). The samples were drawn in different ways. Wilks & Phillips (2017) used MTurk to gather their samples, while Bryant et al. (2019) used CINT. Harris Interactive (2016) recruited participants from online market research platforms which customers opted into, as did both Sentience Institute (2017) through their use of survey company Ipsos and Wilks et al. (2019) through Social Sampling International. Flycatcher (2013) used their own polling database to recruit participants, while Hocquette et al. (2015) distributed their online survey through various mailing lists. The primary outcome measured in the studies varied. All of the cross-sectional surveys above used attitudinal measures. In addition, Hocquette et al. (2015) and Wilks & Phillips (2017) used self-reported

purchasing behavior to gauge acceptance. Most studies provided response options to participants, and it is unclear how this may have influenced the results.

The following tables provide risk of bias assessments for each of the included studies.[18]

Table 1b: Interpretation of risk of bias symbols

Symbol	Risk of Bias Interpretation
+	Low risk of bias: plausible level of bias unlikely to significantly alter the results
?	Unclear risk of bias: not enough information to assess the risk of bias
−	High risk of bias: plausible level of bias that significantly undermines results' validity

Table 1c: Risk of bias assessments for cross-sectional surveys

Study	Representativeness of Sample	Adequacy of Response Rate	Missing Data Within Completed Questionnaires	Established Validity of Survey Instrument
YouGov (2012)	+	?	?	?
Flycatcher (2013)	+	−	+	−
Hocquette et al. (2015)	−	?	?	+
Harris Interactive (2016)	+	?	?	−
Wilks & Phillips (2017)	+	?	?	+
Sentience Institute (2017)	+	+	+	+

[18] These risk of bias assessments are adapted from Section 8.5.a. and Section 8.6 of the Cochrane Handbook for Systematic Reviews of Interventions.

Wilks et al. (2019)	+	+	?	+
Bryant et al. (2019)	+	?	?	+

The risk of bias assessments in each of those domains for the individual studies we analyzed, along with brief justifications, are available here.

In some cases, it was difficult to determine the level of bias in certain studies due to the lack of information provided by the authors. Polls such as the YouGov poll and Harris Interactive poll were most limited in this respect because they offered little to no methodological information. However, for most of the studies, we were able to obtain sufficient information to adequately judge the risk of bias.

Key findings from cross-sectional surveys

Willingness to try cell-cultured meat

A willingness to try cell-cultured meat was observed in 19% of respondents in the YouGov (2012) survey compared to 52% in Flycatcher (2013) and 65% in the Wilks & Phillips (2017) survey. This may be attributed in part to the larger amount of contextual information that the latter two provided to respondents.[19] Bryant et al. (2019) observed significant differences between respondents internationally, finding that 29.8% of U.S. participants were very/extremely likely to try "clean meat" compared with 59.3% in China and 48.7% in India. While most surveys focused on the causes of negative associations with cell-cultured meat, Flycatcher (2013) respondents cited animal suffering and solving the world food problem as the two main factors leading to support.

A major factor affecting acceptance levels was the presence of aesthetic concerns around the taste, texture, and appearance of cell-cultured meat. Limited taste and appeal featured as a primary concern in Wilks & Phillips (2017). Hocquette et al. (2015) and Flycatcher (2013) found that a substantial number of respondents in their samples did not believe that cell-cultured meat would be healthy or tasty. Finally, food neophobia was one of the strongest predictors of negative attitude towards cell-cultured meat found in Wilks et al. (2019).

[19] YouGov (2012) asked whether people would eat "artificial meat grown in a lab," whereas Wilks & Philips (2017) provided additional information about the technology, including by providing an example of a cell-cultured hamburger crafted in 2013.

Concerns over naturalness were slightly less clear. Naturalness was one of the main concerns expressed in Wilks & Phillips (2017), and in Harris Interactive (2016), when citing concerns that would prevent them from buying cell-cultured meat, over 50% of respondents worried about chemicals in cell-cultured meat, 49% were concerned with long-term side effects, and 48% were worried about the "unnaturalness" of cell-cultured meat. Flycatcher (2013) respondents cited "genetic manipulation" as a main reason for not wanting to try cell-cultured meat. However, Wilks et al. (2019) found that the presence of a general naturalness bias in participants did not influence attitudes toward cell-cultured meat.

Wilks & Phillips (2017), YouGov (2012), and Harris Interactive (2016) found that men were more likely than women to be willing to try cell-cultured meat, and Wilks & Phillips (2017) and Wilks et al. (2019) both found that political conservatism was a negative factor in willingness to try.

Other key findings

While willingness to try cell-cultured meat was quite high in some cases, willingness to choose cell-cultured meat over conventional meat was still very limited. In particular, willingness to accept cell-cultured meat over conventional meat was low in Hocquette et al. (2015): between 5%–11%. One-third of the Wilks & Phillip (2017) sample was willing to try cell-cultured meat regularly or as a replacement to conventional meat.

Some studies found a disparity between people's personal willingness to consume cell-cultured meat and what they believed society as a whole should consume. In Sentience Institute (2017), 56.2% of respondents agreed that they would prefer to eat more cell-cultured meat and fewer animal foods while 63.4% agreed with the statement that "People should eat more of these [cell-cultured] foods and fewer animal foods." Hocquette et al. (2015) had similar findings—support for "human beings" to "eat less meat" varied from 59.4% to 64.5% across the three surveys, whereas support for individual reduction in meat consumption varied from 41.3% to 58.7%.

It is important to note that inconsistencies across studies of willingness to try cell-cultured meat may not necessarily indicate that consumers do not support cell-cultured meat research: In Hocquette et al.'s (2015) survey, although most respondents thought that consumers would not accept cell-cultured meat, they also believed that further research into cell-cultured meat should be supported.

Experimental studies

We reviewed 13 experimental studies. (See Table 2a.)

Table 2a: Some key features and findings of the experimental studies included in the review

Study	Verbeke, Sans, & Van Loo (2015)
Context	A study assessing consumer attitudes towards cell-cultured meat before and after being provided with positive information about the product Publication type: Peer-reviewed journal Location: Belgium Sample size: 180
Description of Methodology	- Terms used: in vitro meat/cultured meat - Expectations about cell-cultured meat were measured using seven-point semantic differential scales—e.g not healthy (1) to very healthy (7) and not safe (1) to very safe (7). Three statements were also included comparing expectations about cell-cultured meat with conventional meat in terms of expected price, taste, and sustainability. Participants were asked about their willingness to try, purchase, and pay a premium for cell-cultured meat. This was asked twice, the first time after the provision of basic information about cell-cultured meat, and the second after additional information was given.
Key Findings	- Prior to receiving information, 24% of respondents said they would be willing to try cell-cultured meat, 67% were hesitant, and 9% rejected it. After providing consumers with information about cell-cultured meat's environmental benefits, 43% of participants said they were willing to try cell-cultured meat, and 51% were hesitant. - Price and sensory qualities of cell-cultured meat were revealed to be major barriers to acceptance. - Vegetarians were less convinced of cell-cultured meat's potential health benefits than meat eaters.
Key Limitations	Participants were recruited through convenience sampling and were younger and with higher education levels than the general public (mainly students).

