Note: This is a rough “internal notes” document, which we’re making public in case it’s useful for people. Megan and I (Ben) **don’t necessarily have a high degree of confidence in any particular claim made in this document**, and we don’t guarantee internal consistency or that what’s written here reflects our current beliefs.

Clean Meat

Author: Megan Kinniment

Timeline of Development

Year	Events	Importance	Source
1932	Winston churchill says that in the future we will grow parts of the animal to eat rather than the whole thing	Shows that the basic idea had been floating about quite early on	Timeline of cellular agriculture
1950s	Willem Van Eelen comes up with idea of using cell lines to manufacture meat. (not sure if he published something or not?) He then goes on to tell lots of people about it (both scientists and investors). It also seems like he started doing on and off practical work from around the 50s: “After the war, now living in		Timeline of cellular agriculture Quartz article on willem van eelen and history of cultured meat

	Amsterdam, Van Eelen pursued a medical degree, during which he saw, as part of his education, an actual muscle gain mass outside the body. Since meat is primarily just muscle, why, he figured, couldn't we produce food that way? And so even while he practiced as a medical doctor, he spent decades tinkering, never working full-time on the project, trying to make muscle grow in vitro."		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World
1960	Hydrogel development (a scaffold to encourage tissue growth) Was originally used for other biomedical uses - not sure how relevant it was to tissue engineering at this time	Tissue engineering advance?	Tissue engineering wiki
1970	Jacop Shapira writes "Physicochemical methods for the synthesis of potential foods", talking in broad strokes about synthesising food including mentions of in-vitro. NASA wanted a protein source that could be grown by the astronauts to support long term space exploration.	Well funded gov organisation potentially interested in creating in-vitro food. Probably the goal was only to get a decent protein source for nutrition purposes	NASA page on generating food
1971	First muscle fibers cultivated in a guinea pig - unclear if was done with any awareness of potential cell culture meat applications not created with purpose to advancing cultured meat as far as i'm aware, maybe potentially for tissue engineering in general		Timeline of cellular agriculture
1977	"[WT green] correctly concluded that with the advent of innovative biocompatible materials it would be possible to generate new tissue by seeding viable cells onto appropriately configured scaffolds " (this was published in 1977 but work was done in the early 1970s)	Tissue engineering (neighbouring field) progress - doesn't seem like it was necessarily a big deal at the time	History of tissue engineering 2006 paper
1984	Tissue engineering - bioprinting	Tissue engineering advance	Tissue engineering

			wiki
1988	“Possibly the key point in the birth of [tissue engineering] was in the mid-1980’s when Dr. Joseph Vacanti of the Children’s Hospital approached Dr. Robert Langer of MIT with an idea to prospectively design appropriate scaffoldings for cell delivery “	Tissue engineering progress - these two met in the mid 1980s but their first published article was a keynote presentation given in 1988	History of tissue engineering 2006 paper
1991	Jon F Vein files (and later secures) patent for tissue engineered meat for human consumption [it’s not clear to me where he got this idea from]		Cultured meat wiki
1993	Highly cited tissue engineering paper: (might be highly cited in retrospect as opposed to at the time but seems to have been very impactful to me)		History of tissue engineering 2006 paper
1995 ish	NASA funds research for cultured meat on long haul space flights	Well funded effort to produce cultured meat	History of cultured meat - social studies of science paper
1995	US FDA approves use of commercial in vitro meat production		History of cultured meat - social studies of science paper
1996	Tissue engineering event Pittsburgh tissue engineering initiative founded Generally in the 90’s tissue engineering efforts were being established in multiple countries (US, UK , Germany, France,Japan,China) and also by the late 90s some private efforts in tissue engineering		PTEI founded in 1996 History of tissue engineering 2006 papert
1997	Tissue engineering event - cartilage grown in an ear shaped mould on a mouse to create an “ear mouse” , lots of public awareness about tissue engineering - brought into realm of possibility - also caused a fair bit of backlash - some news	Tissue engineering in public eye	Classic mouse experiment History of tissue engineering 2006 papert

