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Editorial Committee 2017-2018

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Letter from the Editor

Alexandra Jamieson

Appearing in the eighth volume of the St Anne's Academic Review (STAAR) are thirteen pieces from current or recent members of St Anne's College, University of Oxford. This edition of STAAR includes articles from the humanities, sciences, and social sciences and features a themed section on the topic of New Horizons. This year we have included pieces from the JCR (Junior common Room) and SCR (Senior Common Room), in addition to the MCR (Middle Common Room). We are very proud to have expanded into accepting pieces from the whole college community and hope this will continue in future years.

STAAR has been through a number of transformations this year. Most notably this is the first year of peer review. All research articles and subject review pieces have been through a peer review process. In the online version the reviewer comments will be made available for download, in the spirit of open peer review. We are very pleased with how implementing this evaluation process has gone. I am very grateful to my team of editors who were enthusiastically behind inviting reviewers and handling the review process. It has been a great success with each article having at least one review and we have had 24 reviewers involved with STAAR this year.

This year we have eight articles under the topic of 'New Horizons'. We chose this topic to explore how St Anne's members are pushing the boundaries of research to further our understanding of the world. Andrew Briggs, Professor of Nanomaterials, nicely kicks off our delve into new horizons by discussing the advances in artificial intelligence and its impact on our lives. The rest of the articles are from a wide range of topics from 3-D printing to the rights of nature. This section also includes a short story which we hope you enjoy reading.

Up to now STAAR has relied on the generosity of the MCR for financial support. This year we ran a crowdfunding campaign supported by the college. I would like to thank everyone who donated funds to help STAAR grow as a journal and become more self-sustaining. The campaign would not have been possible without the help of a few key members of my editorial team. I wish to thank Valeria Taddei, Erin Hales and Shuchi Vora for helping me film the crowdfunding video and run the campaign, and Laiza Poletti for editing the video. Erin also was a big help with the social media campaign, running both the Twitter and Facebook account.

STAAR can now also count on the support of academic advisors Prof. Kate Watkins, Prof. Liora Lazarus and Prof. Simon Park, and on the editorial suggestions of Marcelo Zanon from Oxford University Press. We thank them for their availability and precious help in making STAAR ever more professional and widely read.

It was a pleasure to have worked alongside such a great team of editors. It has been a joy and I offer my sincerest gratitude to all. They maintained academic integrity throughout and were committed to ensuring the eighth volume of STAAR was a success. Additionally, I am thankful to Valeria Taddei for always being there to discuss ideas and for her commitment to the role of Production and Web Design Manager.

It has been a pleasure to serve as the Editor in Chief.
I hope you enjoy reading our eighth issue of STAAR.

Sincerely,
Alex Jamieson

Announcements

The following members of St Anne's College have publications appearing in 2018:

Roger Crisp, co-editor: *Moral Evil in Practical Ethics,* edited by Shlomit Harrosh, Roger Crisp, Routledge 2018. Details at https://www.routledge.com/Moral-Evil-in-Practical-Ethics/Harrosh-Crisp/p/book/9781138316041.

Eleni Philippou, 'Perennial Penelope and Lingering Lotus-Eaters: Revaluing Mythological Figures in the Poetry of the Greek Financial Crisis', *Dibur Literary Journal*, Issue 5, Spring 2018. Available at https://arcade.stanford.edu/dibur/perennial-penelope-and-lingering-lotus-eaters-mythological-figures-poetry-greek-financial. Some of Eleni's poetry was featured in *TRIPWIRE 14: THE RED ISSUE - a magazine of new poetry and translations, essays, reviews, radical poetries*, in a special section on Greek Poetry of the Crisis. Available at https://tripwirejournal.com/.

Andrew Klevan, *Aesthetic evaluation and film*, Manchester University Press, September 2018. Details at http://www.manchesteruniversitypress.co.uk/9781784991241/.

Jo-Anne Baird, co-author: Jo-Anne Baird, Tina Isaacs, Dennis Opposs, Lena Gray, *Examination Standards: How measures and meanings differ around the world*, UCL IOE Press, Sep 2018. Details at https://www.ucl-ioe-press.com/books/assessment/examination-standards/.

Andrew Briggs, co-author: Andrew Briggs, Hans Halvorson, and Andrew Steane, *It Keeps Me Seeking. The Invitation from Science, Philosophy and Religion*, OUP, September 2018. Details at https://global.oup.com/academic/product/it-keeps-me-seeking-9780198808282?cc=gb&lang=en&#.

Neil Macfarlane, "Contested Regional Leadership: Russia and Eurasia," in Hannes Ebert and Daniel Flemes, eds., *Regional Powers and Contested Leadership* (Palgrave Macmillan, 2018), pp.275-300. Details at https://www.palgrave.com/gp/book/9783319736907. Neil is also co-author of 'China in Pakistan and the wider region: A cautious but effective leader?', *Contemporary South Asia* (forthcoming).

Nicole Eichert, co-author: Eichert, N., et al., 'What is special about the human arcuate fasciculus? Lateralization, projections, and expansion', *Cortex* (2018), https://doi.org/10.1016/j.cortex.2018.05.005, available at https://www.sciencedirect.com/science/article/pii/S0010945218301515.

Antonios Tzanakopoulos, co-author: Dapo Akande, Antonios Tzanakopoulos, 'Treaty Law and ICC Jurisdiction Over the Crime of Aggression', *European Journal of International Law*, 29 (2018) (forthcoming), abstract at http://ilreports.blogspot.com/2018/08/akande-tzanakopoulos-treaty-law-and-icc.html.

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NEW HORIZONS

Perspectives

Why Artificial Intelligence Will Enable New Scientific Discoveries

Andrew Briggs

Abstract. *We are in a time of change; new technologies emerge daily and this is unlikely to slow over the foreseeable future as key advances in artificial intelligence are made. The scientific community has recognised the large-scale impact AI will have on research from machine learning optimising experimentation to AI aiding drug discovery. In the UK there are a number of AI start-ups and research groups, making the country well placed to pave the way for significant changes to scientific research with the aid of AI technology. With these advancements we are on the brink of being able to tackle problems humans have so far been unable to solve alone. This post originally appeared on Graphcore in November 2017. We thank the author for permission to republish it.*

* * *

I am enthusiastically looking forward to a dramatic change in the way science is done. This change will be as significant as the application of science to technology that drove the industrial revolution.

In materials science, as in other branches of experimental science such as drug discovery, we are able to obtain ever larger amounts of data from ever more sophisticated experiments and modelling. And yet the choice of what data to collect, and the process of how best to analyse it, at times seem like a cottage industry compared to the sophistication of internet searches at Google or Baidu. Our current approaches to data in science fall well short of the advanced machine learning techniques social media platforms use to recognize the friend in a photo we've uploaded or what film we might like to watch next.

Advances in AI are likely to change every aspect of our lives, from transport and employment to care of the elderly and will have a huge impact on health care overall. Science and engineering research are set to benefit massively from the application of AI and UK science is sitting in pole position, ready to take the lead. In the future we can aspire to AI achieving a series of increasingly ambitious scientific goals:

- A result worthy of a second year graduate student

- A body of work worthy of a PhD

- An advance worthy of a Fellowship of the Royal Society or the Royal Academy of Engineering

- A discovery worthy of a Nobel Prize

The fourth goal has already been articulated as a Grand Challenge for biomedical science, by Hiroaki Kitano, Director of Sony Science Laboratories, "to develop an AI system that can make major scientific discoveries in biomedical sciences and that is worthy of a Nobel Prize and far beyond." (see: https://www.aaai.org/ojs/index.php/aimagazine/article/view/2642). We should be aiming for Nobel Prize worthy discoveries in all scientific disciplines.

I predict that by 2025, AI will be as ubiquitous for running experiments as computers are today for controlling instrumentation and logging data. The paradigm shift will be from AI used for analysing the data which has already been obtained, to AI deciding what to measure next. The key advances in AI that we are currently exploring to make this possible are reinforcement learning and Bayesian optimisation.

Suppose we have a belief about something, which could be a scientific hypothesis or a function which describes a phenomenon under study. There is some uncertainty, which could be reduced by acquiring more data, but the data are costly to acquire. How should we choose what experiment to do next? How can we optimize for the perennial constraints in scientific research of time and money? Advances in AI, particularly those within machine learning, are now opening up the possibility to automate these processes.

These same methods can also be used to optimise a system for a given set of criteria. By analysing the results of new experiments and new material discoveries we can further tune our approaches, saving time, money and improving outcomes. This can be combined with hardware-in-the-loop testing to tune a component or sub-subsystem for its eventual performance in service. Initially this can be applied to prototypes which have already been made, but eventually it can be applied to the whole design and even to the manufacturing process. This could make a significant difference in the cost of production for advanced materials, allowing them to move from being used only in expensive one-off pieces of equipment into high volume production for new consumer devices.

Artificial Intelligence techniques in science will be applied to quantum technologies, batteries, solid state lighting, nanoelectronics and nanomechanics, for high throughput screening of new materials in both simulation and in experiments, for computer vision in microscopy, radiography and tomography and for optimisation of data-rich manufacturing operations.

However, the types of machine learning techniques that will work best in aiding scientific discovery are complex and will require computing hardware that is much more efficient and flexible than exists today. New hardware that can efficiently accelerate these approaches is becoming available from companies like Graphcore with their Intelligence Processing Unit (IPU) technology. By using these new advanced IPU's we will be able to develop new innovations in machine learning approaches, that will allow us to achieve breakthroughs in scientific research. In addition, we will create a cohort of researchers with first-hand experience of cutting-edge AI and its application to science, engineering and technology. This will further stimulate the development of AI techniques for broader applications in science and engineering research across many fields.

Industry is starting to invest in the automation of research in science. Sony has set a Grand Challenge in biomedical sciences. DeepMind has recently appointed a director for science research. There are several very impressive UK start-ups, both in software and hardware, working in the application of AI to experimental science, who are well placed to contribute, some of them already very well-funded. And many universities, including several in the UK, have groups who are world-leading in the machine learning techniques that are needed for automating science. I believe that the UK is well placed to provide leadership in this new field.

Artificial Intelligence gets a mixed press. Many talk about the risk of jobs being replaced by machines. Today the internet is driven by advertising revenue and so it is also natural to see a lot of AI research focused on improving basic commercial imperatives such as understanding social media feeds or improving internet search.

The application of AI to science research has the potential to make a much more fundamental societal impact. It will allow us to understand and explore the use of new materials and new techniques. Silicon based computers may only have another 10-20 years of advances ahead and so we need to accelerate work on new materials and on the next breakthroughs that will come from quantum computing or eventually from molecular computing. Drug discovery and medical research will also benefit from these new AI driven scientific techniques. Drugs that are able to directly reach the diseased tissues and avoid wider dispersion in the body will result in people suffering far fewer side effects. These types of research breakthroughs will allow our aging populations to live more useful and fulfilled lives.

I am optimistic for our AI future and in particular for the growing role that this new technology will play in scientific breakthroughs. With sufficient investment, very rapid progress could be made within 5 years, maybe not yet to Nobel Prize level, but almost certainly to second year graduate student level. More importantly, new machine learning techniques applied to scientific discovery will quickly enable complex research challenges to be addressed that could *never* be solved by humans alone working within feasible time limits and resources.

Department of Materials

Creative Writing

Sunday Morning Dimsum

Tiffany Ren

Two women sat at a window table in East Buffet.

A dimsum cart stopped by their table. The older woman pointed to several dishes.

"I think that's enough, Ma. We only have twenty minutes before your appointment."

"You're always rushing somewhere else these days. Have some *ha cheung*."

The older woman picked up shrimp wrapped in a noodle sheet and soaked it in a pool of soy sauce. She reached across the table for the girl's plate. Her hand trembled from the weight of the food. The girl moved her plate closer.

"I'm not hungry, Ma." The food plopped onto her clean plate.

"Come, you'll be hungry later." The woman picked up another *ha cheung*.

"I don't really feel like eating that right now. I'm sure we'll come back next week."

"But this was your favorite. Ever since you were a baby."

"Yes, but every Sunday we come here and order the same food."

"We never know what we'll miss until it's gone." The woman's hand shook as she put her chopsticks down. The chopsticks clinked against her clean plate.

"I'll never not have *ha cheung*, Ma. It won't be *gone*. But what if I don't have egg tarts for a couple of Sundays? What's so bad about that?"

"*Ai*, do you still want to go there? It's dangerous, Ma told you already. Not many Chinese there, you know?"

The girl looked away, out the window. "You told me already Ma."

The building across the street took up the entire view. Its windows were thin, rectangular snapshots the girl saw every week: Mrs. Lang, cutting a man's hair, next to waiters polishing wine glasses amid Hot Pot Lamb's mid-day lull.

"And have you seen the news? The attacks? One happened near—"

"Yes, you showed me on the map." The girl looked up. She could see only more brick.

"It's near where you want to go!"

"So security will be increased! It'll be fine, Ma!" No spots of sky to be seen. "There's just, like, so much out there, so many people to meet—I can learn so much from just meeting different people or walking through different streets!"

"But they're dangerous—"

"Not everyone is dangerous, Ma!" She drove her chopsticks into her *ha cheung* like a stake. "Just because they're not Chinese—"

"But if there is danger—" The woman paused. She pressed her lips together, forcing back nausea. "Ma can't be there to help if you need it. Ma needs to stay close to the doctors."

The girl surveyed her food. She reached over to place an egg tart on the woman's clean plate. "Ma, eat this, the doctors say you need sugar."

"I feel better if I don't eat before appointments." The woman looked at the dishes, still untouched. "Maybe we can box it, take it home."

The girl checked her phone for the time. "We should leave, Ma. I lost track of time."

"Why don't you finish the *ha cheung?* The doctors say this time will be longer, and I don't want you to be hungry while you're waiting."

"I'm fine, Ma. I stay full for a while."

"But you won't have it when you leave."

"I'm not leaving, Ma." The girl waved over the waiter for the bill.

"But what about meeting new people?"

"I have all the people I need here." The girl started filling up the cartons. "And what if you… what if I miss you when I'm gone?"

"Ma will always be here." The woman put a quivering hand on the girl's arm, then withdrew it to cough.

"But I want to be there for you. To help drive to the doctors. They said starting radiation—we need to go five days a week."

The waiter returned. The daughter moved to put down money, but the older woman slapped away her daughter's hand. "No, I'm supposed to treat you every Sunday—"

"I know! I know, Ma."

The girl lifted the white teapot and the woman tucked some bills under it.

"Every Sunday," she said to herself.

Faculty of English

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Research

'All models are wrong. Some models are useful'

Shuchi Vora

Abstract. *Models are representations of reality with suitable omissions. On the one hand, there is increasing reliance on models to inform policy design which are based on mathematics and scientific rigour as they are considered free of any biases. However, on the other hand, there is a call within and outside the scientific community to subject models to increased scrutiny due to value-based assumptions and uncertainties especially with respect to the prediction of future scenarios. In case of climate change and water resources management, while climate predictions are increasingly called upon to make policies for mitigation and adaptation, questions have been raised on the effectiveness of models due to various reasons. Cape Town in South Africa is currently at the centre of this debate as it is in the midst of the worst water crisis it has ever seen. This paper highlights the debate on the reliance of models and the issues with the reliance on modelling using the case of the current water crisis in Cape Town, South Africa. It highlights the philosophical underpinning of what makes models wrong, while arguing that models continue to be useful. This piece makes an argument for risk-based drought management using models, while highlighting the need for transparency regarding the limits to current knowledge in water management that models can simulate. The paper concludes that the onus lies on the scientific as well as decision-making communities to bridge this gap through responsible communication.*

* * *

Cape Town in South Africa is being watched keenly by climate scientists, hydrologists, water managers and policy makers alike as it goes through the worst water crisis the city has ever seen. Its main water source, Theewaterskloof dam, is depleting everyday and a disaster relief plan is in place which includes heavy restrictions in water consumption, water supply to public water collection points and deployment of armed forces to manage crowds in the city (Chambers, 2018). This severe drought in the Western Cape region is being attributed to the effects of climate change (Welch, 2018). The media has begun questioning the failure to forecast the severity of the drought and a political blame game has ensued (Welch, 2018).

At this point, George Box's profound aphorism to the scientific as well as decision-making communities in 1976, "All models are wrong; some are useful" is more pertinent than ever. The policy makers in Cape Town did not prepare for the falling water levels in the reservoirs due to the prediction of a wet summer this year (December-January-February) (Wolski, et al., 2017). However, they did not account for the fact that seasonal forecasts are probabilities and not certainties of a weather event occurring (Davis, 2011).

This paper uses the Cape Town water crisis as an example to discuss Box's aphorism. The paper first conducts a literature review on policy responses to drought and the role of modelling in drought risk management. It highlights that while there is an increasing reliance on models for policy-making on climate change and water resources management, there is a call both within and outside the scientific community to subject models to increased scrutiny. The paper argues that while models are useful tools which are simplified representations of reality, there is a need for transparency in communicating the assumptions and uncertainties underlying the models in order to avoid a crisis scenario like the one in Cape Town. The role of models is not to avert risks but to inform policy-makers of the risks, and then plan for them. The paper concludes that the onus lies on the scientific as well as decision-making communities to bridge this gap through responsible communication.

Policy Responses to Drought – A Review of Literature

Droughts are related to images of knee-jerk policy reactions, often to pacify disappointed constituencies and manage demand when situations have reached crisis points. A drought has impacts on ecology, economy and the society in various ways because of the shortage of water due to variations in the hydrological cycle. It is difficult to estimate the spatial and temporal extent of drought, which means that the start and end of a drought as well as exact locations that it affects are difficult to determine. Hence, drought is little understood at present, and a lot of effort has gone into understanding and measuring droughts.

Africa has been especially vulnerable to the impacts of droughts. Drought has been the cause of 95% of the disaster-related death toll in the continent (Sivakumar, et al., 2014). It has direct as well as indirect effects on crops, livestock and the larger economy due to environmental degradation, water scarcity and the increased vulnerability of households exposed to drought shocks. The indirect effects can often be larger than the direct effects (Shiferaw, et al., 2014). Long-term drought resulted in widespread starvation and famine in many parts of Sub-Saharan Africa, which faces a higher risk of failed crops due to droughts (Shiferaw, et al., 2014). Countries of eastern and southern Africa have been dependent on crisis management as a policy response to drought, which has been rendered ineffective due to lack of data, monitoring capacity and coordination in governance (Shiferaw, et al., 2014; Sivakumar, et al., 2014).

Management of droughts requires planning for water shortages that would affect sowing season for farmers, domestic consumption and wildlife in biodiverse regions. It is important for regions to recognise the risk of droughts and plan for the risk through appropriate policy interventions. A risk based approach towards management of droughts may involve a portfolio of interventions including increasing resilience of agriculture, augmentation of water provisioning capacity for domestic and industrial supply by diversifying the supply options to include waste water reuse, managing demand and restoring the natural resilience of ecosystems

as well. Sayers et al. (2016) have argued that the challenge of managing droughts requires a change in approach from crisis management to strategic risk management. They have outlined a Strategic Drought Risk Management framework that relies on a strong scientific understanding of drought indicators for monitoring, planning and decision-making.

Risk management approaches are generally strategies created with the awareness of the inevitable risks while "pursuing positive goals" (Hansen et al., 2014 in Shiferaw et al., 2014). Sayers et al. (2016) define a risk management approach as "a continuous process of data gathering, analysis, adjustment and adaptation of policies and actions to manage drought risks (over the short term and long term). Sivakumar et al. (2014) argue for National Drought Policies in countries that "place emphasis on risk management rather than crisis management" by using drought indicators in monitoring and forecasting droughts. While they give clear details of early warning and prediction systems for African countries based on global circulation models, they do not outline any roadmap for a regime for measurement of local data in these data sparse conditions. Thus, management of droughts using a risk based approach involves the identification and monitoring of variability in hydro-meteorological cycles.

Moreover, droughts should be viewed as a long-term development challenge which requires investment in preparedness and transformative policy responses. Decision-making for droughts should include planning, preparedness and monitoring using reliable drought indices which are suitable for the geography and context of East Africa. There is a need for better data gathering and monitoring capabilities to change the approach of drought management from a crisis based approach to that of risk management.

The Role of Modelling in Water Policy – A Case of Cape Town

The regions of eastern and southern Africa are characterized by mainly sub-humid and semi-arid climates. They have a pronounced dry season in the year and the variability of precipitation is concentrated in shorter time scales. The rainfall variability is directly dependent on the global circulation phenomena such as El Niño-Southern Oscillations (ENSO) and the La Niña cycles as well. The Inter-Tropical Convergence Zone (ITCZ) passes through the sub-Saharan African region, and ENSO also impacts the ITCZ and global wind currents. Thus, ENSO has a strong influence on the anomalies in rainfall over many parts of the sub-Saharan African countries (Masih, et al., 2014). These impacts may vary seasonally and geographically within the region.

The Western Cape region has a climate with winter rainfall and dry summers. The region has been historically drought prone with long-term forecasts predicting more prolonged dry periods (Jaubert & Hewitson, 1997). Cape Town is completely dependent on surface water, with all its rivers dammed, and the impacts of droughts are a common phenomenon. However, the city continues to manage

droughts in a crisis mode with the municipality enforcing restrictions on domestic consumption every time there is a drought (Sorensen, 2017).

The current drought in Cape Town is supposed to have a return period of 400 years, although this is based on limited, coarse resolution or bad quality data (Wolski et al., 2017).The prolonged dry period that led to Cape Town's current drought was not predicted by most weather forecasts. As far as weather models are concerned, there are issues of limited data, coarse resolution and scale of models used for seasonal forecasting in Southern Africa (Davis, 2011). Further, at present the decadal forecasting of climate change is experimental. Further, water infrastructure planning is medium to long-range in nature. Moreover, while the models are either regional or global in scale, the policy response towards adaptation of water resources management is expected at a municipal scale (Mukheibir & Ziervogel, 2007).

A Philosophical Perspective to Modelling - Why are Models Wrong?

Chorley and Hagett (1967) define models as "a simplified version of reality built in order to demonstrate certain properties of reality." Models can be descriptive, visual, iconic or numerical. Based on this concept, models can range from definitions, maps, case studies, flow charts to complex numerical models that simulate the material world (Brunet, 2001). In case of climate change and water resources management, models are increasingly used to measure historic patterns and predict future events within environmental systems.

Why are models wrong? The answers to this question such as the neglecting of processes of society, over-parameterization and their mechanistic nature (Brunet, 2001) seem superfluous when one scratches the surface to reveal a more fundamental philosophical basis underpinning this statement. In order to examine, these philosophical issues in present-day modelling, it is necessary to understand what makes a useful model.

Models are essentially tools to test hypotheses regarding the material world. They should be deductive in nature instead of purely inductive or data-based, since deductive methods use both scientific and empirical techniques and involve "logical comparison of conclusions, comparing with other theories and the empirical application of the final conclusion" (Popper, 1959). Further, unlike normal research, models should continue to challenge the "paradigm choice" of science and not tend towards cumulative research based on methods and concepts already in existence (Kuhn, 1962). Problems should be tested using models keeping in mind that that they are most useful when they challenge existing theories instead of demonstrating the truth in them (Oreskes, et al., 1994).

However, Oreskes et al. (1994) highlight models for policy-making cannot demonstrate the truth (verify) or lend legitimacy (validate) to the predictions because the natural world is an open system. They also argue that there is a bias of "affirming the consequent" in the scientific community and that there is no absolute

way to know if models truly represent all the phenomena of the natural world or only exhibit the relative performance of dependent parameters with respect to empirical observations. This argument of theirs is in line with Hume (1999) who examines the nature and foundation of human reasoning and states that demonstrative reasoning entails all ideas, including models, that judge the future based on past experience. He further states that "whatever is intelligible and can be distinctly conceived implies no contradiction and can never be proven false by demonstrative reasoning." Beven (2018) tries to bridge this gap in modelling by suggesting "model rejection" and "limits to acceptance" as the basis for acceptance of models for decision-making in order to introduce the rigour that Oreskes et al. (1994) have pointed out is lacking.

Towards Drought Risk Management - But, Can Models Be Useful?

The failure of seasonal forecasts in Cape Town is a symptom of the very issues that have been highlighted in this paper. However, despite limitations of models and data in the Western Cape Region, there is a need for modelling to underpin the policy responses to droughts. Drought management needs to be risk-based with the acknowledgement of inevitability of drought risk, rather than a crisis management response. Existing literature in drought science and drought policy highlights the role of modelling droughts for more effective policy responses. Measuring and understanding drought risk while being cognisant of embedded uncertainties is the foundation of robust drought risk management policies.

Thus, models are extremely useful tools that support decision-making in these times of increasing uncertainty. The issues of uncertainty, validation, verification and confirmation of models should be communicated beyond the scientific community to the end-consumers of the forecasts from these models – the policy-makers as well as the public. There is a need for increased transparency and responsible communication by the scientists and decision-makers to retain the usefulness of models and prudently identify trade-offs.