Study	The Good Food Institute (2016)
Context	A study involving two surveys in the U.S. and Canada investigating how terminology referring to cell-cultured meat affects public attitudes Study type: Gray literature (blog post) Location: U.S. and Canada Sample size: 4,300

Description of Methodology	The first survey tested different terms for cell-cultured beef and the second tested terms for cell-cultured chicken. The results of the surveys were combined to determine the best overall term for cell-cultured meat. For each one of the surveys, respondents were randomly allocated one of the five terms: “cultured,” “pure,” “clean,” “safe,” or “meat 2.0.” Then, each respondent was shown a newspaper article about cell-cultured meat. Each participant received an identical article save the inclusion of their assigned term to describe the meat. Next, participants were presented with two products that had a randomly assigned price, product type, and production method (cell-cultured, conventional, or humane) and were asked to rate their willingness to purchase the products on a scale from 1 to 7.
Key Findings	People in the sample were significantly more willing to purchase and eat meat grown in a laboratory if it were labeled “safe meat” or “clean meat” rather than “cultured meat,” “pure meat,” or “meat 2.0.”
Key Limitations	The study did not include a control group/placebo (e.g., by including a non-meat product).

Study	Bekker et al. (2017)
Context	A study assessing the influence of information provision on people’s explicit and implicit attitude towards cell-cultured meat Publication type: Peer-reviewed journal Location: The Netherlands Sample size: Experiment 1: 194, Experiment 2: 192
Description of Methodology	Respondents were exposed to either positive or negative scenarios about cell-cultured meat. Their implicit and explicit attitudes towards cell-cultured meat were then measured.
Key Findings	- Providing information about cell-cultured meat’s sustainability and information about a positively perceived sustainable product (in this case solar panels) positively influenced explicit attitudes towards cell-cultured meat in the experimental group. - The effect of information provision on explicit attitude change was less pronounced with people who were more familiar with cell-cultured meat initially. - Implicit attitudes towards cell-cultured meat were not influenced by information provision or mood state (the effect of being in an experiment).
Key Limitations	There could be external validity/representativeness issues due to the fact that the sample only

	consisted of students.

Study	Siegrist & Sütterlin (2017)
Context	A study consisting of four experiments examining some factors that influence the perceived naturalness of food products, as well as the effects of these assessments on risk perceptions Publication type: Peer-reviewed journal Location: Switzerland (German-speaking population) Sample size: Experiment 1a/1b/2: 244, Experiment 3: 253
Description of Methodology	- Experiments 1a and 1b were related to food additives and not cell-cultured meat. - Experiment 2 was an online experiment with 244 participants. Respondents were randomly assigned to one of two treatments: traditional meat or cell-cultured meat. - In the traditional meat condition, they received the following information: "Heavy consumption of red meat results in a significantly higher risk of acquiring colon cancer." The cell-cultured meat group received the following information: "In-vitro meat is produced by means of biotechnology. In doing so, red meat is produced in the laboratory. This production method is more environmentally friendly and involves less animal suffering compared with traditional meat production. Heavy consumption of in-vitro meat results in a significantly higher risk of acquiring colon cancer. The risk is comparable with that of consumption of red meat from traditional meat production." After the text, participants were asked the following question: "How acceptable do you assess the risk associated with red meat/ [in-vitro meat]?" - Experiment 3 was conducted with 253 participants. It was ensured that the participants had not joined the earlier experiments. Furthermore, only meat eaters were chosen for this experiment. Participants were randomly assigned to one of two conditions: the traditional meat or the cell-cultured meat condition. After receiving information about traditional meat or cell-cultured meat, they were asked, "How artificial or natural do you assess beef from traditional meat production/ [that has been produced in the laboratory (in-vitro meat)]?" Next, they answered the second question: "How acceptable do you assess the risk posed by red meat from traditional meat production/ [that has been produced in the laboratory/ (in-vitro meat)]?"
Key Findings	- The results of Experiments 2 and 3 suggested that the same risk associated with meat consumption was much more acceptable for traditionally produced meat compared with cell-cultured meat. - Experiment 3 indicated that the perceived naturalness of the meat (i.e., traditional or

	cell-cultured meat) affected participants' evaluation of the acceptability of the risk of colon cancer associated with meat consumption. Even if the new production method (i.e., cell-cultured meat) was more environmentally friendly and less harmful to animals, the perceived lack of naturalness might reduce the acceptability of the risk associated with such a product.
Key Limitations	The use of convenience sampling may lead to a less representative sample.

Study	Greig (2017)
Context	A randomized trial examining the effects of terminology (“clean” versus “cultured” meat) on levels of consumer acceptance Publication type: Gray literature (blog post) Location: U.S. Sample size: 3,952 in “clean” group, 4,016 in “cultured” group
Description of Methodology	An article on cell-cultured meat was provided to two experimental groups. The article differed in its use of “clean” or “cultured” to describe cell-cultured meat. Participants in each group were then given eight hypothetical purchasing scenarios to respond to, in which they had to choose between cell-cultured or conventional products that varied in animal cell type, product type, and price.
Key Findings	- 52.4% of participants in the “clean” group expressed a desire to purchase the “clean” meat product. - 41.4% of participants in the “cultured” group expressed a desire to purchase the “cultured” meat product. - Following exposure to a critical article on cell-cultured meat, these percentages decreased to 40.0% and 33.2% respectively.
Key Limitations	Two critical articles were used that had differences other than simply the use of “clean”/“cultured” terminology, so the different effect between the two groups is not solely attributable to the terminology.

Study	Macdonald & Vivalt (2017)

Context	- An assessment of three messaging strategies—direct debunking, embracing unnaturalness, and descriptive norms—for overcoming consumer resistance to cell-cultured meat - A comparison between the effects of being exposed to pro-cell-cultured meat information and anti-cell-cultured meat information from other potential consumers - A study (a three-wave survey experiment over 11 weeks) investigating the effects of different information interventions—including the topics of animal welfare, food safety, and environmental friendliness—on consumers' willingness to try cell-cultured meat Publication type: Gray literature (open access) Location: Global (MTurk) Sample size: Initial: 3,200
Description of Methodology	- Wave 1 was a baseline survey with questions on meat consumption levels, attitudes, and demographics. - In Wave 2, the treatment wave, participants were randomly assigned to receive acceptance or anti-acceptance messaging. - The anti-acceptance social information group was shown a web page listing five short quotes from previous survey respondents with negative statements about cell-cultured meat. - All participants were then randomly assigned to read one of four texts: a placebo message, a debunking unnatural appeal text, an embracing unnatural appeal text, or a descriptive norm appeal text. Immediately after reading the article, all participants completed a 5 to 7-minute survey eliciting their reactions to the article, alongside their attitudes and willingness to pay for cell-cultured meat products. - In Wave 3, the endline survey, 10 weeks after Wave 2, participants were contacted via email and asked to complete a survey measuring attitudes and willingness to pay for cell-cultured meat.
Key Findings	- There were persistent negative effects of anti-cell-cultured meat social information over the study period. - Of the three positive appeals, only the embracing unnaturalness appeal effectively offset the undermining effects of anti-cell-cultured meat messaging. - The embracing unnatural appeal increased consumer willingness to pay and interest in cell-cultured meat over the entire study period. - The debunking unnatural and descriptive social norm appeals generated only short-term improvements in consumer attitudes. - The positive effects of embracing unnatural appeal were more pronounced for consumers who were the least interested in cell-cultured meat products at baseline.

	- Exposure to negative reactions about cell-cultured meat from strangers greatly undermined cell-cultured meat acceptance.
Key Limitations	There was a large drop-out rate in the study (although not differential).