	outlets falsely stated it was genetically engineered		
1998	Human stem cells isolated	“By 1998, embryonic stem cells were first isolated by American biologist James Thomson, which made it possible to have new transplantation methods or various cell types for testing new treatments.”	Tissue engineering wiki Stem cell wiki
1999	Willem van eelen secures patent for cultured meat (wikipedia says its the first but im not so sure) Tissue engineering - lab grown internal organ transplanted NASA contract for touro to produce fish fillets started		Timeline of cellular agriculture Tissue engineering wiki Growing Meat Without Animals Will Revolutionize Dinner and the World
2001	Wiete Westerhof, Willem van Eelen and Willem van Kooten file patent for process to produce cultured meat NASA conducts cultured meat experiments for applications in long term space exploration (gold fish and turkey cells) Around this time Jason Matheny starts working with 3 NASA scientists researching cultured meat		History of cultured meat - social studies of science paper
2002	NSR/Touro Applied BioScience Research Consortium turns some goldsigh cells into edible fish fillets (funded by NASA project) - **NASA Contract NAS 9-99011** Matheny gets in contact with scientists and starts talking to them about feasibility of cultured meat		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World

2003	Oron Catts and Ionat Zurr of the Tissue Culture and Art Project and Harvard Medical School produce an edible steak from frog stem cells “The first cultured muscle cells meat eaten was instead produced by artists. In 2003, Oron Catts and Ionat Zurr (2008, 2013) served in vitro frog ‘steaks’, produced at a cost of approximately US$650/g, at the exhibition L’Art Biotech in Nantes. “ Peter Verstrate of Sara lee foods R&D dept gets hit up by one of Willem van Eelen’s unscheduled investment pitches. Verstate wanted Sara Lee to start funding it , Creation of first bioprinter, bioprinting becomes more widespread		Timeline of cellular agriculture History of cultured meat - social studies of science paper Tissue engineering wiki
2004	Jason Matheny founds not for profit New Harvest aiming to encourage development in the field by funding public research Matheny tries a bunch of countries, including US with no luck. Matheny also manages to convince the dutch government to subsidise cultured meat (2 million euros in subsidies) after being invited to present at 2004 government PROFETAS (Protein Foods , Environment , Technology , and Society) conference after emailing them asking why not consider in-vitro meat? (Matheny was familiar with van eelen’s work but he never replied) PROFETAS was interested (apparently in part because they		Timeline of cellular agriculture The future of meat without animals book Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World

	were aware of WIllem van Eelen's work).[1],[2] After some convincing by peter Verstate, sara lee foods agrees to become a corporate partner to the dutch govt funded experiment (same one matheny helped convince to fund) Mark Post was part of the first research group made using the netherlands subsidies When Mark Post joined the crew apparently all the other scientists (in Maastritch uni) at least only did cultured meat research as a part time thing. He was the first? To make it his front line project. Matheny then sets about "fixing" the lack of academic literature on cell grown meat, invites a bunch of tissue engineering scientists to get together a rough road map It seems like there had already been enough progress on tissue engineering (for medical use in things like transplants where the tissue needs to be alive and functional, so just doing muscle growth isnt actually too bad) - finding the right experts		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World
2005	Jason Matheny and co publish First peer reviewed literature on clean meat "Commentary In Vitro-Cultured Meat Production" Matheny also became a bit of an overnight star after university press release gets picked up by wider		Commentary in vitro-cultuered meat production paper

[1] https://books.google.co.uk/books?id=D-PaDwAAQBAJ&pg=PA123&lpg=PA123&dq=million+euro+funding+in+vitro+meat+%222004%22+%22netherlands%22+%22matheny%22&source=bl&ots=wQEjt2cQbY&sig=ACfU3U0CdVkzuhLD0qmRZsN3w0Q1oOE7-w&hl=en&sa=X&ved=2ahUKEwjy--mmw57wAhWYUBUIHXqhDP8Q6AEwEHoECAYQAw#v=onepage&q=million%20euro%20funding%20in%20vitro%20meat%20%222004%22%20%22netherlands%22%20%22matheny%22&f=false

[2] Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World

	media. Later ends up in new york times “Ideas of the Year” feature and Discover magazine says in vitro meat is one of the most notable tech stories of 2005 (i.e big media impact) Gets some interest from big meat companies, matheny attempts to persuade lots of them to invest in R&D but they say its too early and risky. Matheny gets to visit in vitro meat lab funded by NASA		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World
	2 million euro from dutch government for cultured meat project		The future of meat without animals book
	““In 2005, the European Commission polled residents about their views on potential future applications of technology, asking if they approved of a variety of applications in some, all, or no cases. Perhaps in response to Matheny, the commission included a question about whether Europeans approved of “growing meat from cell cultures so that we do not have to slaughter farm animals.” More than half the respondents said they’d “never” approve of it, though a quarter said they’d approve in some or all cases. Shockingly, more people approved of “developing for children a genetic test that would identify their talents and weaknesses,” Excerpt From: Paul Shapiro. “Clean Meat”. Apple Books. ““It’s also possible that the framing of the question influenced more negative answers since, as we’ll see later in the book, more recent polls that provide better context on the issue have been met with far greater support.”		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World

	Excerpt From: Paul Shapiro. “Clean Meat”. Apple Books.		
2006	New harvest provides funds to dutch cultured meat effort		The future of meat without animals book
2007	Tetrick meets matheny and shows him the 2002 nasa goldfish paper In Vitro Meat Consortium established after workshop at Nowegian University of Lifesciences.		In vitro meat consortium
2008	Dutch gov invests $4mil into cultured meat experiments (this could just be the previous subsidies) PETA offers prize to anyone who can commercially sell clean chicken - extends to 2014, nobody wins. Apparently this got a lot of publicity and attention of scientists In Vitro Meat Consortium (international group of researchers interested in cultured meat) hosts first international conference on it to discuss commercial possibilities. Consortium dissolved shortly after due to lack of funding in cultured meat space[3]		Future of meat without animals
2009	Time magazine declares cultured meat one of the 50 breakthrough ideas of 2009 Dutch scientists manage to grow lab meat from pig cells Mark post and crew also make muscles grow in vitro, media interviews get attention of Sergey Brin (google cofounder): Mark Posts reaction: ““It was so		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World

[3] https://books.google.co.uk/books?id=D-PaDwAAQBAJ&pg=PA123&lpg=PA123&dq=million+euro+funding+in+vitro+meat+%222004%22+%22netherlands%22+%22matheny%22&source=bl&ots=wQEjt2cQbY&sig=ACfU3U0CdVkzuhLD0qmRZsN3w0Q1oOE7-w&hl=en&sa=X&ved=2ahUKEwjy--mmw57wAhWYUBUIHXqhDP8Q6AEwEHoECAYQAw#v=onepage&q=million%20euro%20funding%20in%20vitro%20meat%20%222004%22%20%22netherlands%22%20%22matheny%22&f=false

	clear to me that we could do this. The science was there. All we needed was funding to actually prove it, and now here was a chance to get what was needed." Dutch government cuts subsidies for cultured meat development.		
2010	In 2010, Google co-founder Sergey Brin's family foundation reached out to Dr. Mark Post (also dutch) to support his efforts in developing cultured meat. They also encouraged Mark to create a huge media event where the first cultured hamburger would be tasted, supporting the costs of the research and the event.		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World
2011	Matheny starts referring to in-vitro meat as "cultured" in purposeful rebranding after seeing people's negative reactions and this gets adopted Post and co announce that they plan to produce a hamburger by sept 2012		
2012	In 2012, a total of 30 laboratories around the world were conducting cultured meat research.		
2013	Post's hamburger is presented to public (it seems with a positive reception) "The burger sparking so much attention in 2013 was hence neither the first in vitro meat produced nor the first eaten. But through this burger's spectacular unveiling, in vitro meat became well known also among many without a burning interest in meat debates and/or futuristic technologies. " "was prohibitively expensive for commercial application. Producing a patty reportedly cost €250,000 (US$330,000), funded by		History of cultured meat - social studies of science paper

	Google cofounder Sergey Brin (Jha, 2013). More than a technological breakthrough, however, the burger signalled a 'proof of concept to the public' (Post, 2014a: 1040). This explicit search for attention should, according to the head of the production team, be understood in light of how the Dutch government did not extend funding for the national in vitro meat consortium because researchers 'failed to generate sufficient interest from the private sector and the public' "		
2013	It seems like there were even more startups created after this point		
2014	2014 poll on clean meat acceptance ""The think tank found that only 20 percent of Americans are willing to eat "meat that was grown in a lab." College-aged respondents were the most likely to give it a try, but still, less than a third expressed interest. Men were more interested in sampling the hypothetical product than women, though, like college students, two-thirds of them were still unwilling. A study of Belgian consumers, also published in 2014, found a quarter were willing to try it, with the number rising to 43 percent when informed of the environmental benefits, and another 51 percent said they then might try it." Excerpt From: Paul Shapiro. "Clean Meat". Apple Books. "		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World
2016	Good food institute suggests "clean meat" as best name 2016 survey on clean meat		Clean Meat: How Growing Meat Without Animals Will Revolutionize Dinner and the World

	acceptance: ““ 61 percent of the university students claimed they’d either “probably” or “definitely” eat it. After being told some of the benefits, either ethical, health, or ecological, that number spiked to 77 percent. Among the fifteen hundred adults, the numbers were similar: 62 percent were willing to eat it without knowing its benefits, while 72 percent were willing once they knew of those benefits.” Excerpt From: Paul Shapiro. “Clean Meat”. Apple Books. “		
2020	Lab grown meat goes on sale for first time - according to guardian (haven't looked into this claim massively so just going to take it at face value)		Guardian article

Writeup of Development

The idea to create a more efficient way to produce meat without the need to grow a whole animal has been around for some time (at least from the 1930s and probably since 1912) but the first person to conceive of a way of actually doing this was Willem van Eelen in the 1950s.

William van Eelen was a student at a dutch university and met researchers using stem cell technology to grow cells in a tank, they hoped to use it to create new skin for burn victims. He wondered if it could be used for food (he struggled with lack of food in earlier life). In pursuit of his idea he spent a lot of time finding various researchers who were also interested in cell cultured meat and trying to secure funding. Though he had some success with meeting and convincing other scientists (which may be the reason there was such a high number of dutch scientists involved in cultured meat development), he had less luck with funding: “Funding at that time only came from private investors, and private investors only pay for something if they get money back” - Willem van Eelen’s daughter. Although by the 1990s Eelen had amassed around $750,000 in funding and filed a patent for an in-vitro meat process, i’m not sure if he pushed the field forward that much technically. His biggest impact seems to be that he helped to grow a network of dutch scientists who were interested in

developing cultured meat, and that his wide and extensive search for funding may have led certain key players in the dutch government and in business to be aware of the concept.[4]

Separately (as far as I can tell) in the 1970s, NASA was thinking about how to grow different proteins so that long space flights can grow their own food. In-vitro methods are mentioned but it doesn't seem like in-vitro methods of growing meat are acted upon much. However around 1995 ish NASA started funding a project looking at how they could culture meat on long space flights. This eventually resulted in labs funded by NASA creating edible goldfish and turkey from a few cells in 2002.

Jason Matheny reads this NASA funded research and gets in contact with authors, they discuss the possibility of in-vitro meat being sold commercially. In 2004, Jason Matheny went on to found New Harvest, a non profit aimed at directing more funds towards public research on cultured meat. As a part of this work he contacts different countries to try to convince them to fund and start programs researching cultured meat, with little success (it's implied that the reason was that the benefits were too far away, and at least for the US, that it was considered a threat to the animal agriculture industry). He also emails the dutch PROFETAS (Protein Foods, Environment, Technology, and Society) government program (aiming to create more efficient sources of protein) about using in-vitro meat and is later invited to present at a conference of thiers. This caused the dutch government to invest 2 million euros in subsidies to the development of in-vitro meat (apparently this was also in part due to PROFETAS being aware of Willem van Eelen's work). I'm unsure of this but perhaps the existence of dutch labs already partly working on this (or at least working in tissue engineering) helped too.

Around this time, Sara Lee Foods became a corporate partner to these dutch subsidies for in-vitro meat, after being convinced by their R&D manager after a successful investment pitch by Willem van Eelen a year prior. It is unclear to me how much money they invested, if anything.

Also around this time, Mark Post joined the first research group funded by PROFETAS at Maastricht university. Before the funding, it seems like this research group was scattered across many dutch universities and that they tended to work on in-vitro meat for small amounts of time alongside other main projects (a day a week is given as a ballpark). Not all the scientists in the group were interested in in-vitro meat, some were interested in just increasing animal productivity for example. (My impression is that the dutch research money was for increasing protein yields in general rather than specifically in-vitro meat, but that PROFETAS expected some research into in-vitro meat to be a part of this).

In the space between the 1950s and the 2000s, tissue engineering for medical purposes had advanced greatly. By 2004, it seems like tissue engineering for medical purposes had become advanced enough that it was relatively easy to develop a roadmap to grow muscle for food, since this muscle doesn't have to stay alive or be fully functional. For example in 2003, an edible steak was produced from frog stem cells for a tissue culture and art project,

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[4] "The idea for lab-grown meat was born in a prisoner of war camp ...." 24 Sept. 2017, https://qz.com/1077183/the-idea-for-lab-grown-meat-was-born-in-a-prisoner-of-war-camp/. Accessed 28 May. 2021.

which suggests to me that making expensive small scale prototypes like this was not too difficult for tissue engineering experts.

Some time in 2004 Jason Matheny set about fixing the lack of academic literature on in-vitro meat and invited some tissue engineering scientists to work with him to create a rough road map to creating cell grown meat on a bigger scale. The paper was published in 2005 and gained wide media coverage. After the publication of his paper, Matheny attempts to get some big meat companies on board, they all say it is too early for them to consider investing.

In 2008 PETA offered a cash prize to anyone who can commercially sell in-vitro chicken and the In-Vitro Meat Consortium hosted its first international conference.

In 2009 Mark Post and his group had managed to make muscle cells grow in-vitro, and the resulting media interviews got the attention of google co-founder Sergey Brin. The same year, the Netherlands cut subsidies going towards funding cultured meat research. The next year, Google co-founder Sergey Brin's family foundation reached out to Dr. Mark Post to support his efforts. They also encouraged Mark to create a huge media event where the first cultured hamburger would be tasted, supporting the costs of the research and the event.

By 2012, there were a total of 30 laboratories around the world that were conducting cultured meat research.

In 2013 Mark Post's hamburger was presented and tasted on TV, to pretty positive reactions from the tasters. Creating this burger cost $300,000 (it's unclear how much of this includes research costs).

From 2011 - 2017 many of the first cultured meat startups were launched. In 2020 there were around 30-60 cultured meat startups around the world.

Summary of Development

Willem van Eelen was the first person to conceive of clean meat as we understand it today, he also contributed to making the idea known amongst scientists and some business and government figures, particularly in the Netherlands. He spent a lot of his life trying to get funding and support for his idea with not much success.

Probably independently, NASA started investigating growing meat as a protein source for long space flight in the mid 1990s, with the first successful results coming out in 2002. A similar concept had been investigated by NASA in the 1970s but doesn't appear to have resulted in any practical work. This could indicate that sometime between the 1970s and 1990s tissue engineering had advanced to the point where clean meat was becoming feasible.

Jason Matheny, who was interested in animal welfare but not a tissue scientist, read the NASA paper and became greatly interested in the idea of clean meat. He went on to found New Harvest in 2004, aiming to address the lack of funding in the area and also pitched

clean meat research to various countries, where he was successful in convincing the dutch government to spend 2 million euros on in-vitro meat research. It is possible that some key players in the Netherlands may have already been made aware of the idea through impromptu investment pitches given by Willem van Eelen.

In 2005, Matheny and a team of tissue scientists published the first peer reviewed literature on in-vitro meat outlining a roadmap to large scale manufacturing of clean meat. This paper received quite a bit of scientific attention and a very large amount of media attention. At this point I might say the field has just started to rear its head (though it definitely could have still faded back into obscurity again).

One of the research groups funded by the dutch government included Mark Post, who went on to demonstrate growing muscle from cells in 2009, attracting the attention of google co-founder Sergey Brin. Brin funded and encouraged Post to create a hamburger for public tasting, which was unveiled in 2013 to positive reception. I think Post's work and Brin's backing helped to solidify in-vitro meat as an upcoming research area with big commercial potential. I think it's also worth noting that this "prototype" burger was completely financially unviable in terms of being sold as meat, but was extremely effective for addressing concerns that in-vitro meat would just not be like the real deal and addressing the "ick" factor. Around this time and in the years that followed many private startups aiming to commercialise in-vitro meat were created.

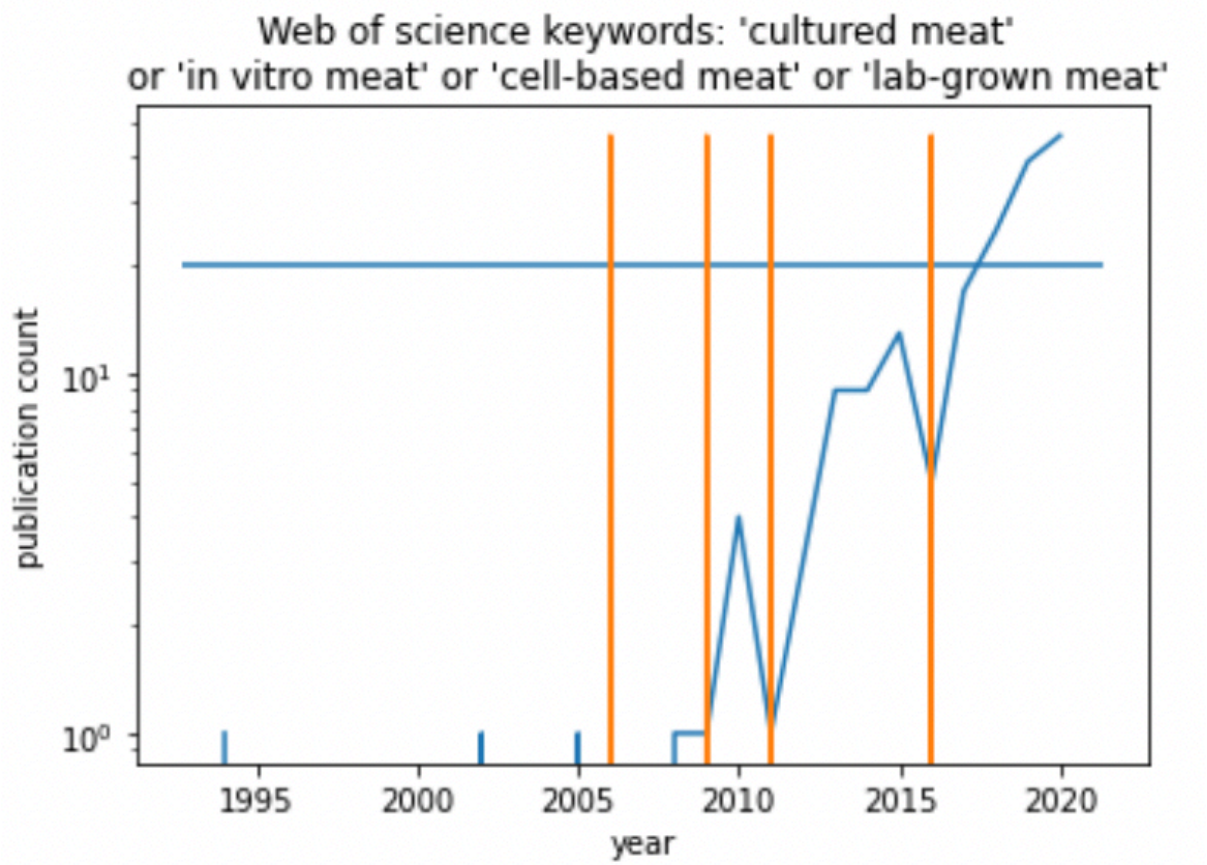
Very Quick Summary of My Opinions of How this Field became established

Clean meat research became established in large part due to the efforts of a few individuals who recognised that existing tissue engineering technologies could be adapted with some work to produce lab grown meat on a large scale. Jason Matheny in particular led the creation of the first influential paper on clean meat and was partially responsible for some of the first government funded research into the area. A few years later a public event was organised unveiling a prototype burger with the intention of selling the idea to the general public, this event received wide media coverage and made many more people aware of the concept.

Development Factors

See Spreadsheet (filter for "Clean Meat")

Development Measures



The y axis marks papers published in that year for that Web of Science Query
The blue horizontal line marks 20 papers published per year
The orange lines mark years in which the papers published per year had doubled or more year on year, over a 4 year time period (where the year marked is the first year of that 4 year period. Our “early growth metric” just takes the first year that the growth condition is met, or the first year that the field hits 20 papers published per year, whichever is first.

So the early growth year for clean meat is 2006

Code Parameters

Query was just articles (as with all that I have done so far)

Threshold = log(1.5) [x 1.5 average year on year growth]
Zero num = 0.5
p = 4
papers = 20