Climate change, healthy ageing and the health crisis: is wisdom the link?

Mike Tipton

Hugh Montgomery

[1]Extreme Environments Laboratory, School of Sport, Health & Exercise Science, University of Portsmouth, Portsmouth, UK

[2]Institute of Sport, Exercise and Health, University College London, London, UK

Corresponding author: Mike Tipton
Michael.tipton@port.ac.uk

The authors have no conflicts of interest.

No funding was received for this editorial.

Key Words: Climate change, Ageing, Sedentary lifestyle, Heat, Cold, Disease.

Several major societal challenges are under serious consideration by many groups, including The Physiological Society. Climate change, healthy ageing and the impact of a sedentary lifestyle on health have been the subject of much debate, including separate editorials in *Experimental Physiology*. In this editorial, the common causation and connections between these areas are considered.

This is an Accepted Article that has been peer-reviewed and approved for publication in Experimental Physiology, but has yet to undergo copy-editing and proof correction. Please cite this article as an Accepted Article; doi: 10.1113/EP090799.

Homo sapiens (Latin: “wise man”) has become the dominant species on Earth, its members using their complex brains and consequent “wisdom”, or intellect, to migrate from their African homeland 300,000 years ago to all areas of the planet. This migration was achieved by largely technological and behavioural adaptations to climatic challenges, rather than physiological acclimatisation. Whilst thermally-related physiological and anatomical differences can be observed in humans from different parts of the globe, they are minor in comparison with those seen in other animals (e.g. fur, blubber, morphological and biochemical changes). Humans followed a more technological route: the oldest building made by hominids (in Tanzania) was a windbreak constructed by *Australopithecus* ~3.25 million years ago. Over a million years ago, *Homo erectus* was building huts from stones, branches and furs. Clothing may have been used by humans 120,000 years ago. Amongst other things, these technological adaptations provided shelter and helped recreate the same microclimate temperature (33 °C next to the skin) as would have been experienced in East Africa **(1)** (even today, anyone at rest reporting feeling thermally comfortable is likely to have a mean skin temperature very close to 33 °C).

This technological approach, founded on intellect, has been “successful”; it has underpinned an exponential explosion in the number of humans on the planet - from one billion in 1804, to two billion in 1927, to three billion in 1960 and another billion every 12-14 years since, reaching an anticipated 8 billion in November 2022. But problems arise from a reliance on technology. The first is vulnerability when it fails, i.e. when the cruise liner sinks and tropical, non-cold adapted elderly humans find themselves in cold conditions. We see tens of thousands of excess deaths occurring in summer and winter, during cold snaps and summer heat waves. The European heat wave of 2003 may have killed more than 70,000 people **(2)**. In the UK we regularly see 10,000 excess deaths over a winter **(3)**.

The second problem is that a technological approach is resource intensive. Even the first fires set by hominids 300,000 – 400,000 years ago consumed finite resources (although at a rate they could be replaced). The increase in the number of humans on the planet, and their increasing dependency on energy, resulted in 2020 in a world energy consumption in excess of 580 terajoules per year, equivalent to just under 60 kWh per person per day (equivalent 7.7 billion people each boiling a kettle 600 times daily) **(4)**. This, in itself, is a problem when energy sources are limited, but when over 80 % of this energy comes from fossil fuels **(5)**, the problems compound. In the span of just 50 years, atmospheric carbon dioxide emissions have reached their highest concentrations in more than four million years. Yeast in a fermentation barrel offers a useful analogy; they multiply exponentially, consuming the resource (sugars) available and producing ethanol and carbon dioxide until these reach concentrations that kill them. For “yeast” read “humans”.

Greenhouse gases allow shortwave (solar) radiation to pass, but trap some of the resulting longwave radiation (heat). It is this which has kept the Earth's surface temperature some 30 °C warmer than it would otherwise have been **(6)**. But human activity means that we are now trapping vast amounts more heat (equivalent to around five, 15 kiloton nuclear bomb's worth a second) - an effect which has triggered positive feedback. Loss of surface albedo due to the melting of snow and ice, has doubled the rate of Earth's energy gain in just the last 14 years. With this energy gain comes increasing extreme weather events and sea level rise, drought, dire heat (and with it, heat stress), flood, fire, famine, conflict (over remaining resource, and through mass migration) and financial impacts (poverty) **(7)** - impacts which are becoming more obvious by the day. None of these are good for human health or survival, nor are the other impacts of climate change, including: changes in zoonoses, vector-borne diseases, malnutrition, and food-borne diseases (**8, 9**). It has been estimated that over half of the known human diseases will be aggravated by climate change **(10)**. However, for many, the increasing temperatures or associated destructive climatic events have still not reached an intensity or frequency that provoke complaint and action about climate change **(7)**.

Given the technological route humans have followed, these climatic challenges are often met, in high-income countries at least, with yet more energy consumption to cool, heat and pump. That is, a consequence of the energy consumption needed to control environments with technology, is the creation of climates that humans have little resilience to and require more technology, and therefore energy, to make comfortable - thereby the destructive descending spiral continues. Warming of 2.7 °C this century (and it could be more) could leave one third (21-42% or 2-4 billion) of a future 9.5 billion population outside the "human climate niche" **(11)**. Limiting global warming to 1.5 °C (which we may reach in 4-10 years) will still impact about 1.5 billion people **(11)**. On top of this comes displacement from extreme weather events and from sea level rise.

There are two other consequences of a technological approach to evolution that relate to our current circumstance. The first is that life expectancy is increasing; by 2050 it should average over 70 years across the globe. In the UK, one in three born in 2016 would (if surviving environmental catastrophe) live to celebrate their 100^{th} birthday **(12)**. However, "healthspan" (years of good health) has remain stable since 2019, so the number of years lived in poor health is increasing. Unless something is done about this, those born in 2019 are forecast to spend up to a quarter of their lives in poor health. As a consequence, many are advocating action to ensure humans have healthier lives **(13)**. Low-carbon living (e.g. clean air from the absence of fossil fuel combustion; active transport; a diet based largely on local, seasonal vegetables) offers one means to maintain and promote individual as well as planetary health. However, whether healthy or unhealthy, the consequences of such demographic changes for population numbers, resource consumption and planetary health represent a conundrum that must be addressed.

One final consequence of an intelligence-based, technologically founded, fossil fuel driven evolution is an increasingly sedentary lifestyle. Indeed, high-income countries are often defined by indoor existence **(14)**, inactivity, material possession and consumption **(15)**. One of the consequences of such a sedentary lifestyle is obesity: by 2034, 70 % of adults in the UK are expected to be overweight or obese **(16)**. Obesity increases the risk of hypertension, heart disease, stroke, cancers, musculoskeletal disease, dementia, kidney disease, depression and anxiety, and is the major modifiable risk factor for Type 2 diabetes. The amount of money spent on the treatment of obesity and diabetes in the UK is greater than the combined amount spent on the police, fire and rescue service and judicial system **(17)**. Worldwide, the healthcare costs of diabetes were at least $727 billion in 2017, 12 % of the total healthcare spend on adults; and we have to add to these costs those of the other conditions (such as cancer) with which obesity is associated.

Through technology, humans are able to control their environment and avoid, for example, thermal challenges and discomfort. But this comes with both a material and physiological cost. Thirty percent of global primary energy supply is used for controlling the climate of public buildings **(18)**. A less considered aspect of a sedentary life in a controlled environment is the absence of any perturbation of the homeostatic processes of the body and the consequent inability to become more resilient to, for example, fluctuations in climatic temperatures. Although such a "thermostatic" existence would seem advantageous for a homeostatic animal, the dynamic equilibria that underpin homeostasis need to be perturbed to remain functional, much in the same way as the musculoskeletal system must be challenged to retain its capacity. Supporting this view, in recent years we have seen numerous research papers reporting the physical and mental health benefits of exposing people to artificial heating or cooling **(19)**, thereby recreating the kind of perturbations and challenges that would occur daily if free-living and active in a natural environment. Of course, with even more extreme natural environments as a result of climate change, people are less likely to be able to exercise outdoors.

INSERT FIG 1 ABOUT HERE

The connections and consequences of the adaptation adopted by humans since the earliest of times are presented in Figure 1. The human brain is a wonder of evolution, but have we been too clever for the good of life on Earth? Many thousands of years ago our ability to consume finite, environmentally damaging resources to control our environment set us on a path that would inevitably end with an existential threat. However, even now, despite the increasing and widespread evidence of climate change in the form of numerous and varied destructive extreme weather events around the globe, the post-pandemic rush back to carbon dioxide-releasing activities seems unabated and lemming-like **(20)**.

The irony is, of course, that it is technology, in collaboration with many other disciplines including architecture, botany and physiology, that will most likely be our salvation as we search for acceptable ways to mitigate climate change and the diseases associated with the way we have evolved **(21, 22)**. But individuals can make a significant difference **(21)**, and it is important that they do because the future is in the balance; let's hope we are more like Yoda than yeast.

Acknowledgements
The authors would like to thank Dr Jo Corbett for his input to this editorial.

References

1. Tipton, M. J., Pandolf, K., Sawka, M., Werner, J. & Taylor, N. A. S. (2007) Physiological adaptation to hot and cold environments. Chapter in: Physiological bases of human performance during work and exercise. *Editors:* Nigel A.S. Taylor, Herbert Groeller and Peter L. McLennan.
2. Robine J-M, Cheung SLK, Le Roy S, Van Oyen H, Griffiths C, Michel J-P, Herrmann FR (2008)_ Death toll exceeded 70,000 in Europe during the summer of 2003. Comptes Rendus Bilogies. 333(2): 171-178. https://www.sciencedirect.com/science/article/pii/S1631069107003770?via%3Dihub.
3. Office for National Statistics (2021) Excess winter mortality in England and Wales: 2020 to 2021 (provisional) and 2019 to 2020 (final). https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/excesswintermortalityinenglandandwales/2020to2021provisionaland2019to2020final.
4. The World Counts. Global Challenges. Terajoules of energy used. https://www.theworldcounts.com/challenges/climate-change/energy/global-energy-consumption.
5. British Petroleum (2020) Statistical Review of World Energy. 69th Edition. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf.
6. Linsey, R (2009) Climate and Earth's energy budget. NASA Earth Observatory. (https://earthobservatory.nasa.gov/features/EnergyBalance.
7. Montgomery, H. & Tipton, M. J. (2019) Matters of life and death: Change beyond planetary homeostasis. Experimental Physiology. https://physoc.onlinelibrary.wiley.com/doi/full/10.1113/EP088178.
8. Watts N, Amann M, Arnell N, Ayeb-Karlsson S, Belesova K, Berry H et al (2018) The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come. The Lancet 393 (10163):

2479-2514. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2818%2932594-7/fulltext.
9. World Health Organization (2021) Climate change and health. https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.
10. Mora, C., McKenzie, T., Gaw, I.M. et al. Over half of known human pathogenic diseases can be aggravated by climate change. Nat. Clim. Chang. (2022). https://doi.org/10.1038/s41558-022-01426-1.
11. Lenton TM, Xu C, Abrams JF, Ghadiali A, Loriani S, Sakschewski B, Zimm C, Ebi KL, Dunn RR, Svenning J-C, Scheffer M (2022) Quantifying the human cost of global warming. bioRxiv 2022.06.07.495131. https://www.biorxiv.org/content/10.1101/2022.06.07.495131v1
12. Office for National Statistics, 'What are your chances of living to 100?', www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/whatareyourchancesoflivingto100/2016-01-14.
13. The Physiological Society (2020) Growing older, better. (https://www.physoc.org/policy/public-health-and-ageing/healthyageing/#:~:text=Growing%20Older%2C%20Better%20represents%20an,meet%20its%20healthy%20ageing%20target.
14. U.S. Environmental Protection Agency. 1989. Report to Congress on indoor air quality: Volume 2. EPA/400/1-89/001C. Washington, DC.
15. Roberts, I (2010) The Energy Glut. Zed Books Ltd.
16. Tipton, M. J. (2019) Time bombs, sport and exercise science and the future of society. Experimental Physiology. https://physoc.onlinelibrary.wiley.com/doi/full/10.1113/EP087927
17. https://www.gov.uk/government/publications/health-matters-preventing-type-2-diabetes/health-matters-preventing-type-2-diabetes.
18. IEA, ECBCS Annual Report 2011. Energy Conservation in Buildings & Community Systems Programme. 2011: Hertfordshire, UK.
19. Tipton, M. J (2018) Humans: a homeothermic animal that needs perturbation? Experimental Physiology. https://physoc.onlinelibrary.wiley.com/doi/full/10.1113/EP087450.
20. Tipton, M. J. & Montgomery, H (2022) Travelling back to normal. Experimental Physiology. https://physoc.onlinelibrary.wiley.com/doi/10.1113/EP090408.
21. The Physiological Society (2021) Physiology and climate change. https://static.physoc.org/app/uploads/2021/11/01082431/Physiology-and-Climate-Change-October-2021_WEB.pdf
22. The Physiological Society (2022) The Climate Emergency: Research Gaps and Policy Priorities. https://static.physoc.org/app/uploads/2022/07/12080835/Climate-Emergency-Research-Gaps-and-Policy-Priorities-Report.pdf.

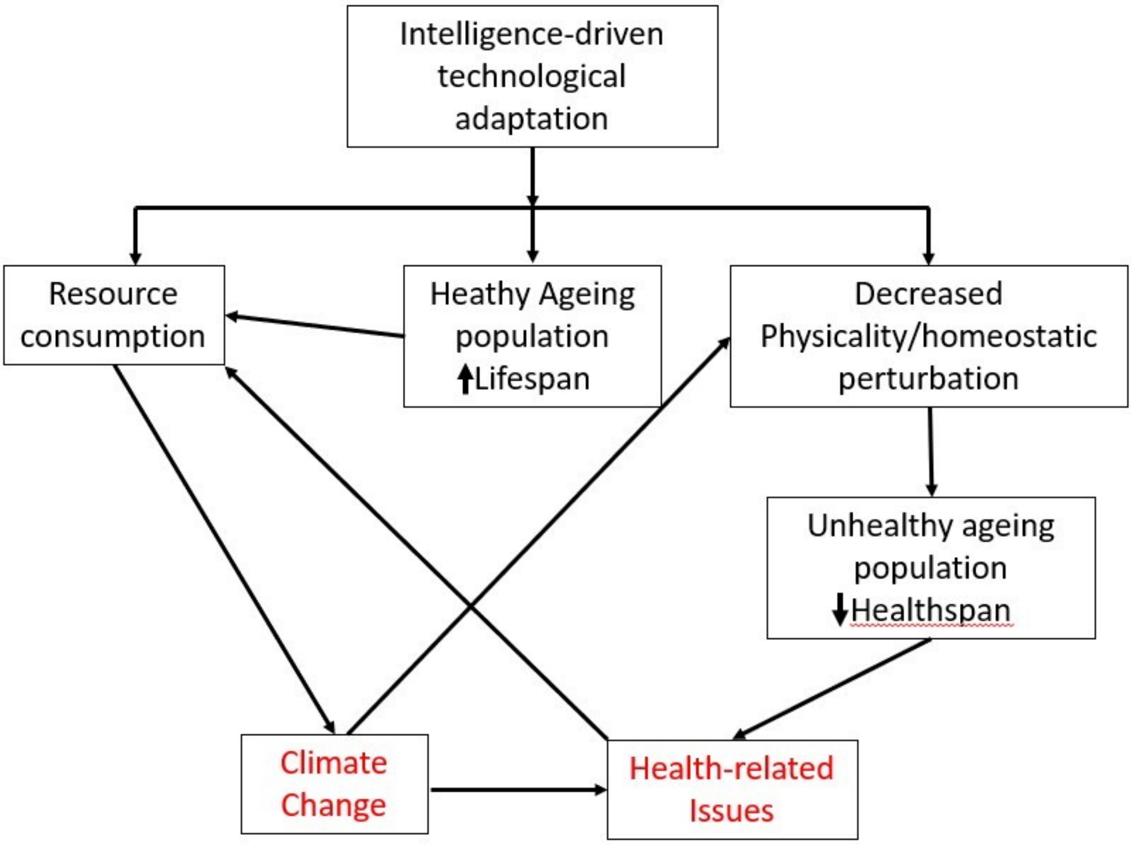

Figure 1. Some consequences of evolution via a technological route