Study	Vivalt & Macdonald (2017)
Context	A study exploring the effects of information provision about cell-cultured meat, as well as availability of the product, on beliefs Publication type: Gray literature (open access) Location: U.S. Sample size: Experiment 1: 1,800, Experiment 2: 4,000
Description of Methodology	- Experiment 1 was a two-wave survey with a total of 1,800 participants. A baseline survey measured demographic information and attitudes towards cell-cultured meat, then participants were randomly divided into several treatments. One set of subjects was exposed to information about cell-cultured meat alongside a persuasive message about the health, environmental, or ethical advantages of reducing conventional animal product consumption. Another set was instead told about a new "animal-free" meat substitute with the same qualities, but they were not explicitly told that it was a cell-cultured meat product. Instead, the product was mentioned in the context of vegetarian substitutes. A third set of respondents was provided the same information without mention of a new product. (Since cell-cultured meat products are new and awareness of them is low, respondents would be expected to infer that it was a standard vegetarian product unless explicitly told otherwise.) The three "product" treatment arms (cell-cultured meat, vegetarian substitute, no new product) were crossed with the three "message" treatment arms (health, environmental, ethical) with 200 subjects in each cell, for a total of 1,800 subjects. After being exposed to one of these treatments, participants answered questions about their impressions of the product. They were also asked to estimate their demand and willingness to pay for conventional meat and cell-cultured meat or vegetarian products, and there was a follow-up interview task. - Experiment 2 referred to the product as "clean" meat rather than "cultured" meat (as in Experiment 1), since research by industry groups suggests people have a more favorable response to the product when described using this terminology.
Key Findings	- The authors hypothesized that the mere availability of a cell-cultured meat product would

	lead consumers to put more moral weight on the environment and farmed animals. They did not initially observe this and their results suggest that information about cell-cultured meat may even negatively affect beliefs. - Due to concerns about the "unnaturalness" of the product, many did not find it an acceptable substitute. However, those who perceived the product positively did change their ethical beliefs.
Key Limitations	

Study	Anderson & Bryant (2018)
Context	A study aiming to identify ways of describing cell-cultured meat that could address naturalness concerns and increase acceptance of this new product Publication type: Gray literature (open access) Location: U.S. Sample Size: 1,100
Description of Methodology	- Participants were block-randomized into one of four treatment groups based on gender and diet (two factors found to predict acceptance of cell-cultured meat). All participants answered questions about their familiarity with cell-cultured meat and read a brief passage describing it, to ensure that everyone's familiarity was from a common knowledge base before they received the experimental message. - Participants read one of three messages intended to address naturalness concerns (an argument that cell-cultured meat is natural, an argument challenging the need for naturalness, and an argument that traditional meat is unnatural so cell-cultured meat is better) or a control message about the health, environmental, and ethical benefits of cell-cultured meat. They then answered questions about their acceptance of cell-cultured meat, including questions regarding their willingness to try it, beliefs about it, emotional reaction to it, willingness to pay for it, and more.
Key Findings	- Trying to directly reduce naturalness concerns was ineffective: Two messages tested in this study—one describing the natural side of cell-cultured meat and one attacking the idea that naturalness is important—were not convincing to participants. - Describing conventionally-produced meat as unnatural produced the most acceptance of cell-cultured meat: Potential consumers who read this message were willing to pay more for

	cell-cultured meat than those who didn't. People who read this message also tended to be the most positive about cell-cultured meat in a variety of other ways: in their attitudes, feelings, and beliefs. - This study's messages produced more acceptance of cell-cultured meat than has been observed in many previous studies: 66.4% of people were willing to try it, 45.9% were willing to buy it regularly, and 52.8% were willing to eat it as a replacement for conventional meat.
Key Limitations	- The study did not directly compare the different aspects of messaging to see which ones were the most effective (e.g., by using different wording). - Assuming that the term "clean meat" reduces feelings of disgust compared to other names associated with the product, its effect may overlap with the experimental conditions, which are also intended to reduce disgust. As such, using this term reduced the chance of detecting a difference in acceptance between the control and experimental conditions.

Study	Siegrist et al. (2018)
Context	A study involving two experiments examining the effects of perceived naturalness and disgust on consumer acceptance of cell-cultured meat: The goal of the study was to examine which factors would shape the acceptance of cell-cultured meat and which mediation factors would be important in shaping consumers' willingness to eat cell-cultured meat compared with conventional meat. Publication type: Peer-reviewed journal Location: Switzerland (German-speaking population) Sample size: Experiment 1: 204, Experiment 2: 298
Description of Methodology	- Experiment 1: a sample of 204 persons filled out an online questionnaire. Participants were randomly assigned to one of two treatments, organic meat or cell-cultured meat. Each group was given a short passage to read describing organic meat or cell-cultured meat. They then answered the following two questions related to the meat described in their scenario: "How artificial or natural do you assess ground beef from organic production [that has been produced in the laboratory/(in vitro meat)]?" and "After reading this information, would you consume ground beef from organic production /[that has been produced in the laboratory (in vitro meat)]?" Next, both groups answered the same two questions related to traditional meat production: "How artificial or natural do you assess ground beef from traditional

	production?" and "After reading this information, would you consume ground beef from traditional meat production?" - Experiment 2: 298 participants were randomly assigned to one of three treatments: cell-cultured meat with a technical explanation, cell-cultured meat with a nontechnical explanation, or conventional meat. They were then asked "How artificial or natural do you assess (in vitro ground beef/ground beef produced by cell cultivation/ground beef from conventional production) to be?," "How disgusting do you assess (in vitro ground beef/ground beef produced by cell cultivation/ground beef from conventional production) to be?," and "How high is your willingness to eat (in vitro ground beef/ground beef produced by cell cultivation/ground beef from conventional production)?"
Key Findings	- Perceived unnaturalness of cell-cultured meat was a big barrier to acceptance. Experiment 1 suggests the participants' low level of acceptance of cell-cultured meat is due to their perception of it as unnatural. - Moreover, informing participants about the production of cell-cultured meat and its benefits had the paradoxical effect of increasing the acceptance of traditional meat. The participants who received information about cell-cultured meat perceived traditional meat as more natural and expressed a higher willingness to buy traditional meat compared with the group that was informed about organic meat. If novel food technologies are introduced that are negatively evaluated by consumers, this may result in a more positive evaluation of the existing technologies. Further examination of this effect is needed. - Experiment 2 showed that the way in which cell-cultured meat is described influenced participants' perception. There was a much higher rate of acceptance when participants were given a non-technical description of cell-cultured meat compared to a technical description. Thus, it is important to explain cell-cultured meat in a nontechnical way that emphasizes the final product—not the production method—to increase acceptance of this novel food. - This study's results suggest that the way cell-cultured meat is described may have a profound impact on its acceptance. Labels such as "in vitro meat" or "cultured meat" may be problematic because they emphasize the production process—using concepts with inherent negative connotations—as opposed to the properties of the novel meat. Thus, the results suggest that differences in the production processes of cell-cultured meat and conventional meat should not be highlighted. Instead, the similarities between the two products should be stressed: They both consist of muscle cells from an animal and are identical with regard to smell and taste.
Key Limitations	- The use of convenience sampling may lead to a less representative sample.

	- The study only tested two possible descriptions of cell-cultured meat. There is scope to test other ways of describing cell-cultured meat.

Study	Slade (2018)
Context	An evaluation of the effect of certain sociodemographic factors—such as age and sex—on willingness to purchase cell-cultured meat Publication type: Peer-reviewed journal Location: Canada Sample size: 533
Description of Methodology	- The study consists of a hypothetical choice experiment. Respondents were asked to imagine if they were in a fast-food restaurant and were offered three different types of burgers (beef, plant-based, and cell-cultured) along with the option not to purchase. - The text description read: "There are three types of burger patties: Beef burgers, which are made from cow meat. Plant based burgers, which are made from plant proteins including soy, peas, and wheat. Cell-cultured meat burgers, which are made from cell cultures grown in a laboratory. The initial cells are taken from animals and are then treated with a protein so that they reproduce." The order in which the three types of burgers appeared was randomized.
Key Findings	- 11% of respondents chose cell-cultured meat over traditional and plant-based meat. - If the choice was between a beef and a cell-cultured meat burger, only 17% of respondents would purchase the cell-cultured meat burger. - In a hypothetical choice experiment, if prices were equal, 65% of consumers would buy the beef burger, 21% would buy the plant-based burger, 11% would buy the cell-cultured meat burger, and 4% would make no purchase. - Vegetarians exhibited a stronger preference for plant-based products over cell-cultured meat products. - Frequency of meat purchasing was negatively correlated with preference for plant-based products but had no effect on preference for cell-cultured meat. - Concerns over naturalness were negatively correlated with preference for cell-cultured meat.
Key Limitations	- Framing and questions asked differed from other studies that assessed whether respondents would or would not purchase cell-cultured meat, making it difficult to compare to other studies.

	- The sample was slightly older and more highly educated than the census population.

Study	Gasteratos & Sherman (2018)
Context	A study exploring consumer interest in cell-cultured meat in the countries with the highest per capita consumption of meat: the USA and Australia Publication type: Master's thesis Location: Florida Campus, U.S. whole, Australia Sample size: 5,072
Description of Methodology	- Participants were presented with a definition of cell-cultured meat and asked how likely they were to consume it (using a 5-point Likert scale). Then, they were exposed to one of three experimental conditions where they were taught about either the health, environmental, or ethical benefits of cell-cultured meat. After these interventions, they were again asked how likely they were to consume cell-cultured meat. - 3,219 respondents from Florida Atlantic University answered the survey in return for course credit. For the U.S. sample, 1,538 respondents answered the survey through Amazon Mechanical Turk. For the Australia sample, 314 respondents answered the survey through Prolific Academic.
Key Findings	- Providing information on the possible benefits of cell-cultured meat increased consumers' willingness to try it. - Providing information on health benefits of cell-cultured meat had the greatest effect of attitudinal change, more so than information on environmental or ethical benefits.
Key Limitations	Over half of the respondents were students, so the sample was not representative of the total population.

Study	Szejda (2018)
Context	A study of consumer perceptions of cell-cultured meat under different names Publication type: Gray literature Location: U.S. Sample size 1: 338

	Sample size 2: 1,004
Description of Methodology	- A shortlist of 74 potential names for cell-cultured meat was refined to 5 options ("clean meat," "cell-based meat," "craft meat," "cultured meat," and "slaughter-free meat"), which underwent testing with two survey groups to determine (i) whether they were appealing names and (ii) whether they affected behavioral intentions and likelihood of trying/purchasing a product with that name. - Participants from the first sample were recruited through MTurk. - Participants from the second sample were recruited from the Datassential omnibus survey.
Key Findings	- "Slaughter-free," "craft," "clean," and "cultured" performed best compared to other terms in name appeal. - "Slaughter-free" and "cell-based" performed best compared to other terms in descriptiveness and differentiation. - "Slaughter-free" and "craft" performed best compared to other terms in likelihood of trying and of purchasing the product. - Results from the two samples supported each other.
Key Limitations	No demographic analysis was provided, although this is reportedly coming in the future.

Study	Bryant & Barnett (2019)
Context	A study assessing consumer perceptions of cell-cultured meat under different names Publication type: Peer-reviewed journal Location: International (MTurk) Sample size: 185
Description of Methodology	- Participants were assigned to one of four groups that used the following different names for cell-cultured meat: "cultured meat," "clean meat," "animal free meat," or "lab grown meat." Participants were then given a word association task based on their group. This was followed by the description: "[X] is meat which is grown from cells taken from an animal who is not killed, rather than being taken from a slaughtered animal." where [X] is replaced with the word in their assigned group. They were then issued a survey measuring their attitudes and behavioral intentions towards cell-cultured meat. - The authors used a one-way MANOVA to analyze the attitude/behavior results, with the four naming options set as independent variables, and attitude and behavior set as dependent

	variables.
Key Findings	- Those in the "clean meat," and "animal free meat" groups had significantly more positive attitudes towards cell-cultured meat than those in the "lab grown meat" group. - Those in the "clean meat" group had significantly more positive behavioral intentions towards cell-cultured meat than those in the "lab grown meat" group.
Key Limitations	The location of participants was not recorded, so it is unclear how representative this would be of the U.S. population. The authors note that 75% of MTurk users are reportedly from the U.S.

The experimental studies were all randomized controlled trials with interventions that involved short exposures (i.e., seconds or minutes) to different messages. All trials had a very short follow-up period after the intervention (i.e., only seconds or minutes), with the exception of the Macdonald & Vivalt (2017) and Vivalt & Macdonald (2017) studies, which followed up with respondents months later. The control groups often received information about another sustainable production technology unrelated to cell-cultured meat, such as solar panels.

There were a total of 31,065 participants in the 12 experimental studies. Macdonald & Vivalt (2017), Greig (2017), Vivalt & Macdonald (2017), the Good Food Institute (2016), Gasteratos & Sherman (2018), Szejda (2018) (first sample), and Bryant & Barnett (2019) drew their samples using MTurk. Anderson & Bryant (2018) employed the survey company Ipsos to recruit participants and Szejda (2018) (second sample) used the Datassential omnibus survey. The rest of the studies relied on a convenience sampling method, and in the cases of Verbeke, Sans, & Van Loo (2015) and Bekker et al. (2017), samples were mainly from student populations. The primary outcomes used in most of the studies were attitudinal measures, as in Verbeke, Sans, & Van Loo (2015), Bekker et al. (2017), Macdonald & Vivalt (2017), Siegrist et al. (2018), Siegrist & Sutterlin (2017), Vivalt & Macdonald (2017), Anderson & Bryant (2018), Gasteratos & Sherman (2018), Szejda (2018), and Bryant & Barnett (2019). Anderson & Bryant (2018) and Macdonald & Vivalt (2017) also used willingness to pay as a measure. Slade (2018), Greig (2017), and the Good Food Institute (2016) used reported purchasing preferences in hypothetical choice experiments.

Table 2b: Risk of bias assessments for experimental studies

Study	**Selection Bias**	**Attrition Bias**	**Reporting Bias**	**Other Bias**

Verbeke, Sans, & Van Loo (2015)	?	+	+	+
The Good Food Institute (2016)	?	+	?	?
Bekker et al. (2017)	+	+	+	+
Siegrist & Sütterlin (2017)	+	+	+	?
Greig (2017)	+	+	+	?
Macdonald & Vivalt (2017)	+	+	+	?
Vivalt & Macdonald (2017)	?	+	+	?
Anderson & Bryant (2018)	?	+	+	?
Siegrist et al. (2018)	+	+	+	?
Slade (2018)	+	+	?	+
Gasteratos & Sherman (2018)	?	+	?	?
Szejda (2018)	+	+	+	?
Bryant & Barnett (2019)	+	+	+	?

The risk of bias assessments in each domain for the individual studies we analyzed, along with brief justifications, are available here.

Reporting bias was often difficult to comment on; in most cases, pre-analysis plans for studies were not provided, so it was difficult to determine whether all the measured outcomes were reported. Also, attrition bias was often not relevant due to the short follow-up times in the studies.

Key findings from experimental studies

Factors increasing acceptance

Slade (2018) found that in a hypothetical choice experiment between different types of burgers, if prices were equal, 65% of consumers would buy the beef burger, 21% would buy the plant-based burger, 11% would buy the cell-cultured meat burger, and 4% would make no purchase. There was no correlation between participants' frequency of meat purchasing and their preference for cell-cultured meat. However, one model found a negative correlation between meat purchase frequency and preference for plant-based products. This may suggest that cell-cultured meat is more preferable than plant-based meat among meat eaters.

Providing information about the benefits of cell-cultured meat seemed to be effective. In Verbeke, Sans, & Van Loo (2015), after the intervention involving providing information about cell-cultured meat's benefits, the number of respondents who said they were willing to try cell-cultured meat increased from about 25% to 43%, and the number of those who were hesitant changed from two-thirds to 51%. Bekker et al. (2017) found that providing positive information about cell-cultured meat's sustainability and information about a positively perceived sustainable product (in this case solar panels) positively influenced explicit attitudes towards cell-cultured meat. Moreover, the Gasteratos & Sherman (2018) experiment demonstrated that presenting information on the possible benefits of cell-cultured meat increased consumers' willingness to try it. Providing information on the health benefits of cell-cultured meat had the greatest effect of attitudinal change, more so than information on environmental or ethical benefits. Therefore, information provision may shape levels of acceptance, although Bekker et al. (2017) observed that the effect of information provision on explicit attitude change was less pronounced with people who were more initially familiar with cell-cultured meat. Likewise, van der Heide (2016) reported that while claims about cell-cultured meat may change some of consumers' expectations, a consumer's prior attitude towards novel food products may still be too strong for an external claim to overcome.

In addition, Siegrist et al. (2018) observed that the way in which cell-cultured meat was described influenced participants' perception: There was a much higher rate of acceptance when participants were

given a non-technical description[20] of cell-cultured meat compared to a technical description[21] (because of increased perceived naturalness). Thus, it may be beneficial to explain cell-cultured meat in a non-technical way that emphasizes the final product—as opposed to the production method—to increase acceptance of this novel food.

The perception of whether cell-cultured meat is natural seems to be an important factor for its acceptance. Macdonald & Vivalt (2017) found that "embracing" the unnaturalness of cell-cultured meat by pointing to the unnaturalness of conventional food was more effective than attempting to debunk the unnatural qualities of cell-cultured meat. A similar result was identified in Anderson & Bryant (2018), who found that trying to directly reduce naturalness concerns was ineffective. Describing conventionally-produced meat as unnatural produced the most acceptance of cell-cultured meat; potential consumers who read this message were willing to pay more for cell-cultured meat than those who did not. People who read this message also tended to be the most positive about cell-cultured meat in a variety of other ways: in their attitudes, feelings, and beliefs.

Moreover, nomenclature is a factor that could affect consumer acceptance quite substantially. Greig (2017) reported that the term "clean meat" resulted in much greater acceptance levels than the term "cultured meat." In the Good Food Institute (2016) sample, respondents were significantly more willing to purchase and eat meat grown in a laboratory if it were labeled "safe meat" or "clean meat" rather than "cultured meat," "pure meat," or "meat 2.0". Szejda (2018) reported that "slaughter-free," "craft," "clean," and "cultured" performed best compared to other terms in "name appeal," while "slaughter-free" and "craft" performed best compared to other terms in "likelihood of trying and of purchasing the product." Bryant & Barnett (2019) found that those in the "clean meat" and "animal free meat" groups had significantly more positive attitude towards cell-cultured meat than those in the "lab grown meat"

[20] Siegrist et al. (2018) provided the following non-technical description: "Red meat such as ground beef is produced by tissue cultivation. In doing so, cells are obtained from the muscle tissue of cows. These cells are artificially grown and develop into muscle cells. This production method is more environment-friendly and associated with less animal suffering compared with conventional meat production. Consumption of ground beef produced by tissue cultivation is comparable with consumption of ground beef from conventional meat production, also with regard to taste."

[21] Siegrist et al. (2018) provided the following technical description: "In vitro meat is produced by means of biotechnology. In doing so, red meat such as ground beef is produced in the laboratory. Cells are obtained from the muscle tissue of cows. By utilizing biotechnology, these cells are artificially grown and develop into muscle cells. This production method is more environment-friendly and associated with less animal suffering compared with conventional meat production. Consumption of in vitro ground beef is comparable with consumption of ground beef from conventional meat production, also with regard to taste."

group, and that those in the “clean meat” group had significantly more positive behavioral intentions towards the product than those in the “lab grown meat” group.

Barriers to acceptance

Price and sensory quality were brought up in Verbeke, Sans, & Van Loo (2015) as a major barrier to acceptance. Unnaturalness was also a key concern. Siegrist & Sutterlin (2017) indicated that the perceived naturalness of the meat affected participants' evaluation of the acceptability of the risk of colon cancer associated with meat consumption. Even if the new production method (i.e., cell-cultured meat) was more environmentally friendly and less harmful to animals, the perceived lack of naturalness might reduce the acceptability of the risk associated with such a product.

Macdonald & Vivalt (2017) found that exposure to negative reactions about cell-cultured meat from strangers greatly undermined cell-cultured meat acceptance, demonstrating that social effects can be quite pronounced. Note that this is in an experimental setting and it is unclear how well the results will translate to real social settings. Similarly, Slade (2018) found that there was a positive correlation between the hypothetical market share of cell-cultured meat products and preference for them. This may be due to social pressure or a higher perception of quality that the increase in market share may bring.

According to Siegrist et al. (2018), informing participants about the production of cell-cultured meat and its benefits may have the paradoxical effect of increasing the acceptance of traditional meat. The participants who received information about the production of cell-cultured meat perceived traditional meat as more natural and expressed a higher willingness to buy traditional meat compared with the group that was informed about organic meat. However, as there was no control, it is impossible to determine whether the difference was due to the cell-cultured meat information increasing acceptance of traditional meat or the organic meat information decreasing the demand for conventional meat.

Systematic reviews

We reviewed three systematic reviews. (See Table 3.)

Table 3: Key features of the systematic reviews included in this review

Study	Hartmann & Siegrist (2017)
Context	- A systematic review of peer-reviewed articles - Includes only quantitative studies - 38 articles analyzed

Question Wording/Framing	Framing questions: - "Are consumers aware that meat consumption has a large environmental impact?" - "Are consumers willing to reduce meat consumption or substitute meat with an alternative?" - "Are consumers willing to accept meat substitutes and alternative proteins, such as insects or cell-cultured meat?"
Key Findings	- Consumer awareness of the environmental impact of meat production is low, as is willingness to change meat consumption behavior through reduction or substitution with alternatives such as cell-cultured meat. - More experimental studies are needed to explore how consumers can be motivated to change their meat consumption, particularly through nudging interventions.
Key Limitations	The review only includes quantitative studies and omits insights from qualitative studies.

Study	Román et al. (2017)
Context	- A systematic review of peer-reviewed articles - Includes both quantitative and mixed-method approach studies - 72 articles from 32 countries covering 85,348 consumers analyzed
Question Wording/Framing	Framing questions: - "How has the perceived importance of naturalness for consumers been defined and measured?" - "To what extent is perceived naturalness important to consumers?" - "Are there individual differences regarding the importance given to food naturalness that can be explained by consumers' characteristics?" - "Do consumers' attitudes toward food naturalness influence their intentions and behavior?"
Key Findings	Perceived food naturalness is a crucial factor for consumers.
Key Limitations	

Study	Bryant & Barnett (2018)
Context	- A systematic review of peer-reviewed articles - Includes both quantitative and qualitative studies - 14 empirical studies analyzed
Question Wording/Framing	Framing question: "What is known about consumer acceptance of cell-cultured meat?"
Key Findings	- The framing of studies is very important for affecting results. - Common objections to cell-cultured meat include personal concerns (such as unnaturalness, safety, anticipated taste/texture/appearance, and anticipated price), societal concerns, doubts, and uncertainty (such as concerns for feasibility, ethical status, and regulation/control).
Key Limitations	- The review does not analyze some polls such as YouGov or gray literature published by companies/research groups. - The articles are Europe and North-America-centric.

While Roman et al. (2017) explored novel food technologies more generally and Hartmann & Siegrist (2017) explored attitudes towards sustainable protein consumption, Bryant & Barnett (2018) specifically examined levels of consumer acceptance of cell-cultured meat. The reviews included peer-reviewed articles in their analyses. Hartmann & Siegrist (2017) included only studies using quantitative methods while Bryant & Barnett (2018) actively sought to include both quantitative and qualitative studies.

Bryant & Barnett (2018) omitted polls and research published by research groups from their analysis, which would have added to the review, though it also may have increased the risk of including poor quality or biased data. It is also important to note that one of the authors, Chris Bryant, works at the Cellular Agriculture Society, which is not disclosed in the article and introduces a possible risk of bias. All three of the reviews followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist and thus were considered to be of high quality.

Key findings for systematic reviews

Both Hartmann & Siegrist (2017) and Roman et al. (2017) looked at wider meat consumption and novel food technologies instead of focusing exclusively on cell-cultured meat, so they drew more general conclusions. Hartmann & Siegrist (2017) reported that knowledge of the environmental impact of meat

production was low among European consumers. Consumers' willingness to change dietary patterns by reducing meat consumption and eating meat substitutes, such as cell-cultured meat, was similarly low. The authors call for more experimental research such as nudging interventions to explore behavior change. Roman et al. (2017) observed that food naturalness was very important for most consumers across spatially and temporally variable studies. They also found that consumers measured naturalness by taking into account three factors: the way the food was grown, the way it was produced, and the attributes of the food product at the end of the supply chain/at the point of consumption.

Bryant & Barnett (2018) focuses specifically on cell-cultured meat and reported that safety concerns, taste, and price were the primary barriers to cell-cultured meat acceptance. They recommend that promoters of cell-cultured meat focus on addressing safety concerns, as taste and price can more easily be resolved through consumer experience.

Synthesis of results

Representativeness of samples was better achieved by the experimental studies than by the cross-sectional surveys as they tended to have much larger samples, although some of the cross-sectional surveys were census-balanced.

Consumer acceptance levels

There was quite a lot of variation in consumer acceptance levels of cell-cultured meat overall. Generally, studies tended to use two types of questions to gauge consumer acceptance levels—willingness to try cell-cultured meat, and willingness to buy cell-cultured meat (see the appendix for a more detailed breakdown of the specific questions asked). As may be expected, willingness to try cell-cultured meat typically scored more highly, ranging from 19% in YouGov (2012) to 66.4% in Anderson & Bryant (2018), whereas willingness to buy ranged from 16% in Harris Interactive (2016) to 45.9% in Anderson & Bryant (2018). There is some evidence across studies that providing information about cell-cultured meat will increase rates of acceptance, as the lowest scoring acceptance levels for both willingness to try and willingness to buy provided no contextual information prior to asking the question, whereas all other studies provided basic information about the definition and production methods of cell-cultured meat. This is supported by Verbeke, Sans, & Van Loo (2015), in which the authors observed an increase in willingness to try from 23.9% to 42.5% and an increase in willingness to buy from 19.4% to 36.3% when the positive features of cell-cultured meat were described in addition to basic information. Given that cell-cultured meat has yet to reach the market, it seems likely that willingness to try is currently the most useful measure of initial consumer acceptance, whereas willingness to buy will likely be affected by how

much future products live up to consumer expectations. It is encouraging, though, that willingness to buy levels are not substantially lower than willingness to try.

One notable alternative method for capturing consumer acceptance levels was via choice. This was used in Hocquette et al. (2015) in which consuming cell-cultured meat was one preference option among others including eating less meat and making no change, with 5%–9% of respondents selecting the cell-cultured meat option across their survey groups. A similar approach was taken in Slade (2018), which used a hypothetical choice experiment in order to determine that 11% of their sample would choose a cell-cultured meat burger when given the choice between beef, plant-based, cell-cultured, or no purchase.

Barriers to acceptance

For the most part, the results from both the cross-sectional surveys and experimental studies emphasized that perceived unnaturalness is a significant barrier to cell-cultured meat acceptance. This was acknowledged in Wilks & Phillips (2017) and Harris Interactive (2016), and further stressed in Siegrist & Sutterlin (2017). The proliferation of experimental studies on information interventions that address unnaturalness concerns—such as Macdonald & Vivalt (2017) and Anderson & Bryant (2018)—indicate that this presents a major obstacle to behavior change. This naturalness concern does not exclusively apply to cell-cultured meat; in their systematic review, Roman et al. (2017) state that this is a concern for all novel foods. One counterpoint to naturalness concerns was Wilks et al. (2019), which found that more general naturalness concerns (i.e. not specific to cell-cultured meat) were not a factor affecting cell-cultured meat acceptance in their sample. More research may be needed to determine the difference between specific naturalness concerns about cell-cultured meat versus more general traits of naturalness concern in individuals.

Other factors affecting consumer acceptance that surfaced both in the cross-sectional surveys and experimental studies were price, as in Verbeke, Sans, & Van Loo (2015), and sensory quality, as in Hocquette et al. (2015) Verbeke, Sans, & Van Loo (2015); Wilks & Phillips (2017).

Demographic trends

We can observe some demographic trends in acceptance levels across the studies. In Wilks & Phillips' (2017) sample, men were more likely to be willing to try cell-cultured meat than women, as was echoed in YouGov (2012) and Harris Interactive (2016), and politically liberal participants were more likely to try cell-cultured meat than were conservative ones. YouGov (2012) found that older participants were less likely to eat cell-cultured meat than younger ones. In addition, Verbeke, Sans, & Van Loo (2015) found that vegetarians were less convinced than meat eaters of cell-cultured meat's potential health benefits.

We did not conduct any additional analyses such as sensitivity, subgroup analyses, or meta-regression because the results were not suitable for this.

We did not find significantly different results from the Bryant & Barnett (2018) systematic review. The results were similar (as expected, because we reviewed similar studies), in terms of finding that aesthetic concerns (taste and texture), price, and safety/unnaturalness objections were the most dominant barriers to acceptance. However, there were some new insights from more newly published studies that added to our conclusions. In their review, they identified the need to build on how different names affected cell-cultured meat acceptance because this did not come through as much in their search of the literature. We synthesized results from more recent articles on this, such as Greig (2017), Szejda (2018), and Bryant & Barnett (2019). Bryant & Barnett (2018) also identified the need for research that looked at how different descriptions of cell-cultured meat products shaped acceptance. Our review covered this to a greater extent, such as in the recently published Anderson & Bryant (2018) and Macdonald & Vivalt (2017). Bryant & Barnett (2018) highlighted the lack of studies that compared the effectiveness of communicating different types of benefits to consumers. We found results on this, such as in Anderson & Bryant (2018). Therefore, while our conclusions were not significantly different from Bryant & Barnett (2018), we were able to further explore the relationships between certain factors and acceptance due to insights from recent studies.

Discussion

Research suggests that initial consumer acceptance levels of cell-cultured products remains low, seemingly due to the objections of perceived unnaturalness, anticipated high price, and concerns about taste appeal. This section links these concerns to wider issues—including the adoption of other novel technologies and the perception of conventional meat—and outlines some recommendations from the literature for increasing acceptance levels.

Overall, low levels of education about cell-cultured meat may partially explain poor acceptance levels, such as the 19% willingness to try amongst the YouGov (2012) sample in which no explanation of cell-cultured meat was provided to participants. (However, without a control group in the study, we can't be certain of this.) Low levels of knowledge about cell-cultured meat may not necessarily be harmful to future levels of acceptance, as prior beliefs are difficult to change. Bekker et al.'s (2017) study on explicit versus implicit attitudes found that the effect of information provision about cell-cultured meat on explicit attitude change was less pronounced with people who were initially more familiar with cell-cultured meat. In addition, wider public awareness of cell-cultured meat may result in increased negative perceptions of

such products, as was found in the case of genetically modified (GM) foods in Sentience Institute's (2018) report on novel food technologies.

It would be useful to consider whether the adoption of other novel food technologies or sustainable technologies can affect consumer acceptance of cell-cultured meat. Indeed, Bekker et al. (2017) found that providing positive information about cell-cultured meat's sustainability, as well as information about a well-received sustainable product (in this case solar panels), can positively influence explicit attitudes towards cell-cultured meat. Drawing upon the case of GM food adoption, Sentience Institute (2018) suggests that other novel food technologies should promote themselves by focusing on their positive aspects rather than addressing negative perceptions. This was also indicated in Macdonald & Vivalt (2017), who observed that out of all their treatment arms, the "debunking unnaturalness" information intervention was one of the least effective messaging strategies for cell-cultured meat acceptance. Sentience Institute (2017)—a report on what we can learn from nuclear power about cell-cultured meat adoption—stated that technical explanations about a novel product's safety are unlikely to succeed. Siegrist et al. (2018) echoed this in their experimental study, where they found that participants who were given a non-technical description of cell-cultured meat had a much higher level of acceptance compared to those who received a technical description. Moreover, an oral explanation of the benefits of cell-cultured meat may be more effective than a written one; Hocquette et al. (2015) observed that more respondents believed that cell-cultured meat could be healthy and tasty in the paper survey than in the internet surveys. This is perhaps due to the oral presentation before the paper survey being clearer and more convincing.

We can also observe a complex interaction between consumer acceptance of new technologies within conventional meat production and cell-cultured meat acceptance. By describing the technology of conventional meat production as unnatural, acceptance of cell-cultured meat may increase; Anderson & Bryant (2018) reported that describing conventionally-produced meat as unnatural produced the most acceptance of cell-cultured meat. Therefore, Siegrist et al. (2018) argue that the similarities in the production processes of cell-cultured meat and conventional meat should be highlighted. Conversely, informing customers about the production and benefits of cell-cultured meat may have an adverse impact: It could increase the acceptance of traditional meat. Siegrist et al. (2018) found that the participants who received information about cell-cultured meat perceived traditional meat as more natural and expressed a higher willingness to buy traditional meat compared with the group that was informed about organic meat. This may indicate that if novel food technologies are negatively perceived, it could lead to a more positive view of the existing meat production. However, as mentioned, this would need to be confirmed against a control group. Additionally, Hartmann & Siegrist (2017) report that knowledge of the harmful

environmental impact of meat production is low amongst European consumers, so if more awareness was raised about this, this could positively affect cell-cultured meat acceptance.

Limitations and future research

In addition to the risks of bias outlined in the results section, there are further limitations to the studies. One limitation across the studies is the possibility of publication bias, where certain studies may not have been published if their outcomes did not support an existing hypothesis. There may be a heightened risk of publication bias due to the fact that many studies were conducted and funded by animal advocacy organizations or other groups invested in cell-cultured meat. We did not attempt to measure publication bias as we did not have access to the results and studies that journals and research organizations did not publish. One way to reduce publication bias is to monitor whether studies with similar experimental designs produced similar results, which would make it less likely that our review is subject to a high level of publication bias.

A majority of the studies in this review, with the exception of Hocquette et al. (2015), had samples that reflected the population structure of the country they were investigating. In some cases, the samples were also census-balanced, such as in Sentience Institute (2017), Anderson & Bryant (2018), and Slade (2018). The samples in these studies are likely to be overall representative of the general population and their attitudes towards cell-cultured meat.

The manner in which the choice experiments were performed may differ from real-life choices around cell-cultured meat purchases. The experimental studies were carried out in controlled environments and relied on reported preferences: There could be meaningful differences between these findings and consumers' revealed preferences. A potential study that would overcome the reliance on self-reported data would track participants' spending, for instance by tracking supermarket expenditure or using food diaries. This is not currently feasible with cell-cultured meat, though there is some existing research that has sought to address the question.[22]

There are also potentially significant differences in the way the studies framed each question, which may have shaped the results. Different questions were posed across studies, making the results incomparable: Some studies such as YouGov (2012) surveyed consumers' willingness to try cell-cultured meat, some such as Sentience Institute (2017) asked participants to agree or disagree with the statement that they should consume more cell-cultured meat and fewer conventional animal products, and others such as Hocquette et al. (2015) investigated consumers' willingness to replace conventional meat with

[22] See, for example, Chang, Lusk, & Norwood (2009).

cell-cultured meat in their diets. (See the appendix for a more detailed breakdown of the specific questions asked.)

There are several important outcomes not measured across the studies. Firstly, with the exception of Hocquette et al. (2015), the studies did not investigate consumers' perceptions of the feasibility of cell-cultured meat, which may affect their estimation of their willingness to try the product. Secondly, they did not measure participants' support for other actions that benefit animals, which could be linked to willingness to consume cell-cultured meat. Moreover, as mentioned above, the studies did not measure actual behavior, but rather reported preferences. They also did not measure reported preferences after substantial media coverage related to cell-cultured meat, which has yet to occur and which could significantly impact those preferences. Finally, if cell-cultured meat fails to become cost-competitive, consumers' willingness to purchase it over animal products should be measured.

There is also scope to observe how a greater variety of factors—which are insufficiently covered in this review—might affect acceptance. The unpublished study by Noah Castelo (forthcoming) offers the most diversity in mediating factors of acceptance. The study examines the possible mediating factors of age; gender; frequency of eating conventional meat; trust in institutions; political party affiliation; social, economic, and general conservatism; frequency of religious practice; income; and urban/rural residence. Relatedly, the focus of this report on quantitative over qualitative studies may also have restricted the scope of factors that influence acceptance.

Moreover, focusing on consumer acceptance—which has been the focus of this review—is not sufficient, and institutional reform must also be examined. Stephens et al. (2018) argue that analyses of the future of cell-cultured meat are too often reduced to discussions of ethics and consumer acceptance, and do not sufficiently pay attention to the need for political and institutional reform in the context of a wider regulatory system. Sentience Institute (2017) echoes this by pointing out the important role that "institutional choices by governments, industries, and news media" will play in making cell-cultured meat widely available.

Conclusion

Acceptance levels measured by willingness to try cell-cultured meat varied between 19% and 66.4% across studies, while acceptance levels measured as willingness to buy cell-cultured meat regularly or replace conventional meat with it entirely was typically lower. Cell-cultured meat has not yet reached the market, and the public currently seems to be generally unfamiliar with it. As such, it is not exactly clear

how degrees of willingness to try should be interpreted at this stage, though further research into acceptance of comparable technologies may provide valuable insight. Experimental studies reveal that attitudes may be positively affected by information interventions on the benefits of cell-cultured meat, although the wording and framing of such information are likely to be important and require further research.

Further research is also needed on the effects of social information on cell-cultured meat attitudes, as explored by Macdonald & Vivalt (2017). Moreover, there is much scope to explore cell-cultured meat acceptance in different cultural contexts, especially outside of the U.S. and the U.K. Hocquette et al. (2015), Bekker et al. (2017), and most notably Bryant & Barnett (2019) have provided some valuable insights on international views, but the majority of the research is currently U.S.-focused. Future research would also benefit from moving away from self-reported data. While this is currently not feasible, it may become more practical if cell-cultured meat becomes more widely available in the future.

Resources

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Questions for further consideration

There are many questions—some of which are listed below—that could lead us to significantly update our views.

- How readily available will cell-cultured meat be in the future?
- How educated will consumers be about cell-cultured meat?
- What are consumer acceptance levels of cell-cultured meat in lower- and middle-income countries?

- What do acceptance levels of other related novel technologies tell us about the likely acceptance levels of cell-cultured products?
- What messages or interventions will most improve low levels of consumer acceptance?
- Is there some other nomenclature that would lead to greater acceptance levels of cell-cultured meat?
- What form are cell-cultured meat products likely to be offered in?

Appendix

The search terms used and the number of pages searched are listed below:

- "Cultured meat consumers" (Google Scholar 10 pages, ACE RL 5 pages)
- "Cultured meat acceptance" (Google Scholar 15 pages, ACE RL 5 pages)
- "Cultured meat attitudes" (Google Scholar 10 pages, ACE RL 2 pages)
- "Clean meat consumers" (Google Scholar 5 pages, ACE RL 1 page)
- "Clean meat acceptance" (Google Scholar 5 pages, ACE RL 1 page)
- "Clean meat attitudes" (Google Scholar 5 pages, ACE RL 1 page)
- "In-vitro meat consumers" (Google Scholar 5 pages, ACE RL 2 pages)
- "In-vitro meat acceptance" (Google Scholar 5 pages, ACE RL 1 page)
- "In-vitro meat attitudes" (Google Scholar 5 pages, ACE RL 1 page)
- "Cultured meat acceptance filetype:pdf" (Google 5 pages)
- "Clean meat acceptance filetype:pdf" (Google 5 pages)
- "In-vitro meat acceptance filetype:pdf" (Google 5 pages)

Table 4a: Questions related to willingness to try *cell-cultured meat asked by studies / surveys in the review*[23]

Study	**Positive Intention**	**Question**	**Response Options**	**Background Information Provided**
YouGov (2012); cross-sectional survey	19%	"Scientists are currently developing artificial meat that can be grown in a laboratory. Imagine artificial meat was available commercially, do you think you would	i) "Yes, I would probably eat it" ii) "No, I would probably not eat it" iii) "Don't know"	None

[23] These entries are ordered by positive intention. This table is not comprehensive: It covers studies that either provided percentage-based results for willingness to try or had raw data available for analysis.

		eat it?"		
Verbeke, Sans, & Van Loo (2015); experimental study	23.9%	Willing to try (exact question unknown)	i) "Not" ii) "Maybe" iii) "Surely"	Basic information
Bryant et al. (2019); cross-sectional survey	33% (U.S.; "Very/Extremely likely")	"Imagine that clean meat has become widely available at grocery stores, restaurants, butchers, and markets. How likely are you to try clean meat?"	i) "Not at all likely" ii) "Somewhat likely" iii) "Moderately likely" iv) "Very Likely" v) "Extremely Likely"	Basic information + some positive features
Verbeke, Sans, & Van Loo (2015); experimental study	42.5%	Willing to try (exact question unknown)	i) "Not" ii) "Maybe" iii) "Surely"	Additional positive information provided (focused on environment and disease)
Wilks et al. (2019); cross-sectional survey	51%	"Would you be willing to try cultured meat?"	i) "No, definitely not" ii) iii) iv) v) "Yes, definitely"	Basic information
Wilks & Phillips (2017); cross-sectional survey	65%	"For the following questions, please imagine that in vitro meat is commercially available in supermarkets and butchers [...] Would you be willing to try in vitro meat?"	i) "Yes, definitely" ii) "Yes, maybe" iii) "Unsure" iv) "No, probably not" v) "No, definitely not"	Basic information
Anderson & Bryant (2018);	66.4%	"Would you be willing to try clean meat?"	i) "Definitely yes" ii) "Probably yes"	Basic information

experimental study			iii) “I am unsure” iv) “Probably no” v) “Definitely no”	

Table 4b: Questions related to willingness to buy *cell-cultured meat asked by studies/surveys in the review*[24]

Study	**Positive Intention**	**Question**	**Response Options**	**Background Info Provided?**
Harris Interactive (2016); cross-sectional survey	16%	“Would you ever buy ‘cultured meat’ grown in a laboratory?”	i) “Yes, would buy” ii) “No, would not buy” iii) “Not sure”	No other information provided to respondents.
Verbeke, Sans, & Van Loo (2015); experimental study	19.4%	Willing to buy (exact question unknown)	i) “Not” ii) “Maybe” iii) “Surely”	Basic information
Bryant et al. (2019); cross-sectional survey	- 29.8% (U.S.) - 48.7% (India) - 59.3% (China)	“Imagine that you have had the opportunity to try clean meat, and you found the taste and texture very similar to conventional meat. How likely are you to [...] purchase clean meat regularly?”	i) “Not at all likely” ii) “Somewhat likely” iii) “Moderately likely” iv) “Very Likely” v) “Extremely Likely”	Basic information + some positive features
Wilks et al. (2019); cross-sectional survey	32%	“Would you be willing to eat cultured meat regularly?”	i) “No, definitely not” ii) iii) iv) v) “Yes, definitely”	Basic information

[24] These entries are ordered by positive intention. This table is not comprehensive: It covers studies that either provided percentage-based results for willingness to buy or had raw data available for analysis.

Wilks & Phillips (2017); cross-sectional survey	33%	"For the following questions, please imagine that in vitro meat is commercially available in supermarkets and butchers [...] Would you be willing to eat in vitro meat regularly?"	i)" Yes, definitely" ii) "Yes, maybe" iii) "Unsure" iv) "No, probably not" v) "No, definitely not"	Basic information
Verbeke, Sans, & Van Loo (2015); experimental study	36.3%	Willing to buy (exact question unknown)	i) "Not" ii) "Maybe" iii) "Surely"	Additional positive information provided (focused on environment and disease)
Anderson & Bryant (2018); experimental study	45.9%	"Would you be willing to buy clean meat regularly?"	i) "Definitely yes" ii) "Probably yes" iii) "I am unsure" iv) "Probably no" v) "Definitely no"	Basic information

Table 4c: Other questions related to consumer acceptance of cell-cultured meat asked by studies/surveys in the review[25]

Study	**Positive Intention**	**Question**	**Response Options**	**Background Information Provided**
Hocquette et al. (2015); cross-sectional survey	5%–9%	"Would you prefer yourselves as an individual: [...]"	i) "Eat no meat" ii) "Eat less meat" iii) "Eat in vitro meat" iv) "Change nothing in meat consumption"	All respondents provided with information about cell-cultured meat either through a presentation or text
Sentience Institute (2017); cross-sectional	56%	"[...] I would prefer to eat more of these [cell-cultured] foods and fewer animal foods."	i) "Strongly agree" ii) "Agree" iii) "Somewhat agree"	No other information provided to respondents

[25] These entries are ordered by positive intention. This table is not comprehensive: It covers studies that either provided percentage-based results for other relevant questions or had raw data available for analysis.

survey			iv) “No opinion” v) “Somewhat Disagree” vi) “Disagree” vii) “Strongly Disagree”	
Anderson & Bryant (2018); experimental study	52.8%	“Would you be willing to eat clean meat as a replacement for conventionally-produced meat?”	i) “Definitely yes” ii) “Probably yes” iii) “I am unsure” iv) “Probably no” v) “Definitely no”	Basic information