School of Geography and the Environment

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Field Reviews

Oil and Corruption in Africa: Who is to Blame?

Pierpaolo Crivellaro

Abstract. *The recent OPL245 scandal, involving Nigerian government officials and oil firms Shell and Eni, was nothing but the most recent scandal in the Oil&Gas sector: instead of enriching Nigerian state coffers, huge amounts of money (more than a billion dollars) were diverted to private bank accounts. Corruption and kleptocracy have undoubtedly become a common feature of oil-rich countries in Africa, with a wide body of literature highlighting the negative impact of oil on governance, the economy, democracy and peace. Writings on the "resource curse" and the "Dutch disease" have brought attention to the paradox of the misery that characterizes resource-rich countries, focusing on the ensuing corruption of the institutions and of the state in Africa. While this paper does not intend to dismiss the blame from corrupt leaders and bad governance, it seeks to redirect the focus of the issue on what is often – and conveniently - left out of the discourse: that is, the structure of global networks and energetic demands that lies behind the emergence of corrupt regimes in African petro-states. It is not the resource in itself, but the international demand for the resource, that triggers this wide range of problems. Therefore, this paper seeks to explore the complex set of networks behind the extraction and consumption of oil and the economic structure of African petro-states to offer a global framework in which to locate the corrupt and kleptocratic behaviours of these leaders.*

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The stipulation of trade deals for the exploration and extraction of oil seems to involve cases of corruption on a regular basis. Etymologically, the word corruption stems from *cum* (an intensifier) and *rumpo* (to break), indicating a condition of rupture in normality: by this definition, the occurrence of bribery and extortion during trade deals should be an exceptional incident, not the rule. However, corruption has increasingly become the norm in the oil and gas sector. Recent scandals such as the OPL245 case in Nigeria (involving Eni and Shell, former Nigerian oil minister Dan Etete and former president Goodluck Jonathan) show that bribery has become a widespread practice to secure the granting of extraction rights[1]. This system benefits not only government officials, but also the oil company chiefs, who reserve a portion of the bribe paid by the company for their own

[1] Retrieved 05/02/18, from: http://www.independent.co.uk/news/business/news/shells-top-bosses-knew-money-from-13bn-nigerian-oil-deal-would-go-to-convicted-money-launderer-a7676746.html

pockets[2]. While some oil-exporting countries have managed to avoid the total squandering of oil revenues, African petro-states have traditionally fallen victim to the 'resource curse', a landscape dominated by corrupt and unaccountable political elites and rapacious oil companies (Beblawi *et al.* 1987; Karl 1997; Soares de Oliveira 2007) .

In his analysis of the impact of oil on politics and wars, Cyril Obi (2010) criticized the 'resource curse' approach, judging it an unhelpful way to represent the issue. According to him, the 'resource curse' puts an emphasis on the *resource*, i.e. oil, as the source of all the problems, and on the *curse*, i.e. mismanagement by the elites, as the main problem. While nobody can deny the frequency of predatory practices or even conflicts in many oil-rich countries, Obi notes that this way of framing the issue reproduces a distorted image of reality. The conventional wisdom, which has been reinforced by the 'resource curse' discourse, presents the following kind of narrative: poor countries discover oil, they are submerged by a great bulk of money, greedy leaders do not know how to administer it and prefer to divert it to their own bank accounts. This oversimplified picture builds a direct nexus between resource and curse, and considers elites as the main actors in the game. There is one aspect of the equation that is implicit to the discourse but often seems to be forgotten: it is not the resource itself, but the *international demand* for the resource that triggers this wide range of problems. While this might seem a tautology, it enables us to trace the real process behind the so-called 'resource curse' back to international actors, accountable for the consequences of their demands. While other models explore the historical ties of hegemony and exploitation behind oil extraction, this paper will focus on two structural constraints that influence the actions of African elites: the structure of the economy of oil-producing states and the international context of oil production and sale.

An analysis of the economic structure of resource-rich countries reveals that the resource curse, while frequent, is not unavoidable. Even in the African continent, where the resource curse has been the most problematic, cases like Botswana and Ghana challenge generally held assumptions. Rather than seeing them as mere exceptions to the rule, Dunning (2008) provides a framework to make sense of the different outcomes by differentiating between resource-abundant, rentier, and resource-dependent states. The first are countries that are naturally endowed with one or more resources, and they can be rentier states or not; the second are states that depend on rents from natural resources to finance their budget and, in turn, they can be resource-dependent or not; the third are countries that depend on natural resources for most of their GDP and, hence, all economic activities revolve around the extractive sector. According to Dunning, predatory and authoritarian behaviour are a feature of resource-dependent countries, while rentier non resource-dependent countries exhibit different tendencies. A typical

[2] Retrieved 05/02/18, from: https://www.ilfattoquotidiano.it/2017/12/20/tangenti-eni-nigeria-descalzi-e-scaroni-rinviati-a-giudizio-per-corruzione-internazionale-a-processo-anche-bisignani/4050617/

example of resource-dependent state is Angola: its spectacular post-war economic growth has been mainly sustained by oil exports, which have skyrocketed growth rates to double digits; as of 2009, oil accounted for 80% of the state budget, 97% of total exports and approximately half of its GDP[3]. Former president Eduardo dos Santos and Angola's elites have notoriously been using the national oil company, SONANGOL, to syphon money from the country and transfer it to private bank accounts: a 2011 IMF report states that between 2007 and 2010, over $32 billion were spent without being properly documented[4]. Moreover, the regime reportedly makes use of torture, rape, summary executions, arbitrary detention, and disappearances; actions that the Angolan government has justified by the need to maintain high oil outputs to sustain economic growth[5]. Thus, the picture emerging from Angola exhibits the general trends of predatory petro-states: the economy is totally dominated by the oil sector or other activities directly financed through oil. Hence, there is no economy outside of oil and the state and the elites have successfully "captured the state" to control the entirety of oil exports which they administer as though it was a personal possession. They do not hesitate to use violent repression to assert their control over oil rents and thus, create a strong rupture with civil society which feels strongly alienated from the state.

In contrast, the elites of rentier non resource-dependent states cannot afford to alienate the people. This is because, outside of the oil sector, these countries have a large economy operating that makes the population relatively autonomous. This explains why many Latin American countries have embarked on a series of populistic policies and democratic reforms that seek to make the oil sector more transparent in order to win votes rather than to repress the voice of the people. In the case of Africa, Ghana's major oil discovery came at a later stage of development, when the country's economy was diversified and relatively strong. Since the start of production, the county has achieved compliance to EITI guidelines (the Extractive Industries Transparency Initiative) and founded a civil society group to monitor extractive activities. Moreover, Ghana was the first African country to design a plan to back up the country's economy in case of oil price variability, by splitting revenues into an annual budget amount and two long-term funds (at least 30%) – imitating the successful Norwegian model. Clearly, this does not exclude corrupt practices, but at least reveals different public attitudes toward political accountability and entitlement to resource exploitation. Hence, bad governance and lack of accountability cannot be reduced to a matter of the elite's preferences; the structure of the economy delimits the space of manoeuvrability of elites and influences their actions.

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[3] Data from: OECD, International Energy Agency, 2006. *Angola: towards an energy strategy*.

[4] Retrieved 08/02/18, from: https://www.hrw.org/news/2011/12/20/angola-explain-missing-government-funds

[5] Retrieved 08/02/18, from: https://www.hrw.org/report/2004/01/12/some-transparency-no-accountability/use-oil-revenue-angola-and-its-impact-human

The second structural constraint, i.e. the international context of oil production and sale, reveals that bad governance is a consequence not only of the elites' actions, but also of global networks: not only have the superpowers done nothing to prevent corruption, but they have directly sustained it to further their own interests. World-systems theories claim that all global elites are interconnected, so that they directly benefit (through private gains) from reproducing the existing mechanism of hegemony, i.e. keeping the periphery subservient to the core (Wallerstein 1974). With specific regard to the politics of oil, we can make sense of kleptocratic regimes in petro-states by looking at how the US prioritized stability in oil-consumer countries.

After WWII, the US asserted its economic hegemony in Europe by imposing a shift from coal to oil as the main source of energy, since global oil flows were controlled by American companies. Traditional readings on the Marshall Plan, the American initiative to finance post-war reconstruction in Europe started in 1948, focus on the liberal assumption that economic interconnectedness and prosperity would lead to peace, liberal democracies and would halt the spread of Communism. However, more critical perspectives on the Marshall Plan, such as Mitchell's (2009), highlight a different underlying aim: i.e. to increase oil consumption in Europe and ensure economic dependency on American-sold oil. In simple terms, the system worked in the following way: the US provided financial support to Western European countries; Europe spent this money to finance post-war reconstruction; the more it achieved economic growth and reconstruction, the more it increased its oil consumption. Hence, by purchasing oil from American companies, European countries were paying their debt to the US. In fact, due to inflation and high growth rates, the prices of oil were on a constant increase, which meant that American companies were making a profit out of this exchange: the total amount of US dollars (the currency of oil exchanges) given by the Americans through the Marshall Plan was lower than that returned by the Europeans through oil purchase. The difference between the two constituted a sort of tax that the US extracted from Europe in return for providing economic prosperity and a liberal democracy. It was in the American interest to nurture social and political stability on the consumers' side (Western Europe).

In contrast, the US had no interest in a stable Middle East and Africa, as the role of these regions on the global chessboard was limited to the exportation of oil (Mitchell 2009). In fact, Mitchell draws an interesting parallel between American interests in global oil trade after WWII and the huge increase in arms sales to oil-exporting countries: the US explicitly supported any regime that espoused American interests and thus, actively helped to perpetrate kleptocracy in petro-states. This system began with the US-Saudi partnership and has since been reproduced various times across the globe, by many other actors beside the US.

What is most fascinating about this perspective is that it makes us question the values and rationales behind democracy and reconsider the importance of economic structure. While the success of liberal democracies in the 20th century is undoubtedly linked to mass society, democratic participation and anti-

authoritarian feelings, the presence of economic interests and hegemonic tendencies are an undeniable reality. The ultimate question to ask ourselves, then, is whether liberal democracy and oil networks can be separated; whether a liberal democracy can be successfully sustained outside of the need to sell and buy oil.

Interestingly, the difference in levels of governance among oil-producing states can be traced back to oil consumption. Oil-producing countries that have escaped the resource curse and present democratic modes of governance are also the countries with high levels of oil consumption to sustain their economy. This goes some way towards answering the initial question of why corruption has become so endemic in African petro-states: most African petro-states are not oil consumers. In the absence of a strong diversified economy, the global system has no interest in supporting good governance and democracy in the continent, but rather prioritizes Africa's role as a provider of oil to oil-consuming democracies. Corruption sustained by global networks offers a reliable mechanism to ensure that this system works. Hence, elites in African countries are not necessarily more corrupt or "evil" than their counterparts outside of Africa; they simply have a global economic structure that allows them, or even encourages them, to repress civil society and engage in predatory behaviour.

The ways in which American interests have shaped global networks lie at the very roots of the process of normalization of corruption in the field of oil and gas. The OPL245 case is nothing but the most recent scandal and shows how these practices have been internalized also by other actors in the field. Such practices benefit all the elites involved, from the governments of extracting countries to the oil firms to the governments and populations in oil-consuming countries; the only actors who are left out from the distribution of wealth are the domestic non-elite public in oil-extracting countries. While petro-elites may have some degree of agency in articulating their preferences, their actions are undoubtedly shaped by the strong set of practices perpetrated by the international system. If elites were to move against this system, the chances are that the elites would be ousted. Moreover, regardless of their preferences, elites are constrained by the structure of their economy. Hence, this paper has shown that, even though oil does benefit the elites and supports their system of patronage, corrupt behaviour based on predatory instincts (the so-called 'resource curse') may be an oversimplified explanation of the real issue. Elites in African petro-states tend to assert their agenda in concordance with structural constraints and so, ultimately, structure – both that of their state economy and of the international demand - might wield more influence in explaining the issue.

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Making the Impossible: An Overview of Additive Manufacturing

Harry Orchard

Abstract. *When one hears the word 'manufacturing', they might think of factories with elaborate cutting tools and large machines churning out large numbers of parts each minute. For many years this has been the norm, but recent developments in additive manufacturing (commonly referred to as 3D printing) have led to a revolution in the way parts can be designed and produced across a wide range of industry sectors. For example, in the world of prototyping and product design, it can often be a time and money intensive process to make incremental changes to potential products. With a 3D printer, however, changes can be made easily, cheaply, and often right in the office where the designers work. Other significant users of additive manufacturing technologies are the automotive and aeronautical sectors where intricate parts, once impossible to produce by traditional methods, can lead to significant material-usage and weight reductions. This review looks to provide an overview of the different additive manufacturing technologies, from desktop Fused Deposition Modelling (FDM) printers to large Selective Laser Sintering (SLS) machines that can produce larger and higher resolution metallic parts. Further to this, some of the current uses of these technologies will be highlighted to show the breadth and depth of their potential applications, followed by a brief outlook to how the world of manufacturing might change in the near future.*

* * *

1. Introduction

When we hear the word 'manufacturing' we might think of factories with elaborate cutting tools and large machines churning out hundreds of parts each minute. For many years this has been the norm, but recent developments in Additive Manufacturing (AM), commonly referred to as 3D printing, have led to a revolution in the way parts can be designed and produced. Many industries utilise additive manufacturing including the medical, product prototyping, aeronautical and automotive industries. In particular, additive manufacturing can lead to significant reductions in manufacturing costs and weight reduction for complex parts in modern cars and aircraft.

As the name suggests, Additive Manufacturing involves adding layers of material sequentially to form the desired part, leading to a few distinct advantages over traditional 'subtractive' manufacturing. Firstly, the manufacturing process is relatively simple compared to normal machining and casting. As an example, to make a metallic part by casting there are several steps required, including making a high-resolution pattern, making a mould, preparing the material and finally the making the casting itself. Overall this process can be quite costly and time

consuming. With additive manufacturing many of these steps are unnecessary as no patterns or moulds are needed, meaning that production can begin much sooner. Another advantage over normal manufacturing is that producing a complicated part is relatively easy due to the layer-by-layer production process. In fact, the introduction of additive manufacturing means that some geometries that were previously considered impossible are now possible to make. One design element that is particularly troublesome for traditional machining techniques is the production of cavities within an object, as regular machining tools cannot get to the inside of a solid shell, but thanks to AM this is no longer a problem. By building up the part gradually the internal cavities can be made by building the material around the empty space. An example of a complex geometry that can be printed easily is shown in Figure 1. This reduction in production complexity results in a corresponding drop in costs. In traditional manufacturing, the cost of the manufacturing process will scale with the complexity of the part to be machined, whereas with additive manufacturing the cost of producing a very intricate part is not necessarily any more than that for making a much simpler one.

Figure 1: An example of a complicated shape that is easy to produce by 3D printing. Making a similar structure using traditional manufacturing methods would be difficult and time consuming.

The first 3D manufacturing technology was patented back in 1986 [1] and since then there has been rapid advancement in the capabilities of 3D printers, especially since the turn of the millennium. In recent years, 3D printers have even become available to consumers in the form of desktop machines. Just like in industry, the user can quickly go from designing to printing an object, and there are even online repositories (e.g. Thingiverse [2]) with files that can be downloaded and sent to the printer in a matter of minutes. There are also decentralized 3D printing services, such as 3D Hubs [3], which can get parts printed for you and save you the cost of buying a printer yourself.

Additive Manufacturing encompasses a variety of techniques, based on a variety of technologies, as outlined in Figure 2. These include material extrusion, vat polymerization and powder bed fusion methods. These methods use different materials, and result in parts that are suitable for different applications, depending on things like the resolution, mechanical properties (such as strength and toughness) and surface finish. We will explain the technology behind many of these techniques and we will discuss their advantages, disadvantages and some applications.

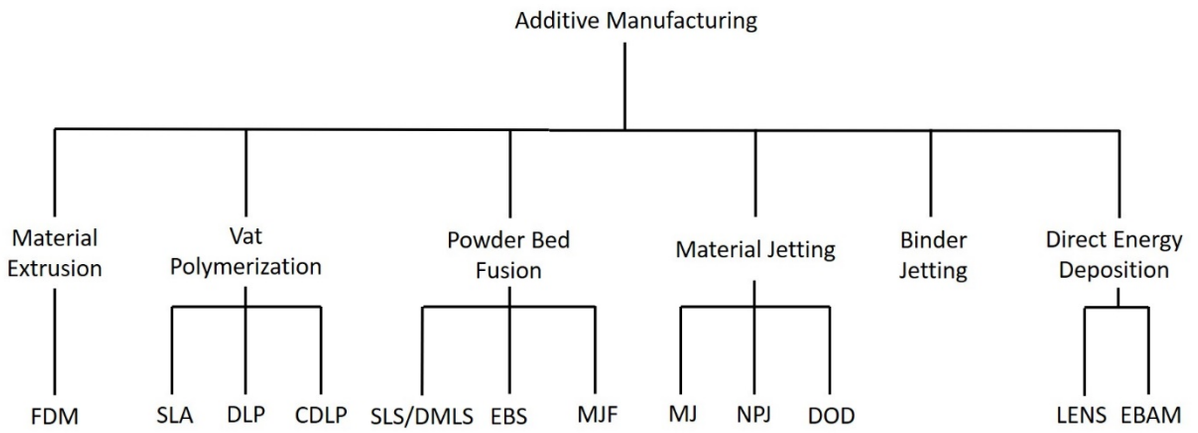

Figure 2: The different additive manufacturing technologies

2. Fused Deposition Modelling

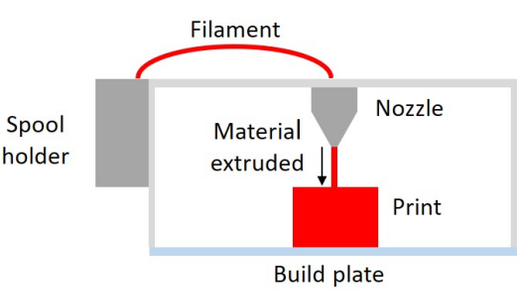

Figure 3: Schematic of a fused deposition modelling (FDM) printer

Fused Deposition Modelling (FDM) is perhaps the most well-known AM method and it is generally what most people have in mind when they refer to 3D printing. The underlying technology is relatively simple compared to the other methods that will be outlined later in this article, but this turns out to be one of its major advantages. The process involves extruding a thermoplastic filament (although the material can sometimes be in the form of pellets) through a heated nozzle, which moves relative to a build plate. As the nozzle moves it deposits a thin line (typically around 0.1-0.2 mm high, 0.4 mm wide, depending on the printer) of molten plastic in precise locations, where it cools and solidifies (see Figure 3). Each successive layer of material undergoes the same process, building up an object. If a design with overhangs is needed, supports can be printed at the same time as the design and are removed by the user once the piece is finished.

Due to the method of feeding in material as a filament, typical materials are polymers with melting temperature of around 280 °C or below, with the common printing materials including polylactic acid (PLA), acrylonitrile butadiene styrene (ABS) and Nylon, although other polymers are available. Some FDM printers are also now capable of temperatures exceeding 300 °C, meaning that materials such as PEEK, which can be used at high temperatures, are also now printable. The desired properties of the printed part will determine the choice of material. For example, if an object needs to be a strong structural part, polycarbonate filament would be a good choice, despite being more expensive than the other materials mentioned. There also some issues with toxic fumes and ultrafine particles given off by some of the melted plastics (e.g. ABS) [4], [5], which may need to be taken into account.

FDM was originally developed by Scott Crump, who later founded the additive manufacturing firm Stratasys, and patented the technology in 1992 [6]. When the patents expired in 2009, it resulted in a large increase in the number of FDM printer manufacturers, with some the big names in the industry currently including Ultimaker [7], Flashforge [8] and Makerbot [9]. This helped to drive the costs of printers down from several thousands of pounds to just a few hundred.

Print times can be a matter of hours and the material costs are generally low (typically from £10-50/kg, depending on the quality of the material, and hence the quality of the final print), making this technology very useful for prototyping designs. The ease of altering digital models to try several different designs is another reason why AM in general is suitable for prototyping. FDM is used widely but, to showcase its versatility, one particularly exciting application is in the construction of tools and other objects in space. The International Space Station's Additive Manufacturing Facility [10] is currently home to a large FDM printer produced by the company Made In Space Inc. [11]. This printer is not too different to the printers available to consumers and it allows astronauts to build tools, spare parts etc. on board rather than relying on expensive resupply missions. Overall, the simplicity of the FDM technology and low cost of the machines mean that they are a popular option for 3D printing hobbyists and experts alike.

3. Vat Polymerization

Unlike FDM, where polymer material is melted and deposited sequentially, Vat Polymerization methods use light of a specific wavelength (typically ultraviolet) to solidify photopolymers one layer at a time. There are a few different methods that use this principle, namely Stereolithography (SLA) and Direct Light Processing (DLP).

One advantage of these techniques is the speed at which prints can be made: for example, large functional parts of several tens of cm in length can been produced within a day [12]. Another advantage is that they can achieve a much better resolution (i.e. better detail) and surface finish than FDM. One disadvantage, however, is higher printer and material costs. Vat Polymerization methods can be used for prototyping, however, another regular application is in the medical industry. For example, data from MRI scans can be used to create a digital model, and then an anatomically accurate printed model of parts of the human body, such as limbs and the skull. Such models can therefore be useful for study and diagnosis [13]. Custom prosthetics and dental implants can also be made using a similar process. Other applications involve the production of moulds for injection moulding or casting when low numbers of each part need to be made, as this would otherwise be financially unsuitable using normal injection moulding dies [14]. An example of this is moulds for the jewellery industry, where 3D printing is now becoming more common.

3.1 Stereolithography

During Stereolithography (SLA), the print build plate is submerged by approximately 0.1 mm in a bath of liquid photopolymer resin. A laser tuned in the ultraviolet (UV) selectively cures regions in the polymer to form a single layer of the build. Once a layer is finished, the build plate drops further into the polymer bath so that a new layer can be cured. A schematic is shown in Figure 4. Due to the nature of the curing process, SLA is limited to photopolymers, i.e. polymers that solidify or crosslink when exposed to UV light.

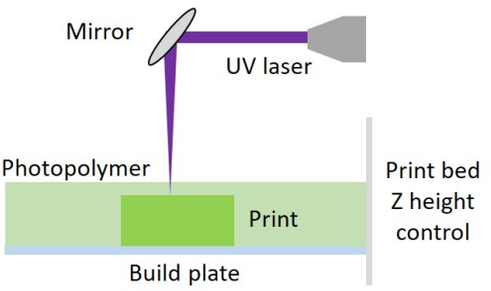

Figure 4: A schematic for a stereolithography (SLA) 3D printer

The term stereolithography was first used by Chuck Hull, who then went on to patent the SLA technology in 1986 [1], several years before FDM was initially patented. In a similar way to Crump and the founding of Stratasys, Hull went on to cofound the company 3D Systems, which at the time was the first 3D printing company of its kind [15]. In the current market situation, printers of this type that can produce parts of the quality and size required for industry typically cost hundreds of thousands of pounds. Fortunately, as the demand for 3D printing technologies increases, it is becoming more economically viable to produce consumer-grade printers using SLA. As an example , there are now smaller versions of SLA machines that are around 100 times cheaper than their fully-sized industrial counterparts, such as the Formlabs Form 2 [16]. For even less money, very compact desktop machines are available for as little as £250 [17].

3.2 Direct Light Processing & Continuous Direct Light Processing

The Direct Light Processing (DLP) technique is similar to SLA but it relies on a light screen instead of a laser to cure all parts of the layer simultaneously. This reduces print times but it has the disadvantage that the print will be made up of small cubes, called voxels, corresponding to the pixels on the screen, which reduces the surface finish.

Another similar technique is Continuous DLP, which has the curing light in constant operation, such that the build plate must be constantly in motion. This further reduces print times compared to DLP and SLA, although there is still an issue with reduced resolution due to the pixels in the light screen.

4. Material Jetting

Material jetting (also known as PolyJet printing [18]) depends on the same type of technology as regular 2D inkjet printing, that is, liquid material is jetted onto the build plate and is cured using UV light or high temperatures (depending on the

material used). The technologies available include regular material jetting, which uses photopolymeric resins like those used in SLA, and there are more specialist machines that function with metals or wax.

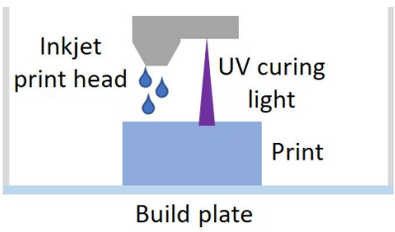

Figure 5: Schematic of a material jetting printer

Objet, who are now a part of Stratsys, were the pioneers of the material jetting technology, where several small nozzles are used to deposit liquid polymeric material onto the build plate, which is cured using a UV lamp (Figure 5). Multiple materials can be used simultaneously and this allows the mixing of polymers to achieve different mechanical properties. This also permits the deposition of separate scaffolding material that can be dissolved away once the print has finished. Due to their good surface finishing and the potential of mixing multiple materials for a variety of mechanical properties, these printers are excellent for prototyping; using this technology a prototype can have the same look and feel in hand as a real product would. These types of printers are therefore regularly found in use by companies such as Oxford Rapid Prototyping [19]. In addition to prototyping, MJ can also be used to produce moulds for injection moulding, like with SLA.

While the visual quality of the parts is often excellent, the thermoplastic polymer resins that are used for this type of printing often have poor mechanical properties such as brittleness. The liquid resins are also expensive at several hundred pounds per kilogram and have short shelf-lives due to their sensitivity to UV, meaning that for many applications this method of producing parts is not cost effective.

4.1 Nanoparticle Jetting and Drop-On-Demand

Nanoparticle jetting, trademarked by the company XJet [20], uses a liquid containing nanoparticles of metal or support material. Once each layer is deposited the liquid is evaporated using high temperatures and it leaves behind the metal or support material. Drop-On-Demand (DOD) printers are used to produce wax parts which are most often used for investment casting purposes. Here the material is again in liquid form and is deposited in a point-like fashion.

5. Powder Bed Fusion

Powder Bed Fusion (PBF) methods use a thermal process to sinter and solidify powders of polymers or metals. Because there is no liquid involved (unlike in Vat Polymerization) the powder must be evenly spread over the build to achieve accurate layers.

5.1 Selective Laser Sintering & Selective Laser Melting

One of the most efficient ways at selectively melting or sintering a powder is using a focussed laser. For this reason, laser sintering and melting are the main PBF methods of producing polymer and metal parts respectively. Selective Laser Sintering (SLS) is the name for processes involving production of polymer parts from powder which is sintered in thin layers at a time. Developed by Carl R. Deckard in the 1980s, with a patent for the technology granted in 1989 [21], this method does not require an additional curing step and so does not require the use of photopolymer material. This results in a larger range of materials that are available to use.

Selective Laser Melting (SLM) (also known as Direct Metal Laser Sintering, or DMLS) is used to produce metallic parts from powder precursors. It involves fully melting the metallic powder which cools to forms a solid object (see Figure 6). The techniques are not limited to single element metals so engineering alloys such as Ti-6-4 and nickel superalloys can also be printed. The major disadvantage of these two processes is the high costs; traditional manufacturing methods may still be more cost effective for simple designs. Regardless of this, there is a wide range of manufacturers producing SLM and DMLS machines including 3D Systems [22], Renishaw [23] and EOS [24].

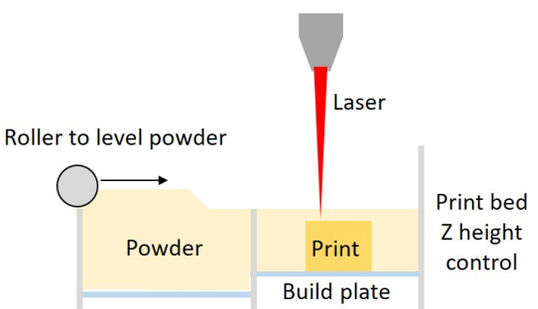

Figure 6: Schematic of a selective laser sintering (SLS) or selective laser melting (SLM) printer

These two methods play an important role in the manufacture of components for use in the automotive and aerospace [25] industries. Boeing [25] and Bugatti [26] are two such companies, with Boeing introducing 3D printed titanium structural components into some of their new aircraft [25], while Bugatti are the first car company in the world to develop titanium brake calipers via 3D printing [26]. The combination of strong metallic materials and the possibility of producing components that are impossible to produce via standard casting/machining methods means that these high-performance parts can be produced with lower weights and less waste material. Another cutting-edge example in aerospace is the fully 3D printed SuperDraco engine chamber built by SpaceX, which will be used for crew-carrying flights into low orbit [27], [28] . These engine chambers were made using Inconel (a nickel-based alloy) and printed using a DLMS machine produced by EOS [24]. SpaceX have also flown 3D printed parts on their Falcon 9 rockets [27].

5.2 Electron Beam Melting

In a similar process to the other PBF methods, Electron Beam Melting (EBM) employs an electron beam rather than a laser to melt the powder. The electron beam requires less energy than the laser which means that the running costs can be reduced. The process is also faster and the final print has less residual stress

due to cooling. However, it generally has a lower resolution and a worse surface finish than SLS and DMLS and is used less frequently as a result.

5.3 Multi Jet Fusion

Multi Jet Fusion (MJF) relies on a combination between SLS and Material Jetting technologies as a method to produce plastic parts. Developed by Hewlett-Packard, these machines deposit a fusing agent on a thin layer of polymer powder, while a detailing agent is applied near to the edges of the design to prevent sintering [29]. A high energy infrared source is used to activate the fusing agent and it causes the powder to solidify only in the presence of the fusing agent.

6. Binder Jetting

As the name suggests, Binder Jetting uses a binder to solidify layers of powder together. The powder, either ceramic, metallic or sand, is spread in a thin layer and the binder is jetted over the desired areas to solidify it (see Figure 7). Once the build is finished, post processing is usually required, and extra chemicals are often added to improve the material's mechanical properties. Ceramic parts produced by this method have excellent surface finishes, making it a suitable method for producing objects that require very exact dimensions, such as packaging and even sculptures. Metallic parts made using this method can be functional and tend to have lower production costs than those produced with SLM and DMLS. High porosity in samples can lead to poor mechanical properties, but this can be addressed by adequate sintering after printing [30].

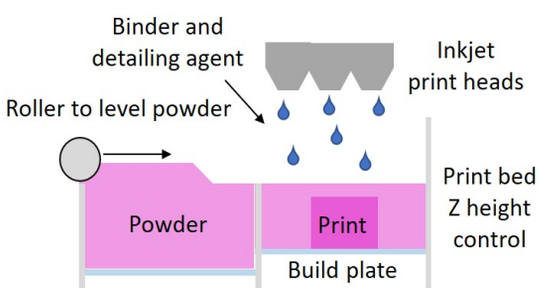

Figure 7: Schematic of a binder jetting printer

One very useful application of Binder Jetting is the production of sand-casting moulds. During the sand-casting process molten metal is poured into a mould made of sand to produce a part. The mould is traditionally created by packing sand around a high-resolution model of the part, which is usually machined, requiring lots of time and resources. Using Binder Jetting, however, the mould can instead be made quickly and cheaply, without the use of a model, and can even have more complicated geometries than can usually be achieved by machined [31].

7. Direct Energy Deposition (DED)

This type of manufacturing process concerns melting a metal powder or wire material as it is being deposited. In particular, these methods are well suited to adding metal to existing parts or performing repairs, so they are not used as often as the other methods mentioned to make parts from scratch. There are two types of DED: LENS and EBAM. Laser Engineered Net Shape (LENS) uses a laser to head

the print bed as the material is deposited, whereas Electron Beam Additive Manufacturing (EBAM) uses an electron beam to heat the metal powder or wire, welding it to the rest of the build material. One advantage to these methods is the great extent to which the microstructure of the metal material can be controlled – something which is often more difficult in other methods of metal additive manufacturing, and is greatly important with regards to ensuring good mechanical properties [32].

8. Conclusions

Additive manufacturing has proven to be a significant step forward in manufacturing technologies, allowing product development to be much faster and cheaper in many cases. It also allows entirely new designs that were not achievable by standard methods (machining or casting) to be possible. As we have discussed, there are several different technologies available, each with their own advantages and disadvantages. The most affordable printers available are desktop FDM printers, but these are limited to using a relatively small selection of polymer materials. For more structural applications, metal printers based on SLM technology are available, although at a much higher cost. A common application of many of these AM types is prototyping, due the ease of changing designs and rapid production of the models. However, across the full range of technologies there are uses in aerospace, medicine, and tool and mould production, to name a few.

Currently, 3D printers are still mostly used in industry and academia, but in recent years there have been significant increases in ownership of 3D printers in the maker/enthusiast community. With the price of additive manufacturing technologies dropping all the time, it is possible that a printer could become as common a household item as an iron or kettle. In the future we might not have to go to shops or look to specialists to get replacement parts or custom-made items, we might instead be able to make some from the luxury of our own homes.

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Understanding Secularism and Secularisation: A Case Study of India

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Abstract. *This paper focuses on the separation of secularisation and secularism from a conceptual lense embedded in the theoretical frameworks presented by contemporary literature. It provides a timely contribution into the understanding contemporary manifestations of religiosity better, in a more holistic manner. The first section of the paper broadly defines the terms secularism, secularisation, manifestation and religiosity. Separation of these two terms, secularism and secularisation, are extremely important as they are often used interchangeably in academic and non-academic literature alike. However, it is not only important to conceptually separate them but also understand the historical processes behind them. Building on these definitions, the paper then offers an analysis of secularism as a concept and its importance in furthering the understanding of religiosity. Furthermore, the paper approaches secularisation in a way to distinguish it as a separate conceptual construction from secularism. Finally, it introduces the case study of contemporary India to further the thesis presented and concludes by summarizing the overall arguments. This paper provides a unique approach to understanding religion in the contemporary world and furthering the debate on religiosity in modern life across both the global south and north.*

* * *

Secularisation as a "historical process" underwent a unique form of "ideological inversion" (Asad 2003, p.192). "The secular" was once part of a "theological discourse" and stemmed from religion itself rather than politics and science (ibid.). In contemporary times – with the inversion of the relationship – the secular discourses constitute "the religious' and religion emerges as a 'construction of the Western secular modernity" (Casanova 2008, p.111). Secularism and secularisation are surprisingly complex and intertwined but are critical to the understanding of manifestations of religiosity. This essay unpacks and analyses their construction as separate concepts using a contemporary case study to support the argument.

The first section of the essay will broadly define the terms secularism, secularisation and manifestation of religiosity. Building on the definitions, the second section will analyse secularism as a concept and its importance in furthering the understanding of religiosity. In the third section, the essay will approach secularisation in a way to distinguish it as a separate conceptual construct from secularism. The fourth section will introduce a case study of contemporary India to further the argument presented. Lastly, the essay will conclude summarizing the arguments presented.

Secularism – in broad and over-simplified terms – is a political project, doctrine and ideology that manifests separation between religion and other aspects

of the society. Asad (2003) has argued that it is much more than that as it "presupposes new concepts" and "new imperatives" in context of religion, politics and ethics (p.2). Philpott (2009) argues secularism is an ideology that marginalises religion from other spheres of society (p.185). Others such as Hallward (2008) maintain that it describes a 'quasi-religious ideology' that contends with religion (pp.2-3). Secularisation – the process and social construct – focuses on the decline of religion in the contemporary world.

The shift of religion and its practice from the public to the private sphere is critical to the understanding of secularisation (Fox 2013, p.22). Asad (2003) describes secularisation as a "process" rather than an ideology. It manifests the privatisation of religion and the increase or decrease in religiosity in the public sphere (Iqtidar 2012, p.54). Secularism and secularisation are complex concepts with multiple and varied meanings. Within this complexity, as Asad (2003) has argued, we must anchor in and relate to religion to understand both these concepts. It is useful to consider manifestations of religiosity as a term rather than two separate concepts. There is no consensus on a specific meaning for the term as there is no single definition of religion that is applicable universally (ibid., p.29). It reflects distinct yet overlapping experiences, belief systems and values associated with spirituality, transcendence and the divine (Berdyaev 1939, Elkins et al. 1988, Mattis 2000; 2002, Potts 1991). Broadly, it reflects the manifestation of religious practices in both public and private sphere and their impact on socio-political structures.

Understanding secularism, the political project and ideology, as a distinct concept from secularisation is critical in unpacking the practice of religion around the world. Manifestations of secularism, on the other hand, are often seen as an alternative to religion and in direct competition with it (Philpott 2009, pp.185-186). Thinking of secularism as an opposing force to religion or something that replaces religion is a popular strand of thought (Juergensmeyer 1993; 2008, Philpott 2009, Stark 1999, Taylor 2007). Secularism as a political doctrine that allows public discourse in a manner that is neutral and non-religious emerged out of religious conflicts by providing some form of lowest common denominator to the over-arching socio-political system (Taylor 1998, pp.2-3). This position is somewhat paradoxical, as Asad (1993, 2003) argues, since we cannot think about what secular constitutes without referring to religion. The tendency to regard religion as alien to secular ideals and practices is self-contradictory (Asad 2003, p.193). Over centuries, secular beliefs paved the way for the rise of mysticism and "oppressive religion", while in more contemporary times it is secularism that helps more moderate manifestations of religiosity to take shape (ibid., p.193). The process works like a feedback mechanism, where the definitions of secular, secularism and secularisation depend on how we define religion and vice versa.

Secularism is not merely the separation of the religion from the state; rather it is the 'continuous management' of religion by the state (Iqtidar 2012, p.54; Asad 2003, pp.190-191). Contemporary manifestations of religiosity including practice and beliefs are increasingly under state management. A Eurocentric illustration is the gradual erosion of the power of the Catholic Church and its eventual

displacement as the centre of power in Europe. The Reformation and the dissolution of Western Christendom reduced the role of papacy as the leader of a global Christian monarchy embodied in the Holy Roman Empire (Casanova 2008, p.107). Before Reformation, the Catholic Church exercised control of national churches, owned vast amounts of land, provided social services, education and health facilities to people through the Treaty of Westphalia 1648. The treaty excluded papacy from European and national affairs of the states (ibid., p.107). Nation states replaced the historic functions that the Church had monopolised for centuries signifying a separation of religion from the state. In modern Europe, Catholic groups such as Opus Dei – a personal prelature of the Pope – still represent and model the historic nature of the work of the Vatican by running schools, universities, social security schemes, and homes for old and orphans (Tourneau 1987, pp.9-23). The difference is that today organisations like Opus Dei function within state laws and constitutions and not under Vatican laws. Through the example of Opus Dei it can be argued that secularism is identifiable as a concept distinct from secularisation and it is useful to think of it as the management of religiosity.

The dual use and interchange of secularisation and secularism is very common but a conspicuous misconception. Charles Taylor (2007) contends that secularism is an ideology that constitutes secularisation. Secularisation is the "move from a society where a belief in God in unchallenged . . . to one in which it is understood to be one option among others" (Taylor 2007, p.3). This is a 'profoundly wrong' position because secularism, the project, does not simply constitute secularisation (Fox 2013, p.30). Secularisation is the quantitative increase or decrease in manifestations of religiosity in the modern era. People who have less belief in religion or are not religious at all have always been present in society. The fact that these groups can now identify with an ideology – secularism – does not mean that there is an empirical decline (Stark 1999, pp.249-273). A large body of work in secularisation theory (Dobbelaere 1999, Haden 1987, Philpott 2009 and Stark, 1999) concentrates on the empirical decline in religion focusing on quantity. The emphasis on qualitative aspects in decline or rise in religiosity is under-appreciated (Iqtidar 2012, p.54). In the conceptual unpacking of secularism, emphasis on both quantitative and qualitative aspects of secularisation is important as the latter can help explain empirical trends witnessed in various religions.

An understanding of the distinction between the public and the private is critical to building an understanding of what constitutes secular. Secularisation theorists such as Chaves 1994, Dobbeleare 1999, Philpott 2009 and Wilson 1982 among many others predict declining religious influence in the public sphere. Religion and its practice are gradually moving from the public sphere into the private (Fox 2013, p.22). Although on the decline, religion may remain an integral part of people's private life and individual beliefs. Secularisation process involves an increase in the autonomy of secular institutions and an increase in the conformity of religious ones to the broader secular world (Wilson 1982, p.149). This privatisation of religion forms a core part of the secularisation theory that furthers understanding of religiosity. The three basic processes in classical secularisation

theory are (1) differentiation of religion from the secular sphere, (2) decline and (3) privatisation of religion (Casanova 1986, pp.1-7). Casanova (1986) using empirical evidence and case studies argues that religions went 'public and deprivatised' through resurgence and that privatisation is not a rule among secularisation thesis (p.3). Differentiation of religion from state, market forces and political power structures forms the "defensible core" of the secularisation theory (ibid., p.7). Asad's (2003) contention that deprivatisation unravels this defensible core of differentiation is very convincing, since both the conceptions are intrinsically connected and not mutually exclusive from each other. Through the ideas discussed above, we can conceptualise secularisation separately from secularism.

The case study of India illustrates secularism and secularisation a separate concept that help understand not just religiosity but also the socio-political environment. India is historically not a single nation but rather a collection of communities practicing their own faiths, traditions and customs. Nehru envisaged the newly independent India as a secular state with a vision of taking the country towards modernity (Khilnani 2006, pp.100-103). Under the Congress Party, India worked its way towards achieving modernity through secularism. India's political leadership believed that to modernize, the country would have to move away from traditional religious practices and superstitious beliefs. Nehru's ideas about secularism shaped the approach that the Indian National Congress - and especially, Indira Gandhi - used in the 1960s and 1970s. The Indian Constitution is secular in its outlook and provisions in Articles 13 to 17, 19, 23 and 25 to 30 lay down the fundamental rights explicitly allowing for freedoms for all religions in an equal manner (Madan 2010, pp.249-248). Article 44 that forms part of the Directive Principles declares that "the State shall endeavour to secure for the citizens a uniform civil code throughout the territory of India" (ibid., p.249). In 1976, the 42nd amendment introduced the word 'secular' in the Indian constitution's preamble for the first time and this represented the point when India adopted secularism as a state project (Sen 2006, p.371).

Secularism in India is distinct from secularisation and this separation helps us understand manifestations of religiosity in the country's diverse Hindu, Muslim, Sikh, Jain and other groups in much better light. It is not only distinct but also very unique from the classical Western conception of secularism both in its nature and implementation. Amartya Sen (2005) explains that there are two forms of secularism, one where there is complete separation of state and religion and the other where the state maintains all religions at an equal standing (Sen 2005, pp.16-33). India, as Sen argues, has a form of secularism that treats all religions in an equal and fair manner, or at least, that is the state policy. Given Indian subcontinent's diverse cultural history and plethora of religious practices, the policy is both pragmatic and problematic. This closely relates to Asad's (2003) view on secularism as the state management of religiosity among its populations. The Indian state manages its diverse religious groups both politically and socially especially through funding and provision of places for worship. When the state project of management comes in direct conflict with certain manifestations of religiosity – e.g., Sikhism in 1980s – the state forces the religion to comply (Madan 2010, pp.101-105).

Indian society, or one should say societies, never managed to adopt secularisation. Religiosity increased in India in the years after the independence especially in the political sense. Communal riots between the Hindu majority and the other minorities occur regularly despite the fact the constitution is secular and India is a great triumph of Western liberal democratic models (Asad 2003, p.8). The rise of Hindu nationalist parties in the 1960s and 1970s with movements such as the *Rashtriya Swayamsevak Sangh* signified an increase in the manifestation of religiosity among the Hindus (Noorani 2000). Conflicts with other religious minorities, such as the anti-Sikh riots (1984), Babri Masjid demolition (1992) and Gujrat violence (2002) illustrate the rising religious tensions within India (Rajagopal 2006, pp.209-212). This reflects that religiosity is on the rise in a secular India, not just on part of Hindus, but also among other religious communities. Indian Muslims, following their own laws, are at odds with the majority Hindu population which often reflects in the voting patterns at the time of the general elections. The recent projection of the Hindu nationalist *Bhartaya Janta Party* to the central government in the 2014 election laid many of the religious cleavages bare when Hindu nationalist groups started asserting their influence.

The underlying cause of these tensions and religious conflict is the failure of the Indian society to embrace secularisation despite the presence of state secularism. Conceptual separation of secularism and secularisation helps to clarify the case of India. Religions are part of India's culture and social life since ancient times and deeply rooted within socio-political structures. A Hindu majority in a nation with many other religious minorities further undermines secularisation processes in the country (Thapar 2006, p.193). Jawarhal Nehru explained the dilemma of Indian secularisation aptly; the "Constitution lays down that we are a secular state, but it must be admitted that this is not wholly reflected in our mass living and thinking" (Gopal 1980, pp.330–1). Secularism exists in India as a state project and political ideology, but secularisation never took hold in the society. Casanova (1986) did not focus on India in his seminal work on public religions, though contemporary India shows the rise of religiosity and de-privatisation of religion.

Investigation into the causes of the secularisation failure in the Indian case leads us back to Taylor's (1998) arguments. Secularism stemmed from the problems in Western society managed by the Church and is applicable to all non-Western societies (Taylor 1998). Classical secularism as we know it is a Eurocentric construct. Scholars like Asad (2003) rightly point out that secularisation preceded secularism in Europe and not the other way around. In non-Western societies like India, states want to usher in a process of secularisation through secularism. The Indian case does prove to some extent that this is not always a success. Structured and well-informed scholarship into the conceptual separation of the two concepts can help us understand the manifestations of religiosity around the world in much more depth and detail.

We can further the understanding of religiosity by drawing the distinction between secularism and secularisation in many other nations as well. The Iranian

Revolution (1979) marked the drift of a secular state under the Shah towards a religious theocracy under the Ayatollahs. The secularism adopted by Reza Shah in 1924 not only separated religion from the state but also subdued and repressed all forms of religious expression particularly Shiite Islam (Ashtiani 1994, pp.66-70). It was this repression of dissent and suppression of religiosity that paved the way for the Revolution in 1979, which Foucalt described as the "first post-modern revolution of our time" (ibid., p.51). Modern France with its state led secularism bans the burqa and other manifestations of religiosity. The French society, in particular its Muslim and Jewish communities, failed to secularise despite the state being secular. Recent attacks such as the one on *Charlie Hebdo* represent the differences between secularism and secularisation in France.

This essay unpacked both secularism and secularisation as separate concepts using insights and arguments from a range of theorists working in the field. Often these two concepts are inter-changed and used synonymously. Seminal work in secularisation theory such as that of Taylor (1998, 2007) revolves around secularism and secularisation being mutually inclusive to some extent. Arguments from the likes of Asad (2003) refute this position by providing insights into secularism as a political project and secularisation as a process in the social structures. The case study example of India sheds light on the usefulness of separating these concepts to understand religiosity around the world. It also illustrates that the Indian secularism model is distinct from our classical Eurocentric construction of secularism. In conclusion, this conceptualisation is not only useful but also crucial in analysing and furthering the understanding of religiosity.

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Emerging Viral Pathogens: New Threats in Global Health

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Abstract. *Emerging Viral Pathogens are some of the most deadly disease that humanity have to face, with high mortality rates and the potential to cause mass panic. The Ebola crisis in 2013-2015 and the Zika outbreak of 2016 brought the dangers of emerging pathogens to the public consciousness, as well as earlier crises such as Swine flu, Avian flu and SARS this millennium. Often occurring at the frontiers of humanity, emerging pathogen outbreaks are predominantly zoonotic, jumping from animal hosts into humans with no pre-existing immunity. In this review I introduce the biology of emerging viral diseases, how they infect human hosts, look at case studies on emerging pathogens with pandemic potential and consider HIV, an emerging pathogen which has reached pandemic levels.*

* * *

Introduction

Emerging pathogens present one of the biggest biological threats to human health. 100 years ago Spanish Flu ravaged the world following WWI, causing illness in up to 30% of the population [1] and killing 100 million; many more fatalities than the preceding four year war. Even further back, the synergy of black death in the old world[2], and smallpox in the new, is considered a contributory factor in the Little Ice Age[3]; lower populations unable to farm sufficient land to prevent forest regrowth and thus CO_2 absorption. In the late 20th and early 21st centuries we have seen the outbreak of HIV[4], Ebola[5], SARS[6] and multiple strains of pandemic flu[7-8]; all representing major threats to global health.

The most severe emerging pathogens, and the ones discussed in this review, are often viruses. Viruses are one of the smallest biological entities, consisting of nucleic acid (either RNA or DNA), wrapped in a protein shell called a capsid[9]. Virus structures are so small and their parasitic lifestyle so different to, and dependent on, other organisms that their definition as living remains a scientifically contentious issue[10].

The Viral Life Cycle

The viral life cycle (Fig. 1) begins when a virus adheres to a host cell. The interaction is mediated by two proteins; one on the virus, one on the target cell. The first is the viral glycoprotein, a protein which has been modified by covalently attached sugars; this glycosylation determined by the antecedent host cell [11]. The glycoprotein is unique to each virus species and, exposed on the capsid or viral envelope surface, can interact with the host. To initiate cell entry requires the binding of the viral glycoprotein with a host membrane protein. Each viral glycoprotein interacts with a specific receptor, or set of receptors, displayed on the target cell membrane[11]. The variation in receptor expression across host cell types and between host species determines the tropism ("cell-specificity") of viral infection[11].

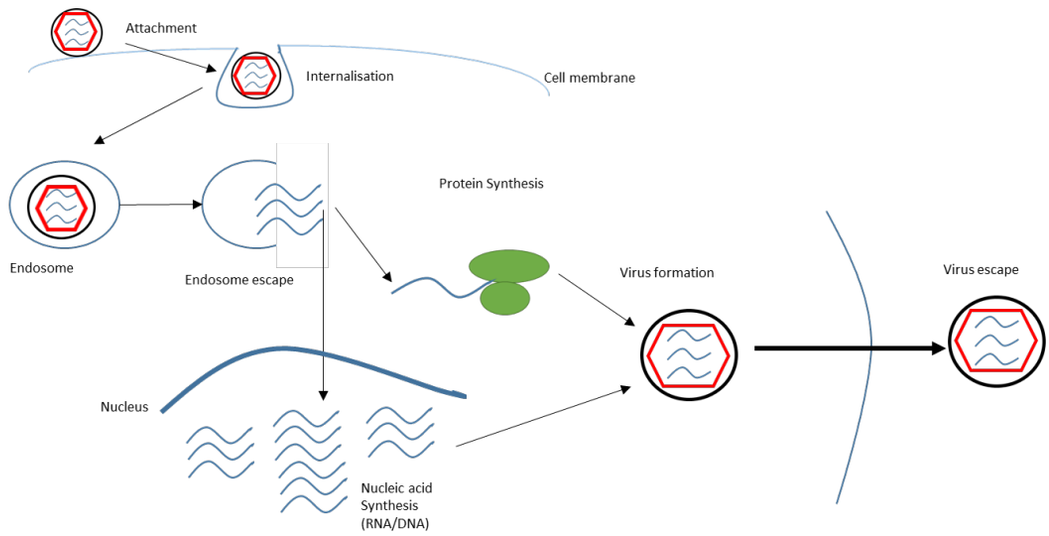

Figure 1 Schematic showing the viral lifecycle of an enveloped virus. Viruses enter cells by a variety of mechanisms. Enveloped viruses attach to the cell surface and are internalised into an endosome; an intracellular membranous compartment. The viral envelope can fuse with the endosomal membrane, releasing the viral genome into the host cell. The host cell machinery then replicates the viral genome and translates its genes into viral proteins. The viral genome and proteins assemble into a capsid, containing the genetic material to produce more viruses in future host cells.

Measles (MeV) is well characterised virus with an elucidated entry mechanism. The surface hemagglutinin is the glycoprotein[12] and can interact with multiple cell surface receptors, such as SLAM and Nectin-4[12]. However, within the same species we can see viral glycoproteins adapt to target new receptors. The hemagglutinin of a MeV laboratory strain has adapted to bind to, and initiate cell entry through, the CD46 protein[12] for example (Fig. 2). The adaption gives the virus a broader target cell tropism, and has been seen in mutant populations outside the lab[12].

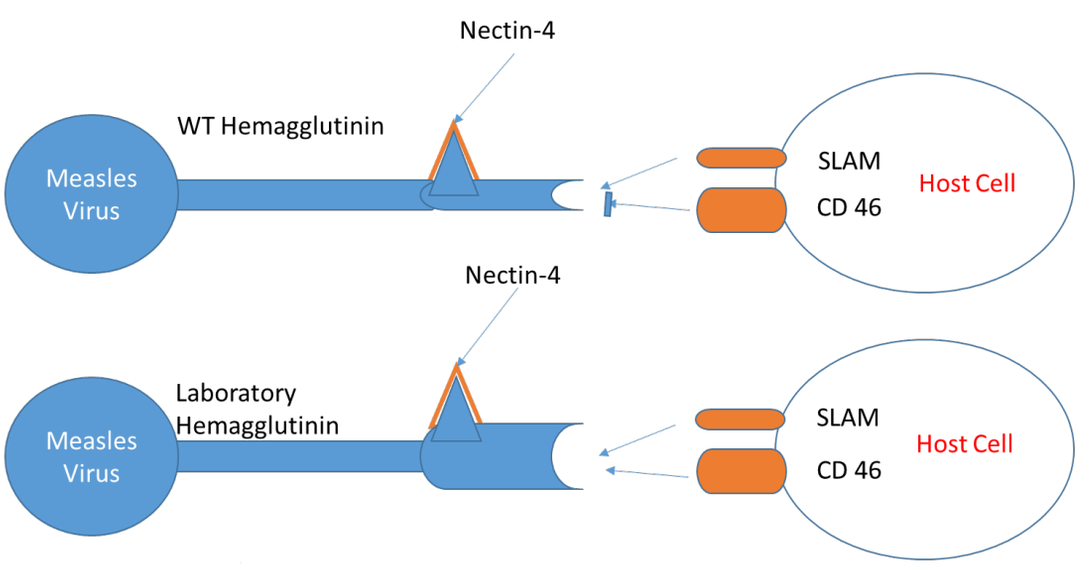

Figure 2 Binding of WT and Laboratory Strain MeV hemagglutinin on the viral envelope to receptors on the host cell surface. The strains differ by a hemagglutinin mutation, allowing the

laboratory strain to bind to a wider range of receptors on the host cell surface; hence allowing a wider repertoire of cell types to be targeted within the host.

PPR (Peste des petits ruminants) is a potential emerging pathogen closely related to measles. In small ruminants its symptoms include fever, gastroenteritis and necrotizing stomatitis, culminating in death[13]. The differences lie exclusively in host receptor preference. PPR hemagglutinin, like MeV hemagglutinin, binds to the SLAM receptor on the cells of sheep and goats, initiating cell entry[13]. However, due to small mutations on the SLAM receptor between humans and ruminants, the PPR hemagglutinin cannot bind to human SLAM; preventing PPR from making the jump from animal pathogen to emerging human pathogen.

Emerging pathogens arise when diseases such as PPR make the jump from an animal to a newly exposed human host, with glycoproteins that bind readily to human cell surface receptors, allowing the virus to replicate throughout the human host. These interspecies jumps, to a host with no pre-existing immunity or evolved resistance, result in an unchecked infection before the body can develop an adaptive response against the new pathogen, leading to high mortality rates. I will now consider some of the most dangerous emerging pathogens of the 21st century, avian influenza and Ebola.

Avian Influenza

Avian Flu is one of the most commonly feared emerging pathogens, periodically breaking out in pockets across the globe. Flu has earned this reputation as a consequence of its ubiquity, annually killing up to 650,000 people worldwide[14]. The aforementioned Spanish Flu[1], for example, was one on the most lethal epidemics humanity has ever seen.

Flu is a negative sense strand RNA virus, of the family *Orthomyxoviridae*, with a genome divided into 8 segments[15]. Specific strains are defined by two surface glycoproteins, hemagglutinin (H) and neuraminidase (N). Alongside native pools of infectious influenza in humans, it is also endemic in bats, birds, pigs, dogs and cats[15]. Within their endemic species, influenza circulates and would not be classed as an emerging pathogen. However, influenza pandemics can occur when the genomes of influenza from different species re-assort[15]. Often using pigs as melting pot[16], re-assortment occurs when two strains of influenza simultaneously infect the same cell (Fig. 3). The two parent viruses proceed to produce capsid proteins and copy their RNA into 8 segments. As the RNA gets packaged, genetic material from different parent viruses can end up in the same capsid, producing a recombinant organism. With co-infection of just two strains there are 256 different possible combinations in which the RNA can be packaged, producing a huge number of variant strains. The result is a virus that can potentially infect a new organism with little pre-existing immunity. Noteworthy examples of this include swine flu[16] (H1N1) and avian flu[17] (H5N1).

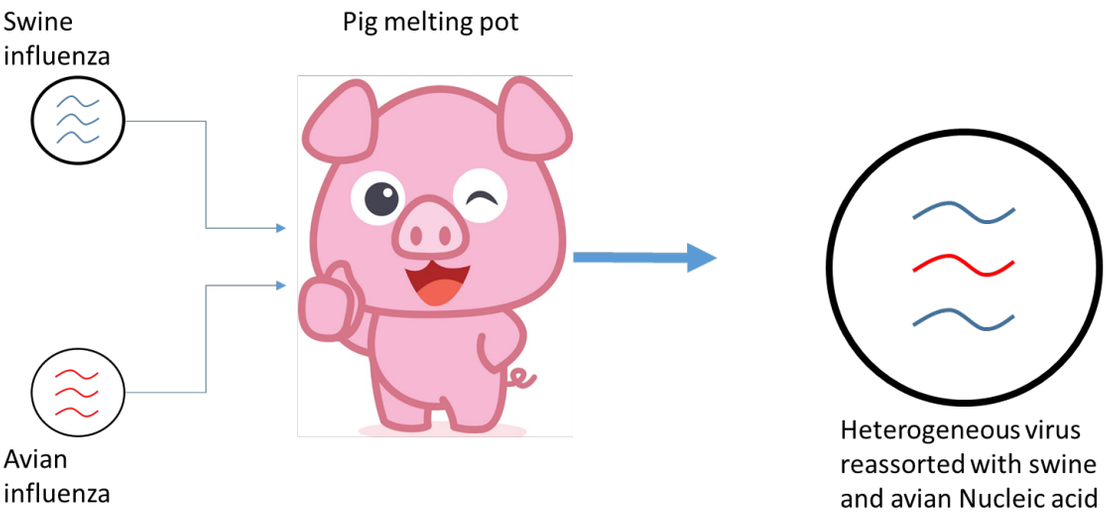

Figure 3 Re-assortment of two distinct strains of virus during co-infection. Swine and avian influenza can both infect pig cells. During virion formation strands of RNA from each can be re-assorted into the same capsid, producing a virus with a mixed heritage, better able to infect new targets. Though illustrated with influenza, such re-assortment is extremely common in segmented genome viruses including Rift Valley and Crimean Congo Haemorrhagic Fever; both WHO neglected emerging pathogens.

H5N1, a purely avian influenza with no circulating human strain, appears to have evolved in the late 20th century[17]. It infects many species, including poultry and wild birds[17]. On infection of the former, the close contact with keepers provides sufficient exposure for the virus to make the species jump from birds to humans [17]. Once contracted H5N1 has an estimated 50% mortality rate in humans[18], which would cause a catastrophic pandemic if human-human transmission became commonplace.

Influenza is clearly a dangerous emerging pathogen. The relative mildness of seasonal flu makes populations complacent about the risk. However, combining significant levels of contagiousness with potentially high mortality rates, influenza likely poses the largest risk to global health of any emerging pathogen.

Filoviruses

The filovirus family contains two viral species, *Marburgvirus* and *Ebolavirus;* some of the most lethal pathogens known to man. The family contains six species, Marburg virus (MARV) and five species of Ebolavirus. The Zaire, Sudan, Tai Forest and Bundibugyo strains all cause human disease[19], whilst Reston Ebolavirus only infects monkeys [19]. Reston is also unique in that it is native to the Philippines[19]; 10,000Km from Sudan, the closest reservoir of any of the other filoviruses. Here I

will focus on the worst filoviruses, the Zaire (up to 90% mortality)[20] and Sudan (up to 65% mortality) strains [20].

The first records of Ebolavirus occur in 1976[21], with the first Sudan outbreak occurring in July (65% mortality rate)[21] and the first Zaire outbreak beginning in late August[22] (88% mortality rate[20]) of that year. Such devastating mortality is one of the hallmarks of emerging pathogens. For Ebolaviruses a challenge has been finding the original animal reservoir. The first transmission of ebolavirus into humans is thought to have come from contact with animals, probably via consumption of bush meat[22]. Though filoviruses appear to have spread to humans from monkeys or apes, we know that they cannot be the natural host, as they also suffer severe mortality from these infections [23][24]. The most likely animal reservoir are bats[25], which are also the reservoir for Marburgvirus; though how they remain infected without symptoms is unknown.

Ebolavirus infection causes severe haemorrhagic fever, as uncontrolled viral replication destroys host cells and leads to systemic infection. The Ebola glycoprotein binds NCP1[27], a cholesterol transporter expressed by many cell types. This gives Ebolavirus the potential to infect a wide range of species and cell types, thus producing simultaneous infections across the body. Particularly targeted are dendritic [28] and endothelial cells[29]. Targeting the former helps Ebola infections evade the adaptive immune response[28], allowing infection to spread unchecked. Specific targeting of endothelial cells causes the symptoms of haemorrhagic fever. As these cells lyse on virus particle exit, blood vessels weaken resulting in bleeding in the GI tract[29], and out of all bodily orifices[29]; a truly horrific series of events leading to rapid death in the majority of infected individuals. Cause of death is hypotension following mass blood loss, leaving the afflicted unable to supply sufficient oxygen to their tissues.

HIV

Human Immunodeficiency Virus (HIV) is one of the most successful emerging pathogens, having spread as a pandemic around the world and now thought to have infected 70 million people[30]; with almost 35 million people dying of AIDS (Acquired Immuno-deficiency Syndrome) in the last 40 years[30]. HIV is part of a family of immunodeficiency viruses, which infect mammals including both cats[31] and non-human primates[32]. The latter appear to be the endemic host of the HIV-related SIV (Simian Immunodeficiency Virus), which circulates in the population, without causing AIDS-like symptoms[32]. At some point in the 1970s, contact between non-primate and human bodily fluids led to transmission into humans[33]; an event only apparent many years later when AIDS was first recognised in 1981[33].

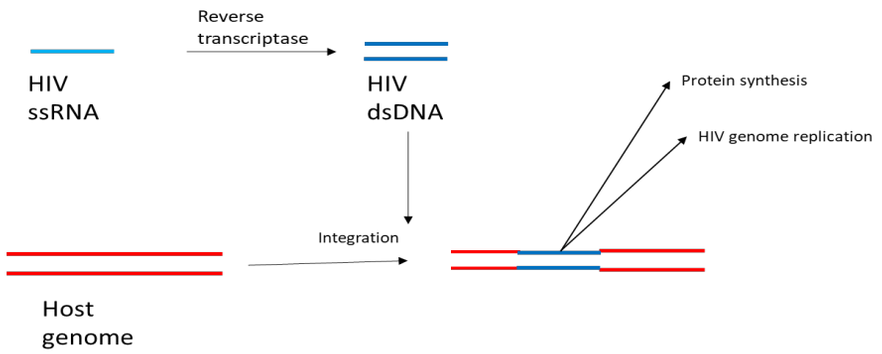

Figure 4 Reverse transcription in the retrovirus life cycle. HIV has a single stranded RNA (ssRNA) genome. Reverse transcriptase, encoded by HIV, copies ssRNA into double stranded DNA (dsDNA) which is then integrated into the host cell genome. From here it can be transcribed back into RNA, facilitating HIV genome replication or protein production.

The HIV-1 M strain is responsible for the continuing pandemic and initiates cell entry through interaction between CD4 and another receptor[34]. The requirement for CD4 binding determines cellular tropism as HIV only infect $CD4^+$ T-cells[34], part of the adaptive immune system. The virus is further split into the two sub-strains depending on the accessory receptor used to initiate cell entry. The R5 strain uses CCR5, whilst X4 uses CXCR4[34]. Post entry, HIV replication is different to that of the previously discussed viruses. HIV is a retrovirus, meaning that in execution of its lifecycle the viral genetic code of the virus is integrated into the host genome[35]. Integration is achieved by reverse transcribing its RNA genome, converting the genome into DNA, which is then inserted into the genome of the host[35] (Fig.4). With HIV DNA within the host cell nucleus the virus remains relatively dormant, producing low levels of virus particles[35] which remain undetected by the immune system.

AIDS arises after many years of such asymptomatic infection, during which HIV can be disseminated without the afflicted knowing they are a carrier. After a period of latency, which can vary widely, the patient progressively develops AIDS[36]; typified by significant depletion in $CD4^+$ T-cells within the immune system. Although $CD4^+$ cells are destroyed in the early stages of infection, pre-AIDS[36], these are regenerated from stem cells, allowing the immune system to continue to function. The ability for the immune system to regenerate degrades with chronic HIV infection[36] however, and eventually the body can no longer replace the lost $CD4^+$ cells, leading to rapid depletion and onset of AIDS[36]. $CD4^+$ cells are a crucial part of the immune system, known as T-helper cells[37]. They manage the rest of the immune system, activating in the case of pathogenic threats[37] and dampening responses against the host's own proteins[37]. $CD4^+$ cells also modulate the host response depending on the pathogen, activating tailored responses against viruses, bacteria and parasites[37]. Without $CD4^+$ cells to regulate the immune system in AIDS, immune responses cannot be mobilised. The hallmark of AIDS is the presence of secondary opportunistic infections such as the bacterial *Pneumocystis carinii*, or *Mycobacterium tuberculosis*[36], viral infections such as herpes simplex or adenovirus[36], or opportunistic cancers such as Kaposi's sacrcoma[36]; all

examples of diseases which would normally be prevented by the mounting of a robust immune response.

Conclusions

To summarise, emerging pathogens are clearly one of the biggest threats to human health. The capacity for explosive outbreaks, akin to Spanish influenza, or for a slow seep into the populace, as seen for HIV, means continued vigilance is essential. Influenza and Ebola both, through unique biological mechanisms, cause severe disease. The latter has emerged into humans repeatedly during the last forty years and appears to show no signs of stopping, causing two outbreaks in the Dominican Republic of Congo this year already. Ebola also devastates ecosystems, highlighting the problem of emerging viruses do not stop at humans. Influenza continuously circulates, giving the population some protection, but re-assortment to display new antigens allows influenza to circumvent natural immunity and cause more severe disease. HIV gives us an example of a pathogen that has emerged relatively recently, and spread rapidly worldwide.

In February 2018 the World Health Organisation published their priority list of pandemic potential emerging diseases[38]. These are:

- Crimean-Congo haemorrhagic fever (CCHF)
- Ebola virus disease and Marburg virus disease
- Lassa fever
- Middle East respiratory syndrome coronavirus (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS)
- Nipah and henipaviral diseases
- Rift Valley fever (RVF)
- Zika
- Disease X (unknown pathogen which may cause severe human epidemics)

These, exclusively viral diseases, are the highest priority for investment in therapeutics and prophylactics to prevent their emergence as epidemics. The diseases on this list share several similarities to those assessed earlier in the article. These diseases, like Ebola and Influenza, circulate in an animal host, producing a continuous lineage and a constant opportunity for mutation to allow re-infection to a non-host organism. On jumping to humans they mostly have high mortality rates, or induce life-altering pathology such as that seen for foetal Zika infections[39]. These diseases, like Ebola, Influenza and HIV before them, thus retain the ability to change the status quo of global public health. On a more optimistic note, steps forward in science are reducing the threat of emerging pathogens. Early warning and identification of these diseases, a luxury not afforded to HIV, alongside decades of vaccine research, honed by the race to keep up with rapidly evolving influenza, is being exploited to generate rapid responses to these new pathogens. Public health programmes, developed in West Africa during the 2014 outbreak, have informed us

on how to contain dangerous haemorrhagic fever, spread by blood, for example. Though emerging viral diseases are a major threat to global health, continued scientific advancements prepare us to push back.

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Meat Without the Animals: Cleaning Our Conscience with Clean Meat

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Abstract. *Clean meat is meat made by the process of culturing animal stem cells in such a way that they produce muscle tissue. The technology reproduces the 3D structure of muscle fibres, closely replicating those found in conventional meat, but without requiring factory farming or slaughtering of animals. Many consider it as a viable option to sustain the world's growing population, on both nutritional and environmental fronts. Although the technology is still in development, increased resources and funding for clean meat research have led to notable advances made possible by scientists in academia as well as in start-ups funded by the likes of Richard Branson and Bill Gates. Still, as the field moves forward, two areas need to be addressed for clean meat to successfully disrupt the current meat industry: first is the perception of lab-grown meat by the public and governments, particularly regarding consumer uptake, regulation and legislation. In addition, technical challenges still remain, including the up-scaling of production to commercial levels and the engineering of more complex cellular structures to better replicate the taste, consistency and texture of meat. In this review, we will discuss the background for clean meat development, and the issues it is trying to address, followed by the production methods. We end with a discussion of current obstacles and our proposals for the future of clean meat.*

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Introduction

"We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium." wrote Winston Churchill in his 1932 essay *Fifty Years Hence*. Despite being acknowledged over 85 years ago, this absurdity still remains. There have been attempts to realise Churchill's vision using meat alternatives based on alternative protein sources such as plants, but in the opinion of many, they fall short of accurately mimicking meat in all its sensations, from sight and feel to taste. Now, decades of biochemical research in tissue engineering, cell culture and protein science amongst other disciplines, are being brought together in the ground-breaking field of clean meat.

This was showcased to the world for the first time on the 5th of August 2013 when well-renowned chef Richard McGeown cooked live on air a hamburger made entirely from cultured stem cells. It was the culmination of several years of work in the laboratory of Dr Mark Post, a Dutch cardiologist turned food scientist who has since founded a start-up developing clean meat. His work had constructed the burger in a laboratory by differentiating and growing stem cells derived from cows.

This was no small feat: the technologies necessary to grow animal tissue were made possible by the preceding decades of stem cell and tissue research. This had not been conducted with the goal of growing muscle for human consumption but primarily in the field of regenerative medicine. However, Dr Post, formerly an assistant professor of Medicine at Harvard Medical School, realised that this research could be used to develop a new avenue of food technology and he pivoted into the fields of vascular physiology and tissue engineering, moving to the Netherlands to establish research groups in these areas.

That world-first clean meat burger from his research group cost over $300,000 to produce and was funded in part by Google-cofounder Sergey Brin [1]. Since then, when the goal was a proof-of-concept example of meat grown in the laboratory that was fit for human consumption, the cost of clean meat has gone down to $5,280/kg as of June 2017 [2].

In the process of clean meat production, living animals are initially used to donate muscle stem cells. Due to the exponential growth of cells in optimum conditions, only a single isolation would theoretically be needed for unlimited meat production and so animals would not be required beyond this first stage. As a result, the meat is 'clean' since it is free from the conditions animals face in factory farms, free from animal slaughter and also free from the antibiotics fed to animals farmed for food.

In this piece, we begin by describing the 'absurdity' that clean meat is tackling from the environmental to ethical issues. We then describe how scientists, NGOs, for-profit companies and governments are working together to realise the mass production of clean meat. Finally, we outline the obstacles that the field of clean meat currently faces and give our views on its future directions, including the important issue of public acceptance on shifting the production of animal meat from living animals to bioreactors in food factories.

The foundations and reasons for pursuing clean meat

Clean meat technology intends to supersede current livestock farming, an industry that generates a substantial burden on the planet and which is set to become economically unfeasible. Below we outline some of the current problems that arise from animal agriculture:

Economics and Sustainability

Global meat consumption has risen substantially in recent years, increasing approximately 5-fold in the 50 years between 1960 and 2010 [3]. This increase in meat consumption has been a differential one: high income countries in the West have maintained roughly comparable meat consumption levels in the last 30 years, whilst there has been a roughly 3-fold increase in meat consumption in China, as well as notable increases in East Asian middle-income countries [3]. Overall, global meat consumption has doubled in the last 30 years alone [3] due to nations

switching from a reliance on grains and starches to vegetables, fruits and meat as wealth increases [4]. Economically, this is partly due to a fall in the relative price of meat as a country's wealth increases although a number of social and cultural factors play a role too [5].

The implications of a rising global population, projected to be nearly 10 billion by mid-century [6], combined with increasing global economic growth are clear: unless supply scales with demand, there will be a significant mismatch between the amount of meat we can produce and its global demand [7, 8]. Although several projections of global meat consumption, using different methods, calculate different figures for the 2050 level [9-11], they all agree that the increase will be significant. Since some estimates even put forward that livestock meat production is already at its upper limit [7], there is a case to be made that meat is on track to become a luxury commodity affordable to a wealthy minority [8].

Environmental Burden

On top of the looming economic issues, a second set of problems associated with the agricultural livestock industry is the burden on the environment, including greenhouse gases, water and land use.

Greenhouse gases

Greenhouse gases (GHGs) like CO_2, methane and N_2O are well-established contributors to climate change [12]. They are produced at different stages and to varying degrees by livestock farming [13] for example, N_2O is produced from manure and soil whereas methane is produced from both enteric fermentation and manure. In particular, cattle bred for meat production are substantial contributors to methane emission and are estimated to contribute around 50 million tonnes of methane per year. This is over three times the quantity of methane produced by the next largest methane-producing livestock, dairy cattle, and over 60% of total methane emissions from livestock enteric fermentation [14].

Estimates of the percentage of total GHG emissions caused by animal agriculture range from 8 - 18% [15]. The Food and Agriculture Organisation of the United Nations estimates that 14.5% of total anthropogenic GHGs are produced from livestock farming [14].

Land and Energy Use

Livestock land use comprises 80% of total agricultural land, with most of this in turn being made up of grazing based pasture [16]. Amazingly, this vast amount of land ultimately produces 1% of global edible energy [16] due to the energy losses at each trophic level. One measure of energy efficiency of livestock production is to divide the calorific energy contained in the meat product by the total calorific energy in the animal's feed (this is called the feed efficiency). While this is a useful and intuitive estimate there is also much uncertainty in its calculation. For example,

beef efficiency estimates vary widely between studies [16]. The different regional values obtained for this metric from different studies reflect factors such as incomplete data and alternative regional definitions [16].

The main contributing factor to the low feed efficiency is the prolonged reproductive rate of livestock like beef and sheep with the least feed-efficient livestock being cattle, whose efficiency estimates range from 0.3 - 2% [16].

Water Use

Livestock farming also significantly relies on water resources. Mekonnen and Haekstra have carried out analyses into the global water footprint of meat livestock farming [17]. They calculate that for every animal product there is a larger water footprint than the calorie equivalent of any crop [17]. For example, beef has 20 times the water footprint per calorie than cereals, which again is a consequence of the low feed efficiency of animal products [17].

Clean meat - a solution?

Relatively few studies have directly attempted to quantify the environmental impact of clean meat production compared to livestock agriculture. The first notable attempt to do this was in 2011 by Hanna Tuomisto at the University of Oxford [18]. The study found that the projected energy cost to produce 1000 kg of clean meat would require 26 to 33 GJ energy. This figure is between 7 to 45% lower than the conventional livestock energy consumption [18].

However, a key assumption in this paper's methodology was to omit the requirement of a constant energy input to heat the bioreactors in which cells grow [19]. In fact, the main energy cost to clean meat production is heating bioreactors, so this paper underestimated the energy use of clean meat production. A revised version of the study was published in 2014 [20], showing that the energy use of clean meat is on par with that of cattle (the most energy intensive livestock farming.). However, there is high uncertainty in these estimates [20].

Mattick and others also completed a projected life cycle analysis for clean meat based on mammalian cell culture lines and found even higher expected values for the energy consumption and land use [21]. Most of the energy for clean meat production is expected to be in the industrial processes of basal media production and bioreactor maintenance [21]. Given that these processes do not currently exist on a large scale, the estimates for energy usage have a large variance and there is considerable uncertainty associated with them. One way in which clean meat production could massively reduce emissions is if clean meat plants are located locally in the cities that they supply. This would reduce transport costs and the associated emissions, and potentially reduce land use if a vertical production system is employed.

Human Welfare

Finally, there are also consequences to human welfare that arise from modern day factory farming. The greatest concerns are the use of growth-promoting hormones and the gross overuse of antibiotics. Eighty percent of antibiotics used in the USA are given to livestock [22] and the inevitable development and proliferation of antibiotic resistance is rapidly manifesting as a global catastrophe. Furthermore, the incredibly densely populated spaces within factory farms are a major repository of potential human pathogens. Given that an estimated 60% of all human infectious pathogens are zoonotic in nature, this dense population represents an unimaginable public health concern [23]. Slaughterhouses and the production process notoriously lack adequate hygiene regulations, and several audits have revealed that meat contaminated with bacteria-containing fecal matter are able to get to market [24]. In this respect, clean meat offers an alternative because the conditions of a laboratory-based facility will be fully sterilised and there will be no need for antibiotic use. Moreover, few contagious pathogens that pose a public health threat infect tissue or muscle cells themselves, so in theory the pool of cells used for clean meat will have a reduced capacity as a repository for potential human disease-causing agents.

Clean meat in 2018 - what, how and who?

The production of clean meat is seen by many as a necessary development for there to be sustainable food production in the future. By being able to grow meat from cells, the issues mentioned above can be addressed without altering current eating habits, as the overriding aim of the clean meat field is to replace conventionally produced meat and match the price of the cheapest available meat, with possibly being even cheaper [25].

Although clean meat technology has been developed relatively recently, other meat alternatives have been commercially produced already. The science behind these products does not require the production of animal tissue from cells but the use of non-meat-based analogues to replicate the texture and taste of meat. Hence, whilst the production of these currently available meat substitutes relies on mimicking meat's flavour and texture with alternative sources such as fungi, e.g. Quorn, or plant-based proteins, e.g. the Impossible Burger, clean meat aims to grow muscle tissue from cells that make up living animals, outside of the animal.

Production of clean meat

As clean meat utilises animal cells to grow tissue, it Is theoretically identical to conventional meat from animals. The work of Dr Mark Post mentioned earlier is an example of so-called cellular methods of clean meat production. There are now around 18 start-ups using similar cell-based techniques [26].

In a living organism (*in vivo*), the creation of muscle is the first step in the meat production process. In order to produce skeletal muscle in adult organisms, a type of stem cell called a myosatellite cell is activated in response to cues such as injury [27]. Because myosatellite cells are adult stem cells, they can only differentiate into a limited range of cell types that make up skeletal muscle [27]. Upon activation *in vivo*, the myosatellite stem cells initially differentiate into myoblast stem cells, which then transform into myocytes. Following this, the myocytes fuse to form myotubes and, in living animals, the myotubes align to make myofibrils that form muscle fibres and then fibre bundles and ultimately muscle [27].

In clean meat research, the possibility of using several cell types to start production has been explored. This is because, as shown in table 1, the number of times a stem cell can replicate depends on the type of stem cell it is. The use of myosatellite cells to mimic *in vivo* muscle generation requires a minimally invasive muscle biopsy [28] to obtain a sample of muscle from which myosatellite stem cells are extracted. Satellite cells can divide up to around a maximum of 40 times *in vitro*, although 20-30 is practically more accurate [29]. As a burger patty probably contains around tens of billions of cells [29], alternatives to satellite cells are desirable and have been investigated. Induced pluripotent stem cells (iPSCs) are stem cells that are produced when mature cells are dedifferentiated into pluripotent states. During reprogramming into iPSCs, cells also become immortal and hence can divide for longer than satellite cells [30]. This would allow for fewer biopsies from animals, as a large number of cells could be generated from the initial population. Another possible route is to generate immortalised satellite cell lines using gene editing techniques to create satellite cells that can divide indefinitely. This would remove the need for biopsies at all, and also ensure consistency between clean meat companies as they could all use the same stock of cell lines. This process has been demonstrated by scientists at North Carolina State University who successfully grew a small turkey nugget in two weeks from the time of thawing an immortal cell line they had created [31].

Type of stem cell	Tissues which stem cell can differentiate into	Number of replications *in vitro*
Embryonic Stem Cell	Most tissues	May be limitless
Totipotent Stem Cell	All body cells	Theoretically high
Pluripotent Stem Cell	Most tissues	Variable
Induced Pluripotent Stem Cell (iPSC)	Most tissues. Mature cells can be reprogrammed to become iPSCs	Variable and often unknown
Adult Stem Cell	Specific to tissues that they originate from	Mostly limited to 50-60
Multipotent Stem Cell	Several tissues based on origin	Variable depending on age
Myosatellite Stem Cell	Muscle tissue	Decreases with age. 20-30 *in vitro*

Table 1: showing the persistency of various stem cells and the body tissues they can differentiate into.

During clean meat production, either of the three cell types described above are used to generate myoblasts *in vitro*, which are then allowed to self-renew, but not differentiate into myocytes. Once a sufficient number of myoblasts are obtained, they are transferred to new conditions which allow differentiation. This capacity of self-renewal and differentiation can be controlled by the components present in the cell culture medium. This usually contains nutrients such as vitamins, minerals and amino acids as well as serum which provides additional components such as hormones, growth factors and other cell survival and growth promoting factors. Serum is used as it is an easy way to obtain all the factors that most cells need to grow and divide in culture. Foetal bovine serum (FBS) - i.e. the serum from new-born calves - is most commonly used. The depletion of nutrients and serum starvation in the myoblast culture is what elicits their differentiation into myocytes and the subsequent formation of myotubes through myocyte fusion.

During clean meat production, the generation of muscle fibres from myotubes is directed into a 3D structure, to resemble conventional meat cuts, by scaffolds that promote myotube attachment. This is necessary as the scaffolds allow for nutrients to access all cells in the tissue and also provide structure for the product to grow and take shape on. In addition, mechanical stimulation of muscle *in vivo* influences the organisation, and hence texture, of conventional meat. In clean meat production, chemical stimulation through calcium exposure can mimic this by causing muscle contraction. Alternatively, mechanical stimulation by applying electric impulses during cell development, can also be used to augment muscle fibre growth [30]. Scaffolds play a role in this process, which is achieved *in vivo* by blood vessels and the extracellular matrix that surrounds cells and tissues. Further research is also ongoing to identify additional components needed for muscle tissue production *in vivo,* such as fat-providing cells (adipocytes) [32]. This is firstly being done so that conventional meat can be accurately mimicked and also to investigate how co-culturing cells (e.g. myoblasts and adipocytes) affects the make-up, and therefore nutritional value, of clean-meat products.

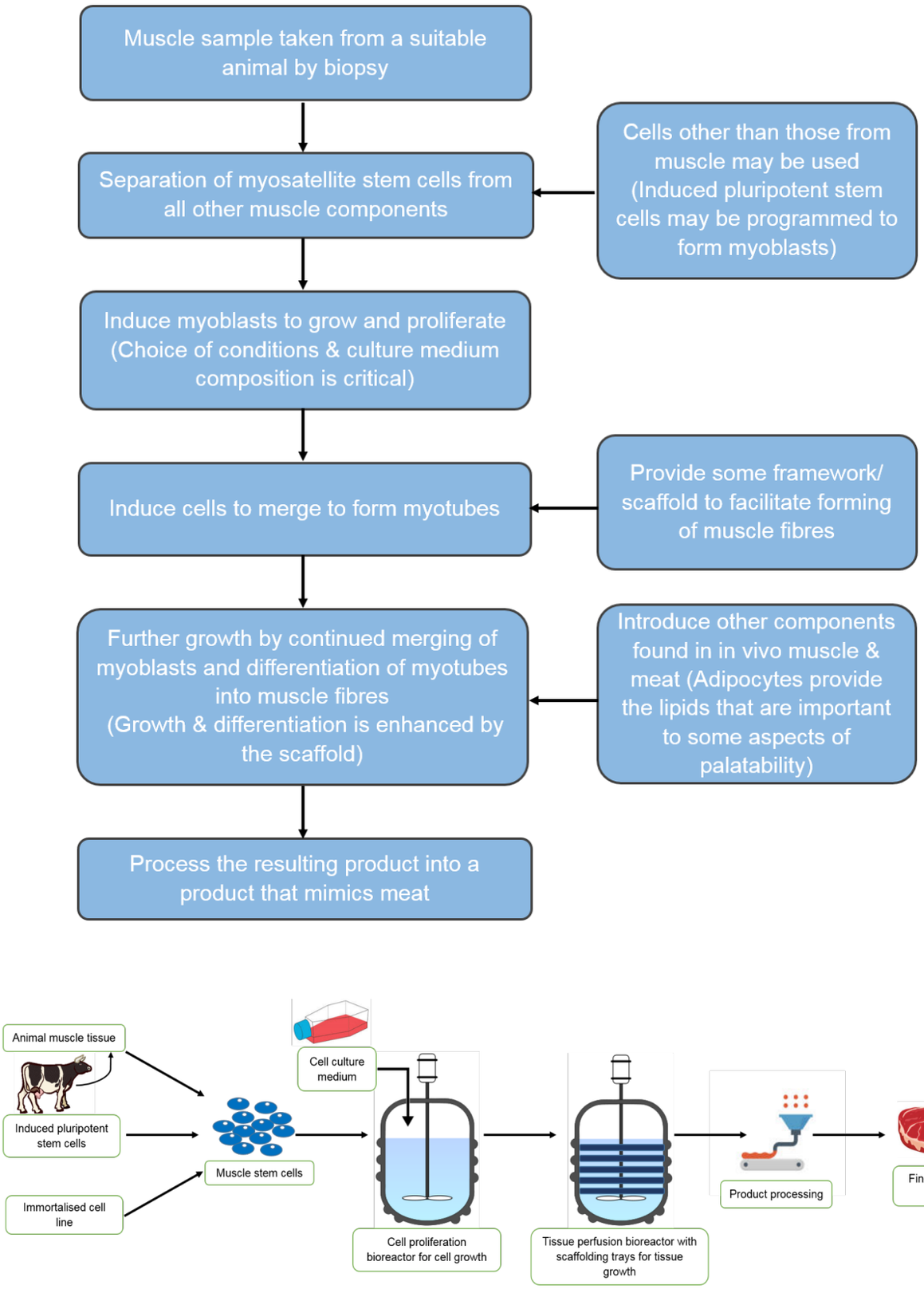

Figure 7: A flowchart and pictorial representation to show the main steps required in the production of a clean meat product.

Two significant advantages of clean meat can be highlighted from the discussed scientific aspects. Firstly, the ability to grow cells in sterile culture conditions theoretically allows for the removal of antibiotic use in food production, as claimed by Memphis Meats CEO Uma Valeti [17]. Secondly, the control over which nutrients, e.g. vitamins and minerals, are added to the cell culture, and also which cells are co-cultured, allows control over the content of fat, protein and other biological molecules produced in the clean-meat product [16]. This creates the potential for cultured meat to be nutritionally tailored as it could be possible, for example, to decrease the content of cholesterol and increase the protein content.

The current commercial climate of clean meat research

The scientific developments, breakthroughs and funding for clean meat production have come from a vast array of organisations, reflecting the notably wide reach of clean meat in academia, industry and policy.

Clean meat research is taking place most prominently in the laboratories of start-ups such as Memphis Meats and Finless Foods. Memphis Meats, which revealed the world's first cell-based meatball in 2016, is working on various products, such as clean chicken and clean duck and has announced product release in 2021 [34]. To date, they have raised over $20 million in funding from sources including Bill Gates, Richard Branson and, in 2018, food giant Tyson Foods [35]. Finless Foods is focused on producing cell-based fish meat using stem cells derived from fish tissue [36]. Their aim is to bypass current fish farming methods to make clean fish products that are healthier, cheaper, more environmentally friendly and produced with more sustainable methods than the aquaculture methods used today. In 2017 they demonstrated the first clean-fish fish cakes and have raised funding of $3.5 million in 2018 to develop cell-based bluefin tuna [37].

These start-ups are developed and funded through incubators, investment funds and private investors, showing how the clean meat field has taken advantage of global interest in start-ups. This has been accelerated through a shift in the focus of incubators from the traditional technology-based start-ups to ventures founded on deep science – i.e. based on discoveries from novel scientific research or research across many scientific disciplines. An example is IndieBio, a US-based incubator that is tailored to the biological sciences and to scientists that want to commercialise their research. They provide funding of $250,000 as well as laboratory space to help scientists create viable products from their initial research in the space of four months [38]. Finless Foods and Memphis Meats are two examples of clean meat companies that have gone through the IndieBio accelerator programme.

Alongside this however, scientific research into clean meat is also undertaken and supported by institutions such as NGOs, universities and governments. The Good Food Institute (GFI) is an NGO whose mission is "to build a healthy, humane, and sustainable food system" [39]. They do this through working with companies such as the start-ups mentioned earlier as well as with policy making institutions, academics, food stores and grant-making institutions [39]. One aim of this is to bring

together non-profit areas, such as academic research, with companies requiring additional scientific expertise and research. In 2017 alone, they provided support to over 100 entrepreneurs working in cell- or plant-based meat [40]. An example of its success is the creation of a food firm in China, Dao Foods International Inc., which was formed through collaborative efforts of three venture groups brought together by the GFI [41]. Dao Foods' aim is to bring clean meat to the Chinese market as the government seeks to cut the country's meat consumption [42]. Moreover, by educating the institutions that provide research grants and make policy, they aim to create a supportive market for clean meat products both in terms of the funding available and the legislation.

The Oxford Martin School is another example of an institution that is bringing together different sectors to use interdisciplinary research to tackle global problems. As stated on its website, the school acknowledges food production and sustainability as a great global challenge of this century: "Without radical change to the way we produce and consume food […] there is a substantial risk of significant increases in food prices with major political, environmental and humanitarian consequences." [43]. Its Future of Food research programme brings together the private sector, academia and government to help try and find solutions to the global food crisis. One aspect of the programme is the development of clean meat production. Other academic institutions also undertaking similar approaches to the Martin School include schools at Harvard, Tufts, Bath, Ottawa, Technion, and Maastricht, showing that the role of academia in bridging different disciplines and sectors is increasingly crucial on large-scale, global issues. Furthermore, the interdisciplinary approach undertaken by NGOs and academic schools is extremely important because, as outlined in the obstacles section below, the hurdles which are facing clean meat now, and those it is predicted to face in the future, are not only scientific.

In addition to these institutions, governments have also played a role in supporting clean meat research. In 2017 for example, the Chinese government signed a $300 million trade agreement with Israel that involved supporting three Israeli clean meat start-ups in order to support their introduction into China [25]. This highly significant deal was possibly the sign of a global shift in the role of governments in food production as they change from initiating and supporting direct research to investing in private companies.

Obstacles to the production and adoption of clean meat

There are three main technological barriers presently withholding the large-scale production of clean meat at a marketable price: the cell culture medium, the scaffold on which myotubes fuse into fibres and the upscaling of the production process [44].

Firstly, the culture medium in which cells are grown for clean meat will need to be serum free. This is because serum production requires animal slaughter, which

clean meat is trying to eliminate. In addition, the composition of animal derived serum varies hugely between batches based on seasonal and geographical changes [45]. Furthermore, whilst demand for serum in research has increased, its supply has decreased leading to a price increase of 300% in the last few years [46]. In addition to this, its supply is not consistent as it is dependent on demand for meat such as beef (serum is a by-product of meat industries) as well as the availability of livestock, which fluctuates based on factors such as natural disasters [45]. Therefore, clean meat production requires a serum-free medium that will be cost-effective, reproducible and free from animal slaughter. Ideally this would involve using nutrients, e.g. growth factors and vitamins, made synthetically or using genetically modified organisms such as yeast. These would be used to create the optimal media for the different cell types that will be used in clean meat production such as iPSCs and myosatellite cells from different animals. There are already developments being made in this field with serum-free media having been shown to support muscle growth *in vitro* from sheep skeletal muscle stem cells [47] and also porcine iPSCs [48].

Another hurdle is the development of the scaffolds that the cells are grown on. These must allow cell adhesion to their surface and support the oxygenation and perfusion of media through the tissue either directly or through a vascular network [44]. This can be achieved directly by using vessel mimicking structures using microfabrication techniques such as 3D printing [49]. Moreover, the scaffold will need to support co-culturing of different cell types and also guide cell differentiation in a spatial manner. This can be achieved through anchoring nutrients [50] and inherent biomechanical properties e.g. elasticity, which has been shown to play a role in skeletal muscle development [51]. Furthermore, the scaffold should be edible and safe for human consumption if it is to be included in the final clean meat product. Hydrogels are being demonstrated as the most promising source of scaffold. They can be dynamic due to their ability to change shape based on light or potential signals, can be made from edible materials e.g. pectin and can also have nano-scale incorporation of materials e.g. growth factors [50].

In addition, the upscaling of clean meat production is one of the toughest technological hurdles facing the industry. This is due to the cost of clean meat being too high for it to be introduced into food markets, even as a premium product, despite the cost of a burger dropping from $300,000 in 2013 to $11.36 in 2017 (about 10x the cost of a standard burger) [52, 29]. It is widely believed that the successful upscaling of production is required to bring down the cost of clean meat by another 10x. The crucial development that would allow this is the production and use of large-scale bioreactors. These are the containers in which cells will proliferate and then ultimately differentiate into meat. Although bioreactors have already been developed and used in other cell-based systems, e.g. vaccine development and fermentation, the complex process of clean meat production poses new technological challenges. This includes sophisticated nutrient recycling systems which aim to minimise waste, as well as monitoring systems that would be able to change the supply of nutrients based on the stage of production. Furthermore, the

bioreactors will need to be designed to incorporate the scaffolds used to grow clean meat.

There are also considerable non-scientific obstacles before clean meat can become a viable consumer product. It is currently unclear which organisations would actually regulate clean meat production. In the United States, the safety and quality of conventional livestock meat is under the jurisdiction of the US Department of Agriculture (USDA), whereas cell cultures and biomedicine are regulated by the Food and Drug Agency (FDA) [53]. However, a recent meeting of the FDA asserted that regulatory processes surrounding clean meat would be firmly within their jurisdiction, despite an earlier drafting bill from the US House of Representatives asserting the same, but for the USDA [54].

Another obstacle may also be the divisions within the industry about what clean meat should actually be. Some of the most influential names in the industry, including Bruce Friedrich of The GFI think that it preferable not to deviate from the normal composition of meat and change its fat and protein content, from a consumer standpoint [55]. However, others such as the CEO of Memphis Meats, Uma Valeti, think that a precision-engineered product will enhance consumer uptake—for example low fat versions of clean meat for health-conscious buyers [55]. Although both versions of livestock meat currently exist, it is unclear which marketing tactic will be optimal for the adoption of clean meat.

Following from this, a market for clean meat must be created so that the scientific and technological investment is not in vain. A 2016 survey carried out on US consumers revealed that most of the participants were willing to try clean meat, but only around one third were 'definitely or probably willing' to eat clean meat regularly in place of farmed meat [56]. The survey notes that the positive attitudes towards clean meat arise from the potential environmental and public health benefits of product, while negative attitudes come from reservations about the feasibility of industrial scaling and overtones of the 'unnaturalness' of meat grown in the laboratory (although this last query is incorrect because clean meat will be grown in bioreactors in food factories) [56]. One strategy to overcome this bias might be to reframe the questions asked in such surveys, emphasising the unnaturalness of the livestock production process [57]. A preliminary study conducted by researchers at Faunalytics and The GFI employed this strategy of positive framing [57]. They found that 45% and 52% of participants would be willing to regularly eat clean meat, and replace conventional meat with clean meat respectively (up from the roughly 33% from the Wilks study) [57]. A notable consideration which will influence consumer perception of clean meat is product labelling, something which has seriously hampered the reputation of GM foods among the general public [58]. There are ongoing disputes concerning this between leaders of the clean meat industry and those of the livestock meat industry [59]. Several petitions prohibiting the labelling of clean meat products as 'clean' or 'beef' have been produced by industry trade groups such as the US Cattlemen's Association and the National Cattlemen's Beef Association [59]. In opposition to this, the GFI has issued statements in the media, citing that such prohibition on

labelling would misrepresent the final product [60, 61]. Careful management of consumer perception through marketing will be a critical aspect of the successful adoption of clean meat.

Finally, we feel that one rarely discussed obstacle to clean meat adoption requires attention: the impact of conventional meat industries on economic factors such as employment. As it currently stands, the proportion of total agricultural GDP that livestock creates is between 20-50% [62]. Globally, livestock contributes to 40% of agricultural value, according to FAO data, and 'support[s] the livelihoods…of almost 1.3 billion people'. Given this massive reliance on livestock farming for millions of people, the economic void left by a potential switch to semi or fully-automated meat production by clean meat companies represents a huge concern for those currently employed in the livestock industry. It is therefore surprising how little attention has been given to the potential systemic change that clean might cause. Proponents of clean meat such as the GFI will have to manage these legitimate concerns and their bearings on clean meat's consumer perception, and wider public discussion will be needed to address the social, economic and political consequences of a disruption to animal agriculture.

Summary and our proposals for the future of clean meat

In summary, we believe that clean meat looks set to overcome some of the world's greatest current issues, though significant challenges remain. The global issues include the provision of meat to the world's growing wealthy population; the ethical considerations regarding the suffering of animals on factory farms; and the potential danger to human populations from factory farming practices such as zoonotic pathogen escape and emerging antibiotic resistance. The challenges to the field most prominently include, but are not limited to, technological hurdles of upscaling cellular growth, efficient growth in serum free media and the availability of scaffolds. Non-technical challenges like the public perception of clean meat and its legislation by governments may prove to be the biggest barriers.

In light of the current state of the clean meat field and its main obstacles, we consider that there are four key areas where there is room for improvement: increasing scientific collaboration; alternatives to serum for media should be more routinely used in cell culture; public engagement with clean meat research should be increased and a policy infrastructure governing the sale, distribution and regulation of clean meat for the relevant authorities should be brainstormed. We believe the first of these is important as developing clean meat requires work from a wide range of scientific disciplines such as tissue engineering, materials science, stem cell research and chemical engineering. This will be needed to take clean meat from the laboratory to industrial food factories and poses a challenge as these fields have not traditionally collaborated significantly in the past. Therefore, new avenues of information exchange and understanding continue to need to be formed by scientists from these areas. Following on from this, sustained research into the development of non-animal derived culture media will also be necessary for clean meat to be truly free of animal slaughter. Linked to the point above, this will firstly

require interdisciplinary research to initially determine the specific molecules a growth medium requires and then mass produce them in industrial quantities. We believe that setting a goal to replace serum in all cell culture media will lead to the much more rapid development of serum free media than if the research is confined to specific areas of research, e.g. clean meat and stem cell culture.

Finally, increased public and authority engagement is a necessity to educate the public on the problems of current meat production techniques as well as ensuring the proper publicity and regulation of clean meat production. Without this there may be a chance that a sizeable market for clean meat will not exist at the right time, when in other circumstances there might have already been a willing consumer base—nurtured through careful marketing and tactful public education about the failures of factory farming and the viability of clean meat. Appropriate development of the clean meat industry also relies on the imposition of regulatory bodies and distribution networks poised to turn the product into a widely available commodity.

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Book Review

The Rights of Nature, by David R. Boyd

Shuchi Vora

David R. Boyd, *The Rights of Nature: A Legal Revolution That Could Save the World* (Toronto, ECW Press, September 2017); 312 pp; ISBN: 9781770412392; English; URL http://ecwpress.com/products/rights-of-nature

Introduction

"Ko au te awa, ko te awa ko au."
"I am the river and the river is me."[1]

New Zealand created history when it passed a law granting legal personhood to the Whanganui river in early 2017. This piece of legislation created ripples in the legal world because of the nature of its clauses which included the above-mentioned Maori saying. In granting the river legal personhood, the law incorporated the Maori worldview of human connectedness with nature into a modern western legal framework.

Can Nature have rights? David Boyd sets out to narrate a story of the progress from anthropocentric to ecocentric laws in his book 'The Rights of Nature'. He points out that while this idea of nature having rights may sound ludicrous to most minds with a western worldview, he quotes John Stuart Mill when he says that this movement towards ecocentrism in law, like all other movements, has had its share of "ridicule, discussion and adoption". The book was published in 2017 and highlights the history of granting legal personhood to nature in the Western world by documenting its watershed moments such as the case of the Whanganui river. This book review first gives a background of the debates surrounding laws governing natural resources, and then goes on to highlight the strengths and weaknesses of the book.

Anthropocentric Vs. Ecocentric Legal Frameworks

The debate within the rights-based natural resource management framework has hitherto been restricted to property rights over natural resources as against the human right to resources. The tragedy of the commons that has been inflicted by

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[1] A Maori Saying that explains the Maori worldview of oneness with nature.

fractured governance and regulation frameworks for nature has been accepted by governments and society alike. However, the means to restoration of degraded ecosystems and conservation of endangered wildlife has often been a subject of disagreement between various groups. The pollution in the Ganges river has been a subject of petitions in the National Green Tribunal of the Supreme Court of India, but neither the government nor the industries have been able to suitably address the issue yet.

Market-based environment discourse has argued that natural resources such as water and forests can be allocated and governed by granting users property rights over them. Australia, California and some other drought prone regions have applied this approach in allocating the entitlement to scarce water resources within their jurisdictions. However, many others including activists who have fought for the rights of the First Nations in North America, have stood by the human right to natural resources over property rights. They have maintained that basic human need for survival should be paramount when allocating natural resources.

However, both these arguments are inherently anthropocentric and part of a Western worldview that treats humans as divorced from nature. In contrast, many indigenous and eastern philosophies have always believed in the interconnectedness of humans and nature, or ecocentrism. For instance, in the Sunderbans islands of the Ganges-Brahmaputra delta where people live in difficult natural conditions fraught with constant erosion, floods and the fear of being preyed upon by tigers, they pray to *Bonbibi*, the Goddess of the forest, who protects them from calamities. On the other hand the laws in much of the world are a product of the Roman philosophy that the purpose of nature and its creatures is to serve humans.

About the Book

The book has been divided into three sections – The Rights of Animals, The Rights of Species and The Rights of Nature. In the first section, Boyd argues that animals are sentient beings with the capability to feel complex emotions such as grief and pain, and are much like humans in many respects such as the use of tools, language and communication, memory, culture and self-awareness. He documents the animal rights movement by describing various cases in the North America in favour of chimpanzees, Asian elephants and marine mammals. In his section on the Rights to Species, he highlights cases such as the case of the rights of the snail darter vs. the Tennessee Valley Authority that forced the US Congress to change its stand on endangered species and infrastructure, those of wildlife trafficking, global laws and cooperation on wildlife monitoring. His last section, the Rights to Nature, provides the most interesting insights into the change in the moral and philosophical compass of the western legal world. He documents cases such as that of the rights of Sierra Valley vs. Walt Disney and the Whanganui river. It is in this section that a more detailed analysis of what the rights of nature may mean in different countries such as Ecuador and Bolivia, apart from developed countries like New Zealand and the USA.

Critique and Conclusion

This book targets minds trained in western thinking and tries to orient such minds to the different worldviews held by indigenous and other groups. The book is heavily focused on North America, and in that, does not answer vital questions that are faced by developing countries in trying to perform the balancing act between economic growth and conservation of ecosystems. He also does not demonstrate awareness of the fact that indigenous communities in poor countries such as Bolivia and Ecuador may aspire for economic growth to escape poverty. After all, it is not for the world to ask these countries to languish at the bottom of the growth curve, when the rest of the world has grown at the expense of what are rightfully their natural resources.

Boyd has celebrated individual heroes such as animal rights lawyers in the 1960s, the lawyers of the Community Environment Legal Defence Fund (CELDF), negotiators from the Maori groups, and leaders such as Evo Morales of Bolivia and Rafael Correa of Ecuador. The animal rights and rights of wildlife are in many ways much more advanced discourses compared to the rights of nature, which makes Boyd's last section the most interesting and ground-breaking. He is one of the few writers who have chosen to focus on this shift in worldview towards natural resources that has been brewing for many decades now in different forms. 'The Rights to Nature' is an important book that highlights the intrinsic value of nature itself and the human interconnectedness with nature; ideas that may prove critical in future as the world grapples with restoring degraded ecosystems and sustaining life on earth.

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MISCELLANY

Research

San Junipero: The Postmodern Dream of Immortality and the End of Utopia

Sotirios Triantafyllos

Abstract. *This article analyses 'San Junipero', an episode of the popular television series Black Mirror, from the perspective of Utopian Studies and the History of Science. This particular episode deals with the issue of immortality and the desideratum for a manmade paradise. In my view 'San Junipero' offers an opportunity to observe how new developing technologies present in contemporary popular culture and how they are linked with the atavistic human desire for immortality and return to the prelapsarian Eden. In this article, I make use of sporadic evidence concerning the 'nature' of San Junipero and its 'miraculous technology' and attempt to examine how this utopian fantasy encapsulates modern anxieties revolving around the replacement of our corporeal lives by virtual ones. As a point of further discourse this article also considers how new technology challenges our very character as human beings while simultaneously our utopian dreams appear to regress into the realm of the personal.*

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San Junipero, the fourth episode of the third season of the popular sci-fi series *Black Mirror* concludes with the following scene: a woman stands on the beach bathed in sunlight. She turns and looks somewhere behind the camera. The angle widens to allow us to view another female figure moving towards her, ultimately joining her. The two heroines then stand happy in a characterless, indiscernible environment full of sun, and blue waves. The characterless environment has a name, *San Junipero*, a small Californian sea resort town. Or, more accurately, it is a simulation of the perfect Californian beach-town. As for the two heroines, what they are is much more complicated.

The first protagonist is tall, blonde, in her mid-twenties, and is named Yorkie. The second, Kelly, is young, African American and filled with joie de vivre. We first meet Yorkie and Kelly at what appears to be a 1980s dance party. Yorkie is uncomfortable and out of place. Kelly, by contrast, is enjoying herself, is well acquainted with the barman, and is being pursued by a former lover. As the plot unfurls, we learn that our episode's young and beautiful heroines are in reality avatars of two much older women that connect to the simulation of San Junipero

for a few hours every weekend. Kelly's motivations in visiting San Junipero err on the side of hedonic. She avoids forming long and meaningful relationships with other visitors or the 'locals.' Yorkie, however, assessing whether this virtual paradise is a suitable afterlife for her. Their different approaches to San Junipero reflect the divergent aims of the visitors and the inhabitants of the city. San Junipero is peopled by two types of residents: a) deceased individuals who have uploaded their consciousness and reside in this paradise eternally and b) old and infirm people who visit every weekend for a few hours as part of a regime of 'nostalgia therapy'; the latest treatment for anxiety and memory loss developed by this world's geriatric research. The episode is focused on the love between the two heroines and the obstacles they must overcome in order to be together. However, in a subtle way this 'love story' with its telenovela elements is linked with the ethical issues that arise with the conquest of immortality as well as the complications caused by the dominant religious doctrines about afterlife and the fear that our species faces with regards to the unknown territory of 'eternity.'

The 'pulp technology' of immortality appears to play a primary role in these fantasies of mind upload as a path to immortality.[1] The idea, of course, is quite old. The conceptual genesis of indefinite life extension through technology is attributed to a 1971 article by the biogerontologist George M. Martin. Today, works of science fiction and futurists frequently return to this idea, emphasizing its viability.[2] Yet, it must be emphasized that there is significant divergence from Martin's first description and the current pulp and pop iterations of mind-uploading in mass media and collective hopes and fears. For Martin and other gerontologists, technologies like cryonics and mind-uploading were seen as potential tools in our species' struggle against aging and death that were worthy of further research and funding.[3] The initial idea was adopted by neuroscientists and computer programmers and engineers who occupied themselves with the practical aspects of this technology, pointing out the difficulty of uploading a human brain and how our current hardware is far from capable of achieving this task. This 'pessimism,' however, has not deterred science fiction writers like Isaak Asimov and Arthur C. Clarke, as early as in the 1960s, to imagine worlds where this technology exists. Writers like William Gibson in *Neuromancer* (1984), then popularized the idea, making it part of the mainstream culture. Hence, *Black Mirror's* '*San Junipero*' is not unique in tackling this issue but it is different from previous examples in its diminished focus on the technology itself and increased attention to the ethical consequences and problems that may arise from its use—thereby asking whether this technology's existence changes our very human nature. Unlike contemporary futurists such as Max Moore, Robin Hanson and Ray Kurzweilwho, who impatiently await the coming of singularity and humankind's liberation from its

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[1] M. Bould, S. Vint, *The Routledge Concise History of Science Fiction* (2011).

[2] G. M. Martin, 'Brief Proposal on Immortality: An Interim Solution', 14 (2) *Perspect Biol Med.* (1971), 339.

[3] P. Nicholls, *The Science in Science Fiction* (Knopf 1983); N. Vitamore, D. Barranco, 'Persistence of Long-Term Memory in Vitrified and Revived Caenorhabditis elegans', 18 *Rejuvenation Research* (2015).

biological constraints, Science Fiction works of the last decades have adopted a more nuanced view, one that acts as a dystopian counter to the triumphant tone adopted by supporters of mind uploading and the singularity.

The 'Utopian' Character of San Junipero

Despite '*San Junipero's*' dark undertones, its creators have described it as a utopia. Hence, it is important to understand the 'utopian' character of the episode. *Black Mirror* has acquired a cult following due to its concern with the negative/dystopian consequences of technology in our lives. As an anthology the series has explored our obsession with the popularity of our carefully cropped social media presence, the horrific implications of the use of virtual reality technology in judicial punishment or modern warfare, and the dehumanizing results of matchmaking algorithms. By tackling these issues, the series has established a dark tone that contests utopian narratives of technology due to humanity's inability to utilize it in a moderate and ethical way. However, Charlie Brooker, the creator and chief producer of the series, tried to disrupt this established pattern in '*San Junipero*.' According to his statements '*San Junipero*' was intended to be a hopeful story with a happy ending.[4] In this way '*San Junipero*' was designed as a utopia. But what type of utopia?

Originally, the word utopia described an ideal society, a better society with improved social and political organizations. Based on this rather skeletal definition San Junipero hardly qualifies as utopia. Instead, it is presented as a playground for adults, or, to be more accurate, as a hedonistic memory lane for the elderly, infirmed and deceased. It seems to have no social or political structure, serving only as the background for the personal fantasies and adventures of its inhabitants. The secondary role that the environment plays in this paradise is evident by the choice visitors are given to change its time period. However, this temporal flexibility is not extended to the town's geography or topography. Moreover, the few glimpses of the town offered through the episode, reveal a townscape absent any of the visible landmarks that commonly serve as the focal point of many utopian cities. As for '*San Junipero's*' Californian setting, initially it seems to have been chosen solely for its agreeable weather and telegenic beaches that evoke a carefree Californian lifestyle. However, the choice of the town's name may suggest a closer relationship with early Californian utopian communities.

Junipero Serra (1713-1784), who the city is ostensibly named for, was a Catalan Franciscan friar who founded many missions in California. Serra's recent canonization in 2015 raised the issue of mistreatment and forced Christianization of California's indigenous population by his hands, tarnishing his traditionally benevolent reputation as a civilizer and protector of indigenous peoples. Potentially, the ambiguity of Serra's reputation is reflected in the ambivalent the

[4] Mallet, W. (Nov 3 2016). *Charlie Brooker Says the New Season of 'Black Mirror' Is All About Gaming*. Retrieved from http://www.vice.com

utopian character of San Junipero. Serra's positive legacy in many parts of California was rooted in the quasi-utopian missions he founded across the state, where the Franciscans taught the Amerindians to farm and offered them 'protection.' The lore surrounding these missions, and Serra specifically, is evident in the number of streets and schools named after him. In any case, as Kelly says to Yorkie when they first meet: San Junipero is a party-town and nothing suggests that it was designed to be anything more. This, however, reveals another issue; this simulated paradise is operated and probably designed by a private corporation. Its parameters and designs may have been made according to their customers' demands, but the horizon of expectations for this paradise was from its very beginning limited and most probably is destined to remain that way.

The individualistic character of San Junipero serves the love story, which ends with a literal 'happily ever after.' Yet, the fact that this fantasy is presented as a utopia raises questions about the meaning of the word and the evolution of its definition and manifestations. It is a garden of earthly delights for individuals or a classical paradise similar to the Fortunate Islands where a few blessed individuals were enjoy immortality amongst a temperate climate and abundant fruits.[5] San Junipero is an updated version of this paradise—a playground in a virtual environment designed to accommodate the needs and wishes of the avatars that log into it. In this way, the 'utopia' that Brooker refers to is nothing more than a video game where people adopted their desired avatars. Still, this simplistic paradise seems to be an accurate reflection of contemporary utopian hopes, encapsulating our waning interest in the commons and increased interest in more individualistic aspirations such as personal happiness and fulfillment.

Homo Virtualis, Cyborgs and Immortality

The rejection of older narratives and radical visions of social transformation, however, does not mean that the paradise of '*San Junipero*' is completely alien to utopia, or worse dystopian. Rather, utopianism, in its broader sense, has many expressions. Ernst Bloch traces in every culture and religion of the world, a memory or a dream of a better world that has haunted our desires for millennia, forcing us to systematically scrutinize our present condition by comparing it with a not yet realized ideal.[6] Yet, in San Junipero, humanity's struggle for a better world and the always present 'not-yet' that forces our critical gaze to seek novel solutions and paradigms for social and political ills is absent. Instead, the focus of the episode is on the two heroines' relationship and, in my view, this is not just a convention of the plot or a restraint placed by the medium or format. The concern of the writers with the personal relationship and welfare of the heroines is not as narrow as it may appear. Rather, it encapsulates the form of contemporary utopian desire and how this utopian dream has shaped the public perception of scientific research in the fields of informatics and cryonics. The focus now is immortality, a very private and

[5] F. Manuel and F. Manuel, *Utopian Thought in the Western World* (Cambridge, 2009), p. 76.
[6] E. Bloch, *The Spirit of Utopia* (Stanford, 2000), p. 158

very old dream—a dream that 21th century technology is going to make a reality, according to futurists like Robin Hanson.[7]

This lead us to the concept of mind uploading as presented in Martin's article where it was seen as a remedy against the ultimate disease of death. *'San Junipero'* offers us the opportunity to observe how these hypothetical technologies were either inspired, appropriated, or popularized by Science Fiction. Since the disappearance of Fountain of Youth myths from our culture, science has come to be viewed as the only mechanism for immortality. The first technology that seems to have been inspired by pulp science fiction and was suggested as a salve for death was cryonics.[8] Robert Ettinger, a mathematician, founded the cryonics movement with his book The Prospect of Immortality (1962). Ettinger was quite clear about the inspiration SF stories and the work of Jean Rostand in cryopreservation, had over his idea of deep freezing bodies. Ettinger, who was also the founder and president of the Cryonics Institute, saw cryopreservation as a technique through which humans could buy time until science has advanced enough to cure all diseases and thereby unlocking the secrets of immortality. Ettinger's view in the utility of this method is clearly expressed by his obituary where his son, Dan Ettinger, noted that his father will someday have a second chance because his body was frozen.[9] Today, cryonics is a staple of our immortality fantasies. The movement has magazines such as the *Long Life: Longevity through Technology* (a bi-monthly magazine published by the American Cryonics Society) and has attracted research funding from the US government and private customers. Interestingly, California is one of the major hubs of cryonics companies and societies. It is also the hub of the transhumanist movement, and is associated with transhumanist centres like F. M. Esfandiary, known as FM 2030, organized by and around a circle of intellectuals. These futurists searched for a way to evolve humanity through technological and scientific achievements in order to overcome our biological limitations. Max More, who in the 90s was among the most vocal proponents of the movement, is considered the inventor of the term transhumanism. In a series of articles More delineated the movement's ideology as one of personal, undeterred advancement based on reason, intelligence and critical thought.[10] According to some of its critics, transhumanism is nothing more than a combination of Nietzsche's philosophy, libertarianism and neoliberalism, whose scientific basis was/is at best questionable—founded on Science Fiction and not hard science.[11] The choice of California, then, as a setting may echo the contemporary transhumanist movement, whose aspirations San Junipero's simulation and brain emulated avatars appear to realize.

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[7] R. Hanson, *The Age of Em: Work, Love, and Life when Robots Rule the Earth* (Oxford, 2016), pp. 158-9.

[8] P. Nicholls, *The Science in Science Fiction* (Knopf 1983).

[9] 'Body of Cryonic Pioneer Robert Ettinger Frozen', The Telegraph (26 July 2011).

[10] J. Raulerson, 'Singularities: Technoculture, Transhumanism, and Science Fiction in the 21st Century', 45 *Liverpool Science Fiction Texts and Studies* (2003).

[11] E. Graham, 'Nietzsche Gets a Modem: Transhumanism and the Technological Sublime', 16 (1) *Literature and Technology* (2002), 65- 80.

The heroines and the San Junipero's virtual paradise represent the pinnacle of the transhumanist movement's aspirations. The deceased inhabitants as well as the 'tourists' both have transcended their human nature, becoming what contemporary futurists have described as 'homo virtualis'. This corresponds to the transhumanist evolution in which we are liberated from the prosthesis of our material bodies, transferring our consciousness to the virtual/digital realm of the internet. But, in my view, '*San Junipero's*' heroines are much closer to Donna Harraway's definition of cyborgs--[12]creatures that have severed their links and relations with the real world, achieving an individuation that frees them from the constructed labels of the 'real' world and as a result from the racism and oppression that they were subjected to in it. The heroines form an interracial, homosexual couple which constitutes a transgressive and revolutionary act enabled by their 'cyborg nature', and their rejection of the clear-cut categories that western civilization imposed on humanity for centuries. Yorkie and Kelly, inhabit a virtual paradise that is far from innocent, as Yorkie's visit to Quagmire—a sex club frequented by both tourists and locals—proves. The symbolism of this place is hard to ignore. It is a garden of earthly delights rendered in similar dark colours as the homonymous painting by Hieronymus Bosch. Bosch's image is a place of mindless carnality, the outcome of a world where no God and only a morality of fear and retribution exists. The imagery, and realization by Yorkie of Kelly's hedonic lifestyle, shatters any illusions that Yorkie or the audience, may have about the character of this virtual paradise. It is a pleasure-land designed to offer an exodus from the misery of real life, a refuge where infirmed and elderly citizens can revisit their golden years.

Moreover, the transgressive nature of both heroines is underlined by the fact that they are expelled from, or have decided to severe their connections with, their families. Yorkie has been disowned by her religious conservative family after coming out. Meanwhile Kelly has lost her daughter before entering '*San Junipero's*' simulation. Her husband decided not to enter the simulation in the hope of an afterlife, where he could be reunited with his daughter, exists. Kelly must choose whether to gamble on an improbable afterlife where her 'nuclear' family could be reunited, or to stay with Yorkie in San Junipero for 'eternity'. Her final choice to ignore the promise she had previously given to her husband, and thus negating the established natural 'order,' is a disruptive act of rebellion. Kelly and Yorkie don't care about entering an edenic world. San Junipero for them is just the background. No meaningful relationship with other characters is seen on screen. Instead, the few other characters operate like video game NPCs minimally advancing the plot through expository dialogue. The only other character that is somewhat developed in the episode is Wes, another visitor in San Junipero. Wes pursues Kelly, claiming that he is in love with her. She rejects him, saying that she does not want anything serious, only attachment-free fun—showing her reluctance to join this virtual community. Throughout the episode the only meaningful relationship is that of the

[12] D. Haraway, *A Cyborg Manifesto* (1984).

two heroines, reflecting Haraway's observation in her Cyborg Manifesto that cyborgs are wary of holism, but needy of connection.[13]

The similarities of these figures with Haraway's definition of a cyborg are striking. The 19th and early 20th century technological utopianism, however, with its vision of a rational society where technological innovations and scientifically organized production act to solve society's ills, seems to have been transformed. The celebratory tone of late 19th century technological utopianism was gradually abandoned by science fiction narrative, which was partly the result of the appropriation of the technology of the digital and information revolutions of the 50s and 60s. Similarly, '*San Junipero'* while initially seeming to describe a utopian community, comes to reveal a much darker vision built around the questionable desirability of this virtual paradise and the 'gift' of immortality that it offers.

The dystopian undertones may be the result of the series' general character that questions the way humans use technology, usually depriving it from realizing its utopian potential. But in this case technology is almost absent for the story. The utopian setting of the virtual paradise has a retro 80s style and in the few scenes where we see the heroines in their true 'real 'form the technology is miniaturized and barely seen. The small size of the gadgets obscures their capabilities. The non-intrusive nature of the technology serves to emphasize how far removed our current technology is from that present in the episode. While we are currently far from technology of this kind, futurists and transhumanists appear optimistic that market forces will someday provoke their development. Still as a 2007 report by the Oxford Institute for the Future of Humanity has underlined WBE specific fields--largescale neuroscience, physical handling of large amounts of tissue books, achieving high scanning volumes, measuring functional information from the images, automated identification of cell types, synapses, connectivity and parameters—have limited practical applications to other industries and as a result have limited research funding.[14]

Another glimpse of this reality's futuristic technology is displayed through Kelly's visit to the hospital where Yorkie's body is paralyzed. There Yorkie is able to communicate with the medical staff through a novel device, which enables her to have limited contact with her environment despite her condition. Through this technology she is able to express her desire to be euthanized and permanently join San Junipero. The shallow treatment of the technology's construction is a recurrent short-coming of *Black Mirror.* In general the show focuses heavily on social consequences of technology and tends to avoid any explanation of how these semi-miraculous technologies came to exist. This especially true of '*San Junipero.'* A virtual eternal life would have caused significant debates in any society, especially in relation to religious teachings regarding the afterlife. However, the piece of

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[13] D. Haraway, *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York, 1991).

[14] A. Sandberg, N. Bostrom, *Whole Brain Emulation (A Roadmap)*, Technical Report (2008), Oxford University.

history we are given is that in its original incarnation San Junipero was a form of nostalgia therapy—used to treat anxiety and dementia by triggering and unearthing past memories through music, old pictures, videos and personal items.[15] Yet we do not learn how the capabilities of this virtual technology evolved to accommodate a 'permanent population.' The only thing we learn is that living older people are limited to five hours every weekend while younger people are not permitted to visit. Once more, *Black Mirror* offers us a glimpse of the dystopian potentials of technology and the propensity of humanity to abuse it. Such a shallow treatment of the how these technologies function, though somewhat expected or excusable in a television series, extends beyond *Black Mirror,* pervading the whole transhumanist movement. Transhumanism seems to be more inspired by Science Fiction than by actual research in the fields of neuroscience and informatics. For all the enthusiastic TEDx appearances of Kurzweil and Morrow who predict that the singularity and WBE technology will be achieved within the next 30 or 50 years, there are neuroscientists like Kenneth D. Miller and Sten Linnarsson who explain the difficulty and complexity of mapping the human brain. This latter group of scholars delineates how far we are from fulfilling the promises of cryonics or brain mapping, emphasizing that the advertisement of such technologies is misleading, unethical and false.

A much wider critique of contemporary utopian hopes is nested within this expert challenge to the transhumanists and futurism movements. The retro paradise of *San Junipero* with its promise of eternal life and endless hedonism presents as an enticing alternative to a bleak world. The life contained within it, is safe (it has no setting for pain) but is also vacant of meaning. Additionally, the program has multiple time settings—Yorkie is encouraged to search for Kelly in the 90s and early 2000s—yet there does not appear to be a setting for the present or future. The backwards looking nature of the program, while partly justified by its use as a form of nostalgia therapy, betrays another trend in contemporary utopian thought. The decline of 20th century grand narratives combined with pessimistic projections for humanity's future have led to an affinity for a 'safe' past. The neoliberal individualistic ideas of transhumanists offer only personal fulfilment, lacking a more comprehensive social vision. Their imagined upgrade to the human species through science, reason and technology is mute when it comes to larger social structures. Conquering longevity or immortality will not provide answers to the pressing issues slated for humanity's future. Hence, the retro style of '*San Junipero*' is not simply nostalgia but reflective of a failure of current utopian visions to design future divorced from the artefacts of the past. Brookes claimed that he wished to create an episode with a utopian content. However, the writers of *Black Mirror* were not able to write a completely futuristic utopia. As Bloch warned seven decades ago in his The Principle of Hope (1954), the most debilitating condition that can befall humanity is an inability to imagine a different society. '*San Junipero*' demonstrates an inability to imagine a positive future void of cynicism. Rather, the only

[15] F. Jameson, 'Nostalgia for the Present' in *Postmodernism, or, the Cultural Logic of Late Capitalism* (1992).

conceptual options appear to be dystopian or a utopia that has regressed into the past or the personal. In the end the paradise is not San Junipero but Yorkie and Kelly's relationship. Cultural critics like Fredrik Jameson have questioned the modern prevalence of nostalgia. According to Jameson late capitalism is rife with postmodern nostalgia which manifests in a pastiche that imitates past styles but is devoid of value. '*San Junipero*,' with its retro nostalgia, is for Jameson a 'blank parody'. Moreover, the pastiche displayed by *'San Junipero'* is divorced from any meaningful categorizations of utopia taught by Classical and Judeo-Christian theology and philosophy. The barriers of past, present and future, with the varying promises of Apocalyptic disaster and Kingdom on Earth, are abandoned for a simultaneity of past memories and future hopes. Our heroines are indifferent to the history they've retreated into precisely because it is a manufactured past derived solely from fashion magazines and old billboards. No real consideration is given to the events and social architecture of the simulated period. Furthermore, Yorkie's awkwardness during her first visits to San Junipero suggests that even the nostalgia that the visitors bathe themselves in is fake. The users of San Junipero are not revisiting their past selves. Instead they generate ideal versions of themselves similar to modern social media profiles.

Conclusions

The utopian vision of '*San Junipero'* represents nothing but the achievement of immortality and eternal youth, the two most fundamental and selfish human desires. Past utopian genres offered similar ideal worlds peopled by immortal inhabitants. The sources of this immortality in pervious iterations, however, were supernatural. Fountains of youth, or magical lands created by Gods to house a few elect—brave heroes or the resurrected Just—are probably the earliest versions of utopian/paradisiacal lands. The modern definition of utopia, which emerged in the sixteenth century, denied these metaphysical dreams, focusing instead on communal visions of an improved social and political organization. The immortal heroes of ancient lore gave to mortal citizens occupied with practical issues, such as advancements in nutrition, healthcare , justice, and equality. The re-ascendance of personal immortality in contemporary utopian narratives, such as '*San Junipero,*' displays how an individualistic paradigm has come to dominate our age. Additionally, it links our modern quest for immortality, despite the much-advertised belief in science and reason, to a metaphysical origin. Ultimately, the postmodern utopia of immortality is only superficially linked to the technological utopianism of the past century and its focus on futuristic sciences. Instead it is closer to the wildest dreams of Science fiction's, and completely divorced from real scientific concepts and technologies. Even if brain emulation technology is our best chance of achieving immortality and even if some neuroscientists are willing to explore this idea, the position of this vision in our contemporary media and public debates is more the result of pulp science and collective anxieties concerning the impact of technology in our lives, and less a sign of its imminent realization.[16] '*San*

[16] K. D. Miller, *Will you Ever Be Able to Upload Your Brain?* (The New York Times 2015).

Junipero' demonstrates how ingrained these futuristic technologies are within our cultural moment, and how they entice through solving our fear of death. Utopias and Science Fiction express broad social and cultural anxieties and hopes, especially those which that have been widely disseminated through pulp science. This miraculous and potentially dangerous science promises to deliver eternal life and youth, but it also brings disturbing costs—costs which haunt contemporary collective consciousness and literature. Ultimately, '*San Junipero'* is unsettling because of its happy ending. A couple enjoying their bond for all eternity seems the definition of a dream come true. But can we weather an eternity removed from the mortality so fundamentally characteristic of our species? If so, will we still be humans? And how logical is this dream that rejects our natural limitations? Perhaps we should pause to remember the religious origins of the promise of immortality, new purposefully hidden behind pulp science, and reflect the apocalyptic of John the Apostle who warns:

Beloved, we are God's children now, and what we will be has not yet appeared; but we know that when he appears we shall be like him, because we shall see him as he is.
John 3:2

Though an immortal paradise has been promised to us before, it is framed with the caveat that we will eschew our humanity upon entering it. The restored Eden of '*San Junipero,'* inhabited by genderless, ageless, cyborgs who ignore past categorizations and typologies, may be a fulfilled Promise of a kind. However, the inhabitants of this cyberspace won't be humans and this eternal Paradise will have robbed us from both past and future, history and utopia.

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Brazilian Voices in the Making: Paulo Pontes, Chico Buarque, and Euripides' Medea

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Abstract. *This article identifies three elements of Euripides' Medea which reappear in Paulo Pontes and Chico Buarque's play, Gota d'Água (1975). These elements, this article argues, enable Buarque and Pontes to reimagine Medea as a commentary on the reality of the Brazilian lower classes in the 1970s. The article proceeds in five parts. The first section is an overview of Brazilian history, contextualising key elements in Brazil's military dictatorship (1964-1985), under which Gota d'Água was written and first performed. The second section is a summary of Gota d'Água. The third, fourth and fifth sections address thematic similarities between the two plays—namely, the relationship between economic power and social climbing, between political power and silencing, and between otherness and marginality.*

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1. Historical background

Brazil was colonised by the Portuguese between 1500 and 1822. Brazilian independence can be traced back to 1808, when the Portuguese court sailed to Brazil in a desperate measure to escape from Napoleon and to establish a power base in the New World. At that time, Brazil was already an economic powerhouse, responsible for approximately 60% "of the exports that earned Portugal's trade surplus" (Skidmore, 1999, p. 31), leading the prince regent João to unify Brazil and Portugal into a "United Kingdom". This bold move had two implications: Brazilian elites, on the one hand, saw the manoeuvre as an opportunity to claim independence; Portuguese elites, on the other hand, felt the need to reclaim Brazil's colonial status and urged the court to return to Portugal. This return, however, occurred only partially: João VI, now monarch, sailed back to Portugal, but his son Pedro remained in Brazil as prince regent.

In 1822, Pedro declared Brazil's independence and was crowned Emperor Pedro I. That Brazilian independence was declared by a member of the Portuguese Royal family reveals the continuities of the socio-political structures of the old regime (Caldeira 2017, p. 208): slavery was not yet abolished, and both economic and political power remained concentrated in the hands of elites. The lack of a sharp divide between Brazil, "the colony", and Brazil, the newly founded "Empire", has survived in Brazil for centuries. Even after becoming a republic in 1889 (tellingly, by means of a military coup d'état rather than a collective upheaval), presidential elections in Brazil remained little more than a formality for decades. Frauds were not uncommon, and candidates appointed by parties that were more influential in the government were often "chosen" by the people – with hardly any use of campaigning or debates (Caldeira, 2017, p. 340-341; p. 395-402).

The military remained a strong presence in Brazilian politics. The first two presidents of the republic were marshals (Marechal Deodoro da Fonseca and Floriano Peixoto), in what became known as the "República da Espada" ("Republic of the Sword"). It was another coup with military support that put Getúlio Vargas in power instead of Júlio Prestes, the official winner of the presidential elections of 1930. Ironically, it was also the military who, in 1945, would put a stop to Vargas' authoritarian rule.[1]

In 1964, the military led yet another coup in an attempt to control the "communist threat" posed by João Goulart, the president at the time, who demonstrated a keen interest in promoting social change (Skidmore, 1999, p. 155). The military dictatorship argued that one of the main reasons for the rampant inflation Brazil was facing at the time was a recent but significant increase in the minimum wage. Attempts to favour the lower classes were also bound to be interpreted as communist-leaning and would therefore risk forfeiting foreign investment, mainly from the United States.

This mindset inevitably reinforced the social inequality Brazil had inherited from its colonial past. The resulting dissatisfaction among parts of the population had fewer and fewer chances to manifest itself as repression by the military government was progressively reinforced over time. The institutional act No. 5 of 1968 enforced censorship on the press, public demonstrations and artistic productions (Skidmore, 1999, p. 164). Torture and purges followed.

2. Plot summary

Such is the context in which *Gota d'Água*, following several censorship cuts given its "strong note of social protest" (Woodyard, 1978, p. 152), was published and performed in 1975. The two authors, Paulo Pontes and Chico Buarque, also wrote a "manifesto" claiming that their work reacted to a political and cultural crisis in Brazil. They state:

> "(…) First and foremost, the play explores a facet of Brazilian society that has gained prominence in recent years: the experience under capitalism (…). There's nothing new in fostering the concentration of wealth in the upper classes through the draining of the income of the lower classes".[2]

While this is a clear reference to the economic measures taken by the military, the authors also attribute the oppression of the Brazilian lower classes to residual colonialism surviving among the upper classes:

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[1] For a more detailed account of such events, see Skidmore (1999), esp. pp. 65-126.

[2] "A primeira e mais importante de todas [preocupações fundamentais que a nossa peça procura refletir] se refere a uma face da sociedade brasileira que ganhou relevo nos últimos anos: a experiência capitalista (...). Forcar a acumulação de capital através da drenagem de renda das classes subalternas não é novidade nenhuma" (Buarque & Pontes, 1975, p. xi). All translations from the Portuguese (with a few adaptations so that they are more accessible in English) are mine.

> "Brazilian history has (…) two cultures: on the one hand, an elitist, **colonising** one, brought here from Portugal; on the other hand, a popular, silenced culture, born of the social experience of the lower classes. (…) *Gota d'Água* (…) *is a tragedy of Brazilian life*".[3]

One of numerous takes on *Medea* onstage across countries and centuries (see Hall, E., Macintosh, F., and Taplin, O., 2000), Pontes and Buarque's play is set in Rio de Janeiro, on a fictional suburban apartment block ("conjunto habitacional") called Vila do Meio-Dia – a residential area not sufficiently deprived to qualify as a slum ("favela"), but one in which its working-class experience severe financial struggles. The main character, corresponding to Euripides' Medea, is called Joana. Though Joana, a lower class Brazilian woman, does not share Medea's status as a foreigner, she does share her magical powers, namely *macumba* – an umbrella-term referring to various African rituals and religious practices often stigmatised as dark magic. She is married to Jasão, who is younger than she is, just as Jason is younger than Medea. Jasão, however, is a less heroic figure in *Gota d'Água*: he is an amateur songwriter uncommitted to music or, for that matter, anything else. Creonte—Euripides' Creon—is the real estate developer who owns Vila do Meio Dia's housing and is portrayed as a nasty and manipulating slumlord. Egeu, an analogue to Aegeus, is a small business owner in the neighborhood and the only character with his own property and, therefore, without any debt to Creonte.

Joana and Jasão live with their children at Vila do Meio-Dia, where most inhabitants pay for their homes in the form of monthly instalments debt to Creonte. Before the events of the play, Creonte had paid a radio station to play Jasão's latest samba song, "Gota d'Água", and turned it into a massive hit. Jasão is also leaving Joana to marry Creonte's daughter. In the play's first act, Joana's female friends and Jasão's male friends form a split chorus: the female characters lament that Joana, stronger and smarter, is about to be abandoned by a boyish, younger man who, until recently, was unable to fend for himself. The male characters, in turn, acknowledge Jasão's talent as a songwriter and celebrate the fact that he is on the verge of gaining financial and social capital.[4] Egeu, meanwhile, has been helping Joana financially during her crisis while plotting an uprising against the abusive Creonte.

In the second act, Creonte promises his residents that he will renovate their houses as long as they stop their riot. Creonte gives Joana one day to leave the house. As revenge, Joana sends her children to Jasão's wedding ceremony with a poisoned cake, but Creonte sends them home. Realising that her plan has backfired, Joana conjures the African deity Xangô and asks him why he will not let her take revenge

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[3] "Ao longo dessa história correram (...) duas culturas: uma, elitista, **colonizadora**, transposta da matriz pra cá; a outra, popular, abafada, nascida da existência social concreta das classes subalternas. (…) *Gota D'Água* (…) *é uma tragédia da vida brasileira*" (Buarque & Pontes, 1975, p. xii-xvii).

[4] See Woodyard (1978, p. 153).

on her enemies. Seeing no way out, she decides that she and her children should eat the poisoned cake and die.

Considerable adaptations and deviations from the original Greek text were made in order for the play to be rooted in its Brazilian context – the most striking one probably being the fact that Joana, unlike Euripides' Medea, commits suicide (which is addressed in the fifth section of the present article). Nonetheless, there are a few significant elements from *Medea* that the Brazilian text seems to be nodding to, which are discussed in the following sections.

3. Economic power and social climbing

Mastronarde (2002, p. 31) points out that Jason "frequently employs commercial and financial terms and metaphors". Though such language is unexpected in the aristocratic environment of Greek tragedy, they reoccur in Jason's justification of his new marriage:

> "(…) but my purpose was that **we should live well** – which is the main thing – and **not be in want**, knowing that everyone gets out of his way to avoid **a penniless friend**".[5]

Medea also implies that social climbing contributes to Jason's betrayal, claiming that "his passion was to marry a king's daughter".[6] This theme becomes prominent in *Gota d'Água*. Several characters comment on Jasão's change of social status throughout the play:

> "Let's drink to Jasão, that lucky bastard
> who is about to marry the king's daughter".[7]

This is hardly the sole instance in which Creonte is referred to as king, and the imagery is reinforced in a scene where Creonte seduces Jasão "into a position of power, symbolized by his chair, a kind of throne" (Woodyard, 1978, p. 153). Allusions to Creonte's royalty are more than mere attempts to reference source material, however, and in fact reveal the relations of power in Brazil from colonialism to capitalism – a time span included in the authors' "manifesto".

McLeod (2000) defines colonialism as the seizing of a foreign land for the economic profit of the homeland while developing unequal relations of power between coloniser and indigenous people. This is not radically different from

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[5] ἀλλ' ὡς, τὸ μὲν μέγιστον, **οἰκοῖμεν καλῶς**
καὶ **μὴ σπανιζοίμεσθα**, γιγνώσκων ὅτι
πένητα φεύγει πᾶς τις ἐκποδὼν **φίλον**. (*Med.*, 559-561). The Greek edition and the English translation are Kovacs (2001).

[6] ἀνδρῶν τυράννων κῆδος ἠράσθη λαβεῖν. (*Med,* 700)

[7] "Vamos beber à Jasão
Aquele sim, nasceu co'o cu pra lua. Está
Pra se casar co'a filha do rei" (Buarque & Pontes, 1975, p. 17).

Creonte's vision of capitalism: he builds houses on a piece of land for his own economic profit and takes advantage of his position to exploit members of lower classes by means of abusive charges. The difference in scale in each case is obvious,[8] but the parallels remain striking. References to Creonte as king, in this sense, broaden his reach, rendering him a generic agent of social injustice that has always been present in Brazil –previously in the form of colonialism, and then in a form of capitalism.

4. Power and silencing

Injustice, in Euripides' play, is connected to the tense relationship between power and speaking. In the *agōn*-scene, Jason ascribes Medea's hopeless situation not to the injustice she has suffered—that is, the fact that her husband has abandoned her—but to her decision to voice such injustice and therefore challenge the ruling power:

> "Although you could have kept this land and this house by patiently bearing with your **superior's arrangements**, you will be exiled because of your foolish talk. Not that it bothers me: go on, if you like, **calling** Jason the basest man alive. But as for your **words against the ruling family**, count yourself lucky that your punishment is exile".[9]

Here, Medea's act of speaking is placed at the center of the threat she poses. Silencing her through exile, then, allows Creon to reinforce his authority. This is but one of many instances in ancient literature in which women are belittled for being vocal[10] – and that includes tragedy. Roisman shows the different textures with which "outspoken women, who speak and act against the ruling powers" (2004, p. 92) are portrayed in Greek tragedies other than *Medea* (namely: Aeschylus' *Seven Against Thebes* and *Agamemnon*; Sophocles' *Antigone* and *Electra*; Euripides' *Electra*).

In *Gota d'Água*, too, Joana verbally challenges Creonte's authority:

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[8] Some actions attached to colonialism clearly do not apply to Creonte's case – e.g. there is no invasion of land (see Hiddleston, 2009), as he is Brazilian and not explicitly associated with a Portuguese ancestry. In a way, Creonte's presence in the play could be also linked with imperialism, which can "be understood as a larger structure of economic or political hegemony that does not have to include the direct rule and conquest of another country" (*ibid.*, p. 2). Due to its broader reach, "Imperialism could, then, continue after the end of colonial rule" (*ibid.*), and in the context of the play may express, by means of Creonte's character, a residue of colonial economic and power abuse in more recent structures.

[9] σοὶ γὰρ παρὸν γῆν τήνδε καὶ δόμους ἔχειν
κούφως φερούσῃ **κρεισσόνων βουλεύματα**,
λόγων ματαιων οὕνεκ' ἐκπεσσῇ χθονός.
κἀμοὶ μὲν οὐδὲν πρᾶγμα. μὴ παύσῃ ποτὲ
λέγουσ' Ἰάσον' ὡς κάκιστός ἐστ' ἀνήρ.
ἃ δ' **ἐς τυράννους** ἐστι σοι **λελεγμένα**,
πᾶν κέρδος ἡγοῦ ζημιουμένη φυγῆ. (*Med.* 448-454)

[10] See Mary Beard's recent *Women and Power: a Manifesto* (2017, p. 3-45).

> "Joana held rallies
> at the *terreiro*, at the bar, in front of the building,
> She cut Creonte to pieces".[11]

The Portuguese word "comício", translated here as "rally", often refers to a public meeting or protest in which a leading figure makes a political speech. The word, therefore, alludes to the power dynamic integral to speaking—one recognised by Euripides. That this term is used to refer to Joana's allegations against Creonte further reveals how marital and social conflicts are deeply intertwined in *Gota d'Água*. Indeed, Creonte uses his social status to silence Joana's voice: escorted by policemen, he forces his way into Joana's house and commands her to leave "calmly, without **complaining**" ("Saia sem **chiar**, calma", Buarque & Pontes, 1975, p. 148). This scene becomes even more powerful when rooted in the context of dictatorship in the 1970s, during which the police repressed rebellion through violence, torture and purges. Joana, in this sense, represents Brazilian voices continuously silenced by the ruling power.

5. Marginality/Otherness

Motifs of marginality and otherness inevitably evoke Euripides' famous passage in which Medea declares herself representative of a marginal, oppressed group—women:

> "Of all creatures that have breath and sensation, **we women** are the most unfortunate. First at an exorbitant price we must buy a husband and **take a master for our bodies**. The outcome of our life's striving hangs on this, whether we take a bad or a good husband. For divorce is discreditable for a woman and it is not possible to refuse wedlock."[12]

The use of master/δεσπότης here reinforces the idea of the oppression of otherness: in this case, male oppression of what is not male. Indeed, much has been said about Medea representing otherness: females, foreigners, witches.[13] Medea actually appeals to such otherness, claiming that her condition is even worse than the one of the women in the chorus, as she is away from home and without

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[11] "Ela fez comício
No terreiro, outro no bar, no edifício,
Deixou Creonte mais raso que o chão" (Buarque & Pontes, 1975, p. 98).

[12] πάντων δ᾽ ὅσ᾽ ἔστ᾽ ἔμψυχα καὶ γνώμην ἔχει
γυναῖκές ἐσμεν ἀθλιώτατον φυτόν·
ἃς πρῶτα μὲν δεῖ χρημάτων ὑπερβολῇ
πόσιν πρίασθαι, **δεσπότην** τε σώματος
λαβεῖν. (...) κἀν τῷδ᾽ ἀγὼν μέγιστος, ἢ κακὸν λαβεῖν
ἢ χρηστόν· οὐ γὰρ εὐκλεεῖς ἀπαλλαγαὶ
γυναιξὶν οὐδ᾽ οἷόν τ᾽ ἀνήνασθαι πόσιν. (*Med.* 230-237)

[13] "The single character Medea is marked in all ways as the other, the different, in the tragedy which bears her name. (...) Medea is not a whole other culture, but the other within the city" (duBois, 1982, p. 118-119). See also Mastronarde (2002, p. 15) and Hall, Macintosh, and Taplin (2000). For a more nuanced interpretation of Euripides' character, see Rabinowitz (1993).

supporting family. By the end of the play, however, she is no victim. In the final scene, she "rises to complete triumph over her enemies and appears physically raised above Jason (…) like the gods for whom the upper level and locomotion by the theatre-crane are normally served" (Mastronarde, 2002, p. 12).

In *Gota d'Água*, Joana echoes Medea's monologue (adding an extra layer of social struggle) in stating that, if God were good, he would not have created poor people or women ("não criava duas coisas: primeiro pobre, segundo mulher", Buarque & Pontes, 1975, p. 65; see Woodyard, 1978, p. 154). Joana's otherness manifests itself in what escapes the Portuguese colonising culture mentioned earlier in the manifesto: Joana is not male, not elite, not catholic and, as a *macumba* practitioner, linked to the colonial oppression of Africans. The big difference, however, is that Joana, unsuccessful and driven to suicide, concludes her story rather differently. Her last lines are:

> "To Creonte, the daughter, Jasão and others
> I'll leave this wedding gift
> I'll give you **our** agony
> because, oh Father, I learned that the pain
> from living in tragedy every single day
> is worse than dying from poisoning".[14]

In using the first-person plural here, Joana speaks not merely for herself and her children, but for the otherness she impersonates. Further, the choice to use an ending that differs from Euripides'[15] – where Medea survives and revenges herself on her enemies – elicits more sympathy than the Greek character and intensifies the tragedy of Brazilian life highlighted in the manifesto.[16] These Brazilian voices of which Joana is a spokeswoman are bound to be silenced again and again throughout history. Such silence, Joana maintains, though experienced while living, proves even less bearable than the silence of death itself.

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[14] "A Creonte, à filha, a Jasão e companhia
vou deixar esse presente de casamento
Eu transfiro pra vocês a **nossa** agonia
porque, meu Pai, eu compreendi que o sofrimento
de conviver com a tragédia todo dia
é pior que a morte por envenenamento" (Buarque & Pontes, 1975, p. 167).

[15] This ending was inspired by a Brazilian television adaption of *Medea* that, as they claimed, "showed that the elements of the tragedy we wanted to disclose already lied in Euripides's dense plot" ("nos forneceu a indicação de que na densa trama de Eurípides estavam contidos os elementos da tragédia que queríamos revelar", Buarque & Pontes, 1975, p. xx)

[16] In an interview about a more recent production of *Gota d'Água* (2005 to 2013), director Heron Coelho argues that this kind of passional suicide is a Brazilian cultural reference: "Chico and Paulo Pontes are dealing with a Brazilian context and Brazilian cultural references. There is a samba of the 1940s which deals with a very similar situation. It talks about a Joana who commits suicide on account of someone called João. It is called *Notícia de Jornal* ("News Piece"). Chico recorded this song later" (in Gemelli, 2015, p. 716).

These three elements – social climbing, the tension between power and speaking, and marginality – reveal that the authors of *Gota d'Água* engaged with *Medea* in a way that enhances the socio-political tensions present in the Greek text. Although they may not be central aspects in Euripides' play, they serve as springboards for the authors to comment more effectively on the constraints facing Brazilian lower classes at that time and, more broadly, on a scheme of social inequality that can be traced to Brazil's colonial days.

Faculty of Classics

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Field Review

Understanding the Paleofluid Records: a Case Study of Southern Utah

Rebecca Tyne

Abstract. *The ability to understand subsurface fluid-rock systems is critical to the development of geological carbon dioxide sequestration and hydraulic fracturing. The Colorado Plateau in the United States of America is an archetypal location for diverse fluid flow. Across the plateau, especially in southern Utah, the Jurassic Navajo sandstone has remarkable red and white colour variations, which are a result of sandstone bleaching. This spectacularly preserved fluid flow event, accompanied with extensively drilled wells and the well characterised geological history, means that southern Utah is an ideal natural laboratory for studying the paleoflow. The type of the fluid flow responsible for the bleaching is highly debated; the main candidates are a huge exhumed hydrocarbon field bigger than those in Saudi Arabia, a natural carbon dioxide flow or hydrogen sulfide. The spatial and temporal interaction of simple, independent factors, as seen in the Colorado Plateau, leads to complex results not relatable to any individual process. This article critically reviews the evidence for paleo-hydrocarbon, carbon dioxide and hydrogen sulfide flows across the basin. It also suggests that future paleofluid flow studies, both in this region or across the world, need a whole basin-scale perspective in order to truly understand the interaction between the fluid flow and the subsurface.*

* * *

Introduction

Recent debates over hydraulic fracturing and its link to seismicity and geological carbon dioxide sequestration have resulted in an urgent need to better understand subsurface fluid and paleofluid flow and interactions. This would allow the development of natural analogues for these modern systems. In addition, there is an increasing awareness about the role of subsurface fluids in connecting the lithosphere with the critical zone (the near-surface environment where the interactions of rocks, fluids, atmosphere and biological organisms control and regulate the availability of resources needed for life to exist). As a result, an understanding of subsurface fluid-rock systems is becoming increasingly important. The subsurface migration for specific types of fluids over short timescales has been extensively studied in order to assess and manage groundwater, hydrocarbon and ore deposit resources. However, fewer studies have explored multiple fluids within a flow, and how these fluids interact. An understanding of these interactions during flow, especially in areas of rock deformation, could aid in the human management of subsurface resources.

Consequently, a suitable natural laboratory is required to explore and understand the connection between paleofluid flows and the lithosphere and critical zone.

The Colorado Plateau in the United States has some of the most iconic and controversial records of diverse fluid flow in the world, which have been recorded in the rock record as extensive bleaching of the upper sandstones and remarkable colour variations (see Figure 1). This makes the Colorado Plateau an ideal natural laboratory for studying paleofluid flow. The incised 3D exposure in southern Utah, extensively drilled wells, subsurface samples, and a relatively well-characterised geological history make it especially well suited for studying paleofluid flow. The spatial and temporal interaction of simple, independent factors seen in the Colorado Plateau leads to complex results which are not relatable to individual process. Therefore, this article will look at fluid responsible for this bleaching in this basin as well as the need for a basin-system-scale perspective to truly understand how both the reservoir and rocks have responded to paleofluid flows.

Geological Setting

The Colorado Plateau is located in the four corners region (where the states of Arizona, Utah, Colorado and New Mexico meet) in the southwest of the United States (Figure 2). It covers an area of approximately 50,000 km^2. The plateau's interior is largely unaffected by significant tectonic deformation. Southern Utah is an archetypal location for paleofluid flow, made up of a thick Palaeozoic-Mesozoic sedimentary sequence. The Jurassic to Cretaceous system rocks make up the main sedimentary sequence. They consist of thick marine and non-marine sequences formed from erosion, especially resulting from during the Nevadian and Sevier orogenies to the west of the Colorado Plateau. The Jurassic units are generally flat lying and comprise of four main aeolian units affected by diagenetic iron. In ascending order, these are the Navajo Sandstone, Page Formation, Entrada Formation and the Summerville/Morrisson Formation [1, 2, 3, 4, 5]. The Navajo sandstone and its equivalent units are dominated by large scale high angle aeolian cross stratification (Figure 1) [6]. Together, these units form the largest dune field preserved in Earth's history [1]. The Navajo Sandstone is a well sorted, fine-medium grained quartz arenite that was oxidised during diagenesis [6] and it is the main aquifer unit in some areas of the plateau. The well-preserved porosity and permeability of the Navajo sandstone most likely allowed for large fluid flows and the resultant bleaching through the unit [7]. The Page formation is local to the Moab area and it is only a few metres thick. It is a basal chert–pebble conglomerate and fines upwards to a coarse-grained sandstone [4]; this unit also has a high permeability. The Entrada formation contains three different members (Dewey Bridge, Slick Rock and Moab Tongue) with differing lithologies and characteristics affecting the fluid movement. The Dewey Bridge Member is an interbedded sandstone, siltstone and mudstone with local bed scale breccia. The Slick Rock Member is a largely aeolian sandstone, sea-dune deposit with a moderate permeability [3, 8]. The Moab Tongue member is local to southern Utah and pinches out to the south and west of the Moab. It is a relatively thin fine-grained unit which is commonly jointed and contains cross-stratified aeolian dune sets. The

permeability is similar to that Navajo Sandstone. The Summerville formation and Tidwell member of the Morrison formation are both very thin-bedded sandstones and mudstones overlying the Moab Tongue. They are non-calcareous red beds from a marine incursion of sandstone in a coastal to tidal setting separated by an unconformity; these represent the confining layer in the system and have remained red [4].

Figure 1: Exposure of the bleached Jurassic sandstones in southeastern Utah, near Moab. Cross stratification from dunes (CB) can be seen in both bleached (B) and unbleached units (R).

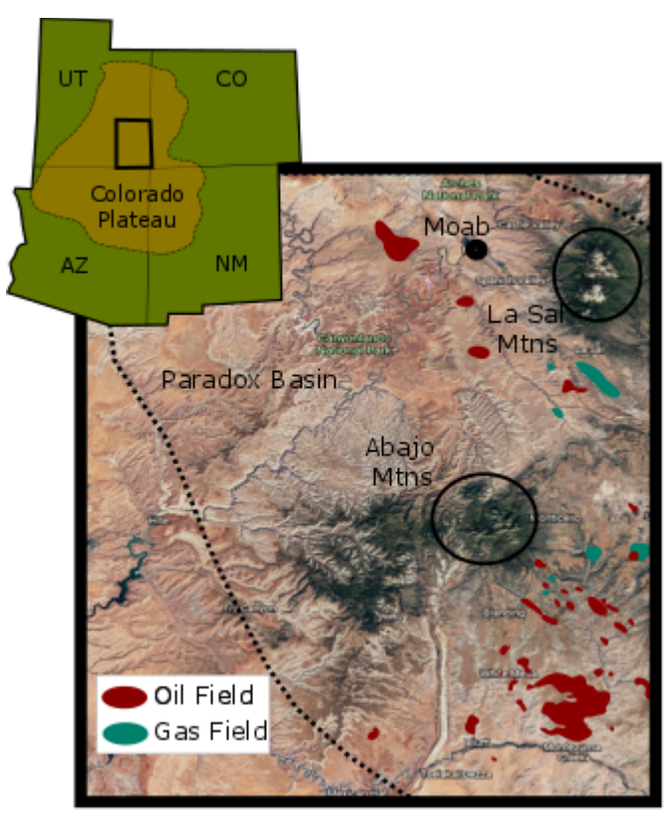

Figure 2: A map of the broader Four Corners Region of the U.S.A and a more detailed map of the study area. Satellite image is taken and modified from Google Earth; Oil and Gas Fields are adapted from *assets.geoexpro.com*.

The Colorado Plateau includes salt tectonics, monoclinal folds and broad flexures, faults, and igneous laccoliths and volcanic features. The Laramide orogeny which occurred during the early Tertiary resulted in uplift of the Colorado Plateau, monoclinal folding and minor faulting, which link to regional faults at depth [9]. The thick salts of the Paradox sub-basin have added additional structure to the Colorado Plateau by deforming and folding the overlying structures and creating eight salt anticlines, the crests of which were eroded prior to burial. The salt diapirs have subsequently collapsed, creating valleys at the centre of the anticlines. Between 6 million and 1200 years ago, the edge of the plateau was subject to volcanic activity which created volcanic extrusive features, laccoliths as well as natural CO_2 fields.

Bleached Sandstone

The Jurassic sandstones of southern Utah were stained red during early diagenesis, as a result of the release of iron from detrital minerals and subsequently oxidized to form hematite grain coatings or iron cements [10, 11]. Today the rocks that remain red represent the least altered parts of the formations. However, large areas of the region have been bleached as a result of a reducing paleofluid flow [6]. The Navajo and Entrada sandstones are both heavily affected by this bleaching [4, 10, 12]. There is also minor bleaching of the Permian White Rim sandstone [13] and the Triassic Moenkopi Formation [14]. The bleached sandstone tends to be at the top of formations suggesting that the responsible fluid is buoyant. The bleaching also cuts across stratigraphic and petrographic boundaries. The contacts between the bleached and unbleached zones are sharp which could suggest significant burial of rocks before bleaching [15]. This is consistent with rapid subsidence of up to 10 km during the Cretaceous [16].

Although bleaching occurs across the entire plateau, the most continuous and extensive bleaching is in southern Utah at the crest of steeply dipping Laramide uplifts and monoclines. There is also a spatial relationship between the iron oxide deposits and faults in the region (especially the Moab fault) [4] indicating that faults in the region were conduits for the reducing fluids that bleached the sandstones.

Iron oxide deposits appear as concretions in the bleached zones and throughout the Jurassic stratum. These concretions vary in shape and size from millimetres to centimetres in scale and cut across bedding planes. The iron is also deposited as hematite columns and pipes (tens of centimetres in diameter and several meters long) and erosionally resistant towers (up to tens of meters high e.g. at Duma Point). The red staining of the hematite columns decreases toward their cores and they can have both sharp and diffuse edges. The type of edge is dependent on the groundwater flow: in the places where water streaks the hematite column the edges become diffuse and resemble ‘Comet Tails’, which could indicate paleo flow direction [4].

Detailed geochemical studies of the bleached zones show they are depleted in ^{18}O and ^{13}C suggesting that a reducing fluid ascended through faults and mixed progressively with younger groundwaters. The fluid subsequently became

oxidising, causing deposition of calcite, copper and other minerals (see Figure 3) [4, 11, 17, 18]. There is evidence that a high salinity brine ascended through the faults from either the Upper Palaeozoic aquifer or that it resulted from evaporate dissolution [19]. This brine may have been associated with the reducing agent or may have ascended during a separate event; and at least two different fluids have been found to have ascended up the Moab Fault [4].

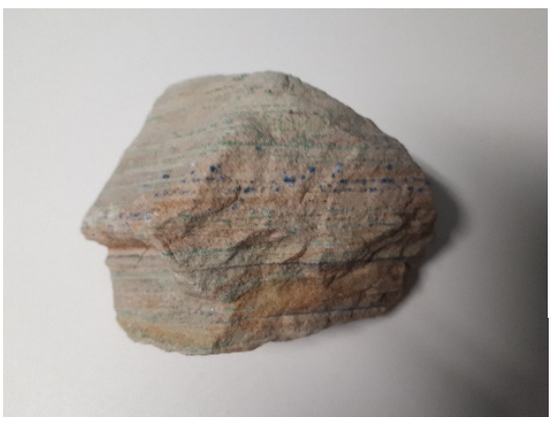

Figure 3:
Hand specimen showing copper mineralisation in linear planes as a result of fluid flow along boundaries.

The fluid flow responsible for this bleaching is highly debated. The main candidates are a huge exhumed hydrocarbon field or a natural carbon dioxide flow. Both of these options will be discussed below.

Possible bleaching fluids

In order for the sandstone to be bleached, and to explain the precipitation of uranite, pyrite and pyrite pseudomorphs, the iron grain coatings must have been reduced and mobilised by a fluid [18]. As the fluid migrated, it must have been both stratigraphically and structurally controlled. Possible iron reducing fluids that could be responsible for the colour change are: hydrogen sulphide (H_2S); hydrocarbon; CO_2; methane; and organic acids [4, 20]. This mobilised iron can be seen to have travelled up to several kilometres prior to precipitation.

Similar bleaching is observed in Montana and is a result of the direct contact of hydrocarbons with iron. It has been suggested that this could also be the cause of the bleaching in southern Utah [20, 21, 22, 23, 24]. Experiments by Chan et al. confirmed the ability of hydrocarbons to bleach sandstones [4]. They found that hydrocarbons, in the presence of an acid, reduce and mobilise the iron, producing CO_2 and water as by-products (Eq. 1). Organic acids and methane which may also be present in hydrocarbons can also reduce the iron and release CO_2 and water (Eqs. 2 and 3 respectively). The chemical equations that govern these processes (taken from Chan et al. [4].) are given below.

$$CH_2O+2Fe_2O_3+8H^+ = CO_2+5H_2O+4Fe^{2+} \quad \text{(Eq. 1)}$$

$$CH_3COOH + 4Fe_2O_3+16H^+ = 2CO_2 + 8Fe^{2+}+10H_2O \quad \text{(Eq. 2)}$$

$$CH_4 + 4Fe_2O_3 + 16H^+ = 10H_2O + CO_2 + 8Fe^{2+} \quad \text{(Eq. 3)}$$

Based on bleached rock volumes and on pore volumes, it is estimated that 18.5×10^{12} barrels of oil would have been needed prior to the erosion to cause the observed bleaching. This figure would have made it the world's largest hydrocarbon field (currently, the largest field is the Ghawar field in Saudi Arabia which contains approximately 1×10^{10} barrels) [25]. This is not an unfeasible estimate for southern Utah as several hydrocarbon fields in the plateau would have reached maturity during the late Cretaceous [14, 26, 27]. The timing of these fields maturing coincides approximately with the Laramide orogeny and the beginning of the sandstone bleaching. The anticlines associated with the location of bleaching would have also provided major structural traps for this paleo hydrocarbon reservoir. Furthermore, bitumen veins and tar sands within the bleached sandstone provides additional evidence that hydrocarbons were once present. Bitumen veins occur across the region with the highest concentration within 250 m of the Moab fault. They have bleached the edges of the sandstone they are in contact with, confirming their ability to cause the bleaching seen [6]. Tar sands occur in the Slick Rock Member of the Entrada formation and are up to 9 m thick [4]. The depleted ^{13}C signature seen in the calcite veins and cement of the sandstones can be attributed to carbon exchange with hydrocarbons which can cause decarboxylation [4, 6]. This again confirms the viability of hydrocarbons as the reducing fluid and paleo-fluid flow responsible for the bleaching of the sandstones.

However, bitumen is not found in all bleached layers and there is currently no indication as to what happened to the remaining hydrocarbons [20]. Additionally, to explain the preferential bleaching at the top of formations, hydrocarbons would have had to migrated through the formations as a buoyant fluid and therefore, they would not have been constrained to down dip directions. However, the comet tails on the hematite pipes suggest a single down dip flow direction [20]. The flow directions suggested by the comet tails are inconsistent with hydrocarbons as the responsible reducing agent. Chan et al. suggested that multiple fluids —one reducing fluid and one that later caused the oxidation— might have migrated up the faults [4]. Nevertheless, the single flow direction seen from comet tails make it unlikely that these fluids would have occurred as distinct episodes with multiple flow directions. This again suggests that it is unlikely that hydrocarbons alone could be responsible for the extensive bleaching.

Loope et al. proposed that the reducing nature of the fluid could have been instead a result of dissolved CO_2 [20]. Within the pre-Triassic strata in the Colorado Plateau there are eleven CO_2 fields [28, 29, 30], and CO_2 springs are associated with local faults [31]. The abundance of CO_2 in the region indicates that CO_2 could be responsible for the reducing groundwater. Carbon dioxide could have seeped through the Triassic sealing sediments via faults and interacted with the groundwaters [29]. The depleted ^{13}C ratio observed by Chan et al. could also be explained by upwelling of dissolved CO_2 [4]. However, laboratory experiments indicate that CO_2 does not cause the bleaching of the iron in sandstones. Though,

CO_2 was able to aid in the mobilisation of large amounts of iron from fractured minerals suggesting that it is a possible source of iron in modern pore fluids [31]. Therefore, the presence of a reducing agent is required alongside CO_2 to dissolve the hematite [31, 32].

Alternatively, hydrogen sulphide on its own (as opposed to mixed with hydrocarbons) could be the cause of the bleaching. It is abundant in southern Utah as evidenced by cold H_2S seeps (especially within Salt Valley), pyrite mineralisation and very H_2S rich brines in the formation underlying the Dolores River. Hydrogen sulphide could then be brought up from the brines to the sandstones via faults. Purser et al. have conducted preliminary experiments to determine the viability of H_2S as the sole cause of iron bleaching, which could be applied to the area (Eq. 4) [31].

$$2H_2S + Fe_2O_3 + 2H^+ = FeS_2 + 3H_2O + Fe^{2+} \quad \text{(Eq. 4)}$$

Hydrogen sulphide could be sourced from the interaction of groundwater with gypsum, within the paradox salt formation, or from the reaction of thioacetamide and water [41]. Preliminary results show H_2S to have five times the reducing power of dissolved hydrocarbons [31]. However, the volumes of H_2S across southern Utah and the Colorado Plateau, are unlikely to be large enough to cause the amount of bleaching seen, especially as the salt is localised to Paradox Basin and not widespread. Therefore, it is likely that H_2S could have caused some of the sandstone bleaching, especially in southern Utah, but other agents must also have been present to cause the extent of bleaching seen.

Conclusion and additional work required

In conclusion, it seems unlikely that any of the fluids so far proposed (hydrocarbons, CO_2 and H_2S) are solely responsible for the bleaching of the sandstone in southern Utah. This is mainly due to the volumes of fluid that would be required at a given reducing power. Hydrocarbons seem to be the most plausible cause for the bleaching because it seems feasible that they could reach the required volume. However, whilst hydrocarbons appear to play a key role, they are not the only contributing factor and it is likely that the bleaching was caused by a combination of hydrocarbons, CO_2, H_2S and other agents.

In southern Utah the first step to understanding the complex paleoflow in the area to is to determine the fluid responsible for the bleaching. However, to understand the full paleofluid flow history of the area and in other regions of the world, the sedimentation, deformation and lithological change through history also need to be well characterised. This will allow for the development of conceptual models to understand system-scale fluid evolution and the formation and management of resources. An understanding of the modern fluid flow in the basin including sources, residence times, and flow paths, will provide additional insight into the basin characteristic and possible constraints on the paleoflow. This could be determined by the use of several techniques including noble gases, radiocarbon,

stable and clumped isotopes and strontium isotopes. This broader outlook will go beyond determining specific fluid types and restricted spatial and temporal perspectives to elucidate long-term and possible evolutionary fluid flow relationships. Insights from this will improve the understanding critical zone interactions, and aid in resource management and the further development of carbon capture and storage.

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Book Review

NO MONO. Capitalism without corporations, by Walter Oswalt

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Oswalt, Walter, *NO MONO. Kapitalismus ohne Konzerne. Für eine liberale Revolution* [NO MONO. Capitalism without corporations. For a liberal revolution] (Münster, Lit Verlag, 2017); 240 pp.; German; ISBN 978-3-8258-7256-4; URL http://www.lit-verlag.de/isbn/3-8258-7256-4

'It is not about tackling the so-called abuses of economic power, but rather about economic power itself.'
Walter Eucken

The publicist and philosopher Walter Oswalt has made the question of how to limit and control power in modern societies his life's work. Born in 1959, Oswalt studied philosophy under Karl Popper in Vienna, then represented the Green Party in Frankfurt's city council, and worked recently as journalist and scientific advisor for ATTAC, an organisation involved in the anti-globalization movement. In many ways his thoughts follow those of his grandfather Walter Eucken, a German economist who established a school of thought called Ordoliberalism during the 1930s. Ordoliberal thinking combined ideas about economic organisation with aspects of social philosophy, ethics and religion. As part of this 'Ordo' programme, Eucken developed radical anti-monopoly policy proposals that are hitherto largely unpublished but stored by Oswalt in the Walter-Eucken-Archive in Frankfurt.[1] While modern Ordoliberals have assimilated into mainstream economics Oswalt follows his grandfather's radical-liberal tradition. Eucken's comment about power at the top of this review also prefaces NO MONO and captures the essence of Oswalt's work. This review summarises NO MONO, discusses its weaknesses and strengths, and illustrates the applicability of its conclusions.

1. Small is beautiful: the central argument

NO MONO's basic premise is that 'capitalist oligopolies' evade the political sphere, defy competition in the marketplace and destroy the environment because economic power is not effectively limited. In five essays, the book conceptualises an

[1] Peukert, E. (2000). Walter Eucken (1891–1950) and the Historical School. In P. Koslowski (ed), *The Theory of Capitalism in the German Economic* Tradition (p. 130). Hannover, Germany: Springer.

economic order that counteracts this concentration of power. The first essay demands that one should 'act in such a way that in all that you do, […] no more power is exercised by people over people than is unavoidable' (p. 28). Oswalt derives nine practical implementations of this anti-monopoly imperative ranging from the removal of patents to rules for woodland development without human influence. The second essay discusses the state-market relationship: according to Oswalt, the state should develop framework conditions for markets 'with the same rationality and care as computer chips, medical devices or transport networks' (p. 66) so that markets become social spaces where people interact with a minimum of hierarchies and a maximum of diversity. The issue is not whether we need 'more market' or 'less market' since only the oligopoly-free market is democracy-compliant (p. 89). The third essay, a history of liberal political thought, rediscovers the perspective of the 'great revolutions:' referring to the radical liberal levellers in the English Revolution, the supporters of egalitarian capitalism in the young US, and the early supporters of individualist socialism in France, Oswalt develops proposals for a radical-democratic social contract (pp. 143ff.). Building on the previous essay, the fourth criticises the Treaty of Lisbon (2009) and presents twelve proposals for a new EU-constitution that guarantees equality of power (pp. 174ff.). The fifth essay deals with questions of civilization theory. In contrast to Norbert Elias and Michel Foucault, Oswalt does not see the development of our civilization as an inevitable process of centralization. Reflecting on Karl Jasper's 'Achsenzeit'[2] and the developments of Judaism (pp. 215ff.), Oswalt claims that civilisation progresses by taming political and economic power.

2. Ordoliberalism ≠ Neoliberalism: contribution to the literature

Given the subject's wide nature and NO MONO's mere 234 pages of essayistic analysis Oswalt's approach can easily be criticised for its cursory inspection, frequent shortage of references to related literature, and occasionally sensationalist language. Given that supportive data are often missing, the informative graphics on pp. 93-103 are a noteworthy exception. Oswalt prefers to focus on the idea-historical and philosophical foundations of his anti-monopoly policies, while circumventing the more problematic question of political implementation. Having said that, scholars of economic and political thought will benefit from the fact that Oswalt provides a unique interpretation of Ordoliberalism that corrects several misunderstandings that characterise previous literature.[3] While many scholars reading about the Ordoliberal concept of a 'strong state' suspect a close proximity to National Socialism,[4] Oswalt's state conception is linked to ideas about democracy and minimisation of power (pp. 89ff.). Some critics understand

[2] Jaspers argues that the main ideas of the great cultures were born between 800-200 BCE (*Achsenzeit*), leading to a structural break in the history of humankind.

[3] Also: Oswalt, W. (2001). Die falschen Freunde der offenen Gesellschaft. In W. Eucken, *Wirtschaftsmacht und Wirtschaftsordnung* (pp. 87-152). Münster, Germany: LIT.

[4] Haselbach, D. (1991). *Autoritärer Liberalismus und soziale Marktwirtschaft. Gesellschaft und Politik im Ordoliberalismus*. Baden-Baden, Germany: Nomos.

Ordoliberalism merely as a prelude to the later Neoliberal revolution.[5] This fails to recognize that Ordoliberals did not aspire to grant the economy an absolute power over society, but rather advocated a power limitation within the economic sphere to guarantee everybody's freedom. This understanding of competition as a means to an end and not an end in itself is present throughout NO MONO, for example in Oswalt's discussion of 'achievement competition' (p. 91). Although Ordoliberalism is often subsumed under the category of Neoliberalism Oswalt stresses the differences between these schools of thought (pp. 85f., 121ff.).

3. Beyond 'I Like:' implications

A final example illustrates the applicability of Oswalt's considerations. On the day of the 2010 US Congressional elections, each relevant *Facebook* user received an automatic message inviting her or him to vote. For the moment, this procedure may appear unproblematic, but it raises – in a very Ordoliberal sense – the issue of power. 0.39% of the notified users went to the election solely due to this *Facebook* message,[6] that is hundreds of thousands of people. Following the social network's recent *Cambridge Analytica* scandal *Facebook*'s status as quasi-monopolist has been highlighted and calls for tougher regulation have become louder. NO MONO increases awareness of such topics at the interface of economic and political power. By insisting on its radical-liberal origins Oswalt is assigning Ordoliberalism to the academic periphery. However, it may be from this position that Ordoliberal thought is most inspiring.

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[5] Starting with: Foucault, M. (2006). *Die Geburt der Biopolitik. Geschichte der Gouvernementalität II. Vorlesungen am Collège de France 1978/1979*. Frankfurt a.M., Germany: Suhrkamp.

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ENDNOTE

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