Distinguishing polemic from commentary in science:

Some guidelines illustrated with the case of Sage and Burgio, 2017

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Exposure to non-ionizing radiation used in wireless communication remains a contentious topic in the public mind - while the overwhelming scientific evidence to date suggests that microwave and radio frequencies used in modern communications are safe, public apprehension remains considerable. A recent paper in Child Development has caused concern by alleging a causative connection between non-ionizing radiation and a host of conditions, including autism and cancer. In this work, we outline why these claims are devoid of merit, and why they should not have been given a scientific veneer of legitimacy. We also outline some hallmarks of potentially dubious science, with the hope that authors, reviews and editors might be better able to avoid suspect scientific claims.

Electromagnetic radiation is ubiquitous in our world: since the dawn of human life, it has perpetually surrounded us, illuminating and irradiating our world. In the modern era, wireless and cellular communication based on low-energy microwave / radio frequencies (RF) have become essential tools in our day-to-day life. But while radiation might be ever-present, it is frequently misunderstood. There are also concerns over the safety of household devices in the microwave region. To date, the scientific consensus is that WiFi and Cell phones are non-ionizing and pose no known risk to health, with the WHO stating that there is *"no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects."* (World Health Organization, 2006). Despite this, there is still apprehension in the public mind regarding such technologies.

The respected journal Child Development recently featured a commentary that attributed a number of negative health consequences to RF radiation, from cancer to infertility and even autism (Sage & Burgio, 2017). It is our view that this piece has potential to cause serious harm and should never have been published. But how do we justify such a damning verdict? In considering our responses, we realised that this case raised more general issues about distinguishing scientifically valid from invalid views when evaluating environmental impacts on physical and psychological health, and we offer here some more general guidelines for editors and reviewers who may be confronted with similar issues. As shown in Table 1, we identify nine questions that can be asked about causal claims, using the Sage and Burgio paper to illustrate these. No one question alone is sufficient to evaluate a paper, but taken together they can highlight the distinction between polemic and scientific argument.

Table 1: Questions to ask of causal claims

1. Is there a plausible mechanism for the effect?
2. Does evidence come from peer-reviewed sources?
3. Are all relevant studies considered?
4. Are results of specific studies misrepresented?
5. Are there claims of impacts on multiple diseases and disorders?

6. Are causal claims based on experiment, correlation or analogy?
7. Is technical, scientific terminology used to obfuscate rather than clarify?
8. What are the academic credentials and track record of the authors?
9. Is there conflict of interest?

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1. Is there a plausible mechanism for the effect?

If links between an environmental factor and health are to be believed, they must involve a plausible physical mechanism. Electromagnetic radiation (EMR) refers to waves of the electromagnetic field (or their quanta, photons) propagating through space, carrying radiant energy. This encompasses all light, from low energy radio waves to high energy gamma rays. Electromagnetic radiation moves at the speed of light in a vacuum, and is characterised by its frequency, ν, a measure of the oscillations of the electric and magnetic field per unit time. The energy of a photon, E , is directly related to its frequency by the Einstein-Planck relation, given by

$$E = h\nu$$

where h is Planck's constant. As the range of possible frequencies for light spans orders of magnitude, so too does the energy of light quanta. A portion of the electromagnetic spectrum is illustrated in Figure 1, spanning 22 orders of magnitude – from this diagram it is clear that visible light constitutes only a tiny portion of the EM spectrum, and most EMR is invisible to humans. WiFi routers and cell phones operate in the microwave spectrum, typically between 2.4GHz – 5.9 GHz (IEEE, 2007).

Sage and Burgio make repeated references to DNA damage from electromagnetic radiation, and assert that conventional WiFi and cellular phones pose a risk of causing such damage. This indicates a fundamental misunderstanding of radiation physics; it is true that high-energy, high-frequency light can ionize molecules, making them chemically reactive and inducing DNA damage. This can occur with ultraviolet radiation (Grimes, 2015), and indeed with X-ray and gamma radiation, where their ability to ionize matter and thus damage DNA is used in conventional radiation therapy for curative effect (Grimes, Warren, & Warren, 2017; Hall & Giaccia, 2006). But the assertion by the authors that DNA damage can be induced by radio-frequency waves makes no sense – microwave radiation is strictly non-ionizing, lacking sufficient energy to eject electrons and far below the threshold energy to do so. This can be easily seen by comparison with visible light, another non-ionizing EMR type. If we take the lowest energy in this band (corresponding to red light at about 4×10^{14} Hz), a simple application of the Einstein-Planck relation shows that even this weak red light has roughly 68,000 times the energy of a photon in the most energetic wireless band radiation (5.9 GHz).

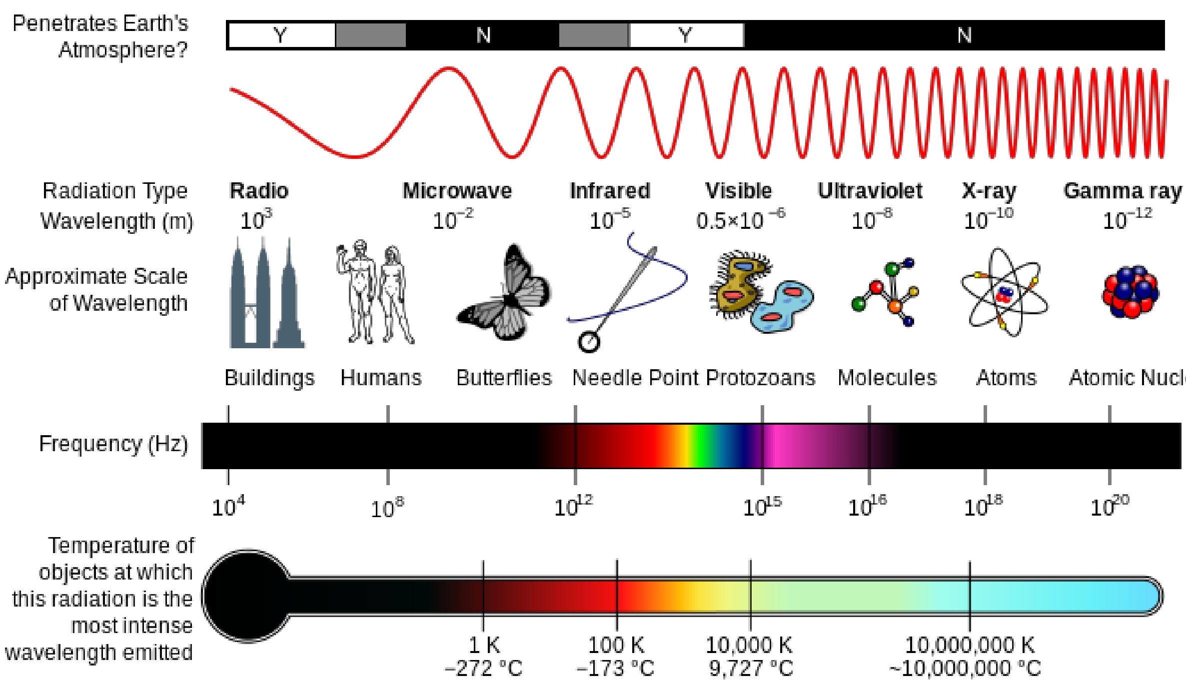

Figure 1 - The electromagnetic spectrum (taken from https://commons.wikimedia.org/wiki/File:EM_Spectrum_Properties_edit.svg)

The authors provide no potential mechanism or biophysical explanation for this purported DNA damage at low energies; nor do they address the serious physical shortcomings of their assertions. These claims betray either a fundamental misunderstanding of radiation physics, or a deliberately misleading conflation of different radiation types to add a superficial veneer of legitimacy to a suspect thesis. In either case, implausible mechanisms presented without supporting evidence should raise alarms.

2. Does evidence come from peer-reviewed sources?

Throughout their commentary, Sage and Burgio reference a particular source (Sage & Carpenter, 2012) to buttress numerous claims. In particular, they state:

<EMF... results in...> "..diminished capacity to grow and develop normal neurologic, immune, and metabolic functions, and result in serious health and learning impairments and chronic disease (Sage & Carpenter, 2012). In adults, the evidence points to increased cancer and neuro degenerative diseases (chronic degenerative and inflammatory diseases). Fertility and reproductive harm is rather consistently documented in men with damage to the DNA of sperm and deterioration of the testes (Sage & Carpenter, 2012, sections 1 and 18). "

The work cited is the latest version of the Bio-initiative report, a non-peer reviewed forum which has been widely dismissed by scientific bodies the world over (Repacholi, 2010), as discussed further below. As of 2012 there is a newer version of this report, which incorporates the 2007 edition *in toto*. This newer edition does not attempt to address any of the previous criticisms (outlined in detail in the following section) and is similarly flawed. Sage is lead author on this scientifically discredited report.

The Bio-Initiative report is not an incidental reference in the Sage and Burgio commentary: it is referenced persistently, and in many cases is the sole cited evidence for claims made. Given that Sage and Burgio engage in heavy self-citation, and that neither has a significant oeuvre of peer-reviewed work, their arguments are heavily reliant on papers and assertions that have not been subject to peer review. Clearly, it is sometimes necessary to refer to sources outside the peer-reviewed literature, particularly if one needs to note contents of official reports or online commentaries (see section 3). However, this is not appropriate when making claims about scientific evidence. While peer-review is far from perfect, it functions as a useful filter to identify reliable sources recognised by the research community, and any ostensibly scientific document which pivots on upon unverified claims raises suspicions of lack of objectivity.

3. Are all relevant studies considered?

It is always possible to find a published study to support a link between an environmental hazard and a health outcome, which is why individual studies cannot be relied upon (Schoenfeld & Ioannidis, 2013): the gold standard is a systematic review. This has several key features designed to avoid bias and arrive at an accurate synthesis of findings (Gough, Oliver, & Thomas, 2017). The researcher specifies the domain of enquiry, and identifies specific keywords that can be used in a literature search. All papers identified on a search are then scrutinised and evaluated as to whether they address the question of interest and whether certain pre-specified methodological standards are met. Findings from the resulting papers may then be synthesised in a meta-analysis, which considers all the evidence, not just that supporting a particular position.

The approach adopted by Sage and Burgio (2017) could not be further removed from this scientific ideal, as has been noted in numerous evaluations of the BioInitiative report. A non-exhaustive list of rebuttals includes the following comments.

- **Health Council of the Netherlands:** *"In view of the way the BioInitiative report was compiled, the selective use of scientific data and the other shortcomings mentioned above, the Committee concludes that the BioInitiative report is not an objective and balanced reflection of the current state of scientific knowledge."*(Health Council of the Netherlands, 2008)
- **Australian Centre for Radiofrequency Bioeffects Research (ACRBR):** *"Overall we think that the BioInitiative Report does not progress science, and would agree with the Health Council of the Netherlands that the BioInitiative Report is "not an objective and balanced reflection of the current state of scientific knowledge". As it stands it merely provides a set of views that are not consistent with the consensus of science, and it does not provide an analysis that is rigorous-enough to raise doubts about the scientific consensus."(*Croft et al., 2008).
- **European Commission's EMF-NET:** *"There is a lack of balance in the report; no mention is made in fact of reports that do not concur with authors' statements and conclusions. The results and conclusions are very different from those of recent national and international reviews on this topic… If this report were to be believed, EMF would be the cause of a variety of diseases and subjective effects"* (European Commision Scientific Committee on Emerging and Newly Identified Health Risks, 2009).
- **Institute of Electrical and Electronics Engineers (IEEE) Committee on Man and Radiation (COMAR):** *"...that the weight of scientific evidence in the RF bioeffects literature does not support the safety limits recommended by the BioInitiative group. For this reason, COMAR recommends that public health officials continue to base their policies on RF safety*

limits recommended by established and sanctioned international organizations such as the Institute of Electrical and Electronics Engineers International Committee on Electromagnetic Safety and the International Commission on Non-Ionizing Radiation Protection, which is formally related to the World Health Organization." (Adair et al., 2009).

4. Are results of specific studies misrepresented?

Those engaging in bad science do not only cherry-pick the studies to suit their story, they also cherry-pick convenient details from specific studies while ignoring others. Throughout the manuscript, Sage and Burgio make a number of assertions that there is a link between cancer and radiofrequency (RF) radiation, flying in the face of overwhelming evidence to the contrary. Ostensibly supporting their claim, the authors reference the INTERPHONE study (Cardis et al., 2010), but they distort the conclusions of that study - the 13-country INTERPHONE study concluded there was no apparent causal relationship between phone use and the rates of common brain tumours such as glioblastoma and meningioma. The dose-response curve did not betray any obvious signs of correlation: in some instances, a decrease in risk was even seen, with the possible exception of heaviest users, where biases in the data made it impossible to ascertain any solid relationship. The account of this study is at odds with what the paper asserts. Moreover, a number of other large studies have seen no increase in brain cancers despite the huge uptake in mobile phone usage (Frei et al., 2011; Hepworth et al., 2006). Findings discrepant with the authors' beliefs are simply ignored, and their misleading conclusions are stated as fact.

5. Are there claims of impacts on multiple diseases and disorders?

One characteristic of those promoting pseudoscientific arguments about environmental risks is that they often maintain that a risk factor is implicated in a huge range of problems. According to Sage and Burgio, EMF increases risk of cancer, immune and metabolic dysfunctions, sleep disorders, headaches, seizures, cardiac symptoms, addictive behaviour, fatigue, autism, ADHD and sperm damage. Such universal arguments should prompt concern, particularly when the evidence proffered to support these claims is suspect, as elucidated in points 1-4.

6. Are causal claims based on experiment, correlation or analogy?

The strongest kind of scientific evidence for causality comes from experiment: manipulate one factor and observe its effect. For many environmental factors in the natural world, experiment is hard and evidence instead comes from observational studies: correlation between a potential risk factor and a given condition. The weakest kind of evidence is from analogy: going out in the sun makes you hot, therefore fever is caused by going out in the sun. This is the type of argument advanced by Sage and Burgio to support their claim of links between EMF and neurodevelopmental disorders. They argue that 'Many of the behavioural and biological characteristics seen in autism are similar or identical to those produced by typical daily exposures to cell or cordless phone radiation, cell towers, baby monitors, wireless tablets, Wi-Fi, and other sources of pulsed electromagnetic radiation.' Elsewhere in their paper, ADHD is also mentioned. At no point in their commentary do Sage and Burgio describe any studies relating exposure to EMF and these conditions. Even if there were actual evidence that EMF led to the claimed 'behavioural and biological characteristics', this would not come close to demonstrating a causal link.

7. Is technical, scientific terminology used to obfuscate rather than clarify? The physicist Richard Feynman (1974) coined the phrase ‘cargo-cult science’ to describe practices which have some semblance of being scientific, but in reality do not follow the scientific method, instead being a hollow image of scientific endeavour. Robust science demands that conclusions be supported by the data, and that findings (and limitations) are clearly reported and not cloaked in nebulous language. An illusion of scientific rigour is often the Trojan horse which allows suspect claims to evade the gatekeeper of peer review, and reviewers and editors must be vigilant about the quality of the arguments presented to prevent dubious literature being published. Conversely, authors should ensure their central points are clearly made and not masked behind layers of jargon-laden prose. Epigenetics is a case in point. This concerns 'heritable alterations of gene expression that do not involve DNA sequence variation and are changeable throughout an organism's lifetime.' (Duarte, 2013). Sage and Burgio make liberal use of epigenetic terminology, but in a nebulous and non-specific fashion, being deployed as an apparent *deus ex machina* to attribute negative health effects to WiFi in the absence of any evidence. Epigenetics is a term used to refer to the case where environmentally-induced modifications persist across generations, but Sage and Burgio treat it more as a synonym for gene-environment interaction. This usage is common among advocates of complementary and alternative medicine, but unhelpful as it confuses rather than clarifying the role of environmental effects (Gorski, 2012).

The authors issue warnings about the dangers of EMF for the developing brain, and the potential for epigenetic changes in gene expression, citing an alarming range of biological impacts: 'electrophysiology and bioenergetics of cells, neural synchrony and brainwave activity, brain inflammation, oxidative damage from free-radicals, pathological leakage of critical separations between gut-blood or blood-brain barriers, disrupted mitochondrial and immune functions, and depleted glutathione reserves.'

This sounds impressive, but the actual evidence provided is so scant as to be immaterial, and it appears that the authors are employing technical scientific terminology to obfuscate poor reasoning rather than illuminate valid arguments.

8. What are the academic credentials and track record of the authors?

An unusual feature of the Sage and Burgio paper is that neither author has a current academic affiliation. Cindy Sage is the owner of Sage Associates, an environmental sciences consulting firm. Ernesto Burgio gives his affiliation as the Scientific Office of the International Society of Doctors for Environment (ISDE).. Clearly, it would be wrong to suggest that only eminent authors should publish in Child Development, and an academic position is of course not necessarily a pre-requisite for contributing to literature. Yet we would argue that if one wants an expert view on a controversial topic with considerable public health implications, then it is important to select authors with substantial research experience and reputation. Lack of a significant track-record of peer-reviewed research in a field should function as a warning sign for reviewers and editors to be especially vigilant.

9. Is there conflict of interest?

Conflicts of interest (COI) can distort scientific reporting, and it is important they are declared so that any potential impediment to objectivity by authors be known to reviewers. In journals where there is blind review, the onus falls on editors to check authors' credentials (point 8 above) and identify COIs. Such conflicts can be difficult to elucidate and there are several broadly similar definitions - the International Committee of Medical Journal Editors define COI as occurring when *"...professional judgment concerning a primary interest (such as* *patients' welfare or the validity of research) may be influenced by a secondary interest (such as financial gain). Perceptions of conflict of interest are as important as actual conflicts of interest."*

In this regard we note that COI concerns have been raised in criticisms of the Bio-Initative Report (Parthasarathy, 2017).

Conclusions and recommendations

We need scientific debate on controversial topics, and we need people who are open to new ideas. But if we are to retain trust in science, it is vital that a journal like Child Development holds its authors to the highest standards. Of course, authors are entitled to express viewpoints in commentaries, but they should be informed and objective, rather than polemics based on cherry-picked information dressed up in impressive-sounding technical language. It is unfortunate that a number of red flags were missed by the editors that should have alerted them to the nature of this piece: the lack of appropriate academic credentials of the authors, excessive self-citation of a non-peer-reviewed source, and claims of damage caused by EMF that are so comprehensive in biological and health terms as to be implausible.

We hope that the pointers that we have illustrated in our analysis of Sage and Burgio will be of more general application when evaluating commentaries on controversial topics. The importance of maintaining high scientific standards cannot be overestimated. The appearance of such a polemic in a peer-reviewed and respected journal is regrettable, and adds fuel to a blaze of misinformation, making it harder to parse fact from fiction. For instance, this paper has already been adopted by the electromagnetic hypersensitivity (EHS) community as proof of their position. While the specifics of EHS claims vary, the essential core belief is that cellular signals or biologically inert electric fields can trigger specific illness. EHS is not a medically-recognised diagnosis. The WHO (2006) note that "..*The symptoms are certainly real and can vary widely in their severity. Whatever its cause, EHS can be a disabling problem for the affected individual. EHS has no clear diagnostic criteria and there is no scientific basis to link EHS symptoms to EMR exposure.*" Ultimately this kind of misinformation is damaging to the public perception of science, and leaves a false impression with deleterious consequence.

The potential for damage to families is also substantial. Cancer, autism spectrum disorder and attention-deficit hyperactivity disorder are all conditions that can place a heavy burden on families. In her blog, Emily Willingham has expressed the frustration felt by parents who are presented every day with a new theory about the environmental causes of ASD (Willingham, 2013). Speculating about such causes is all too easy, but it can add to the burden of families by inducing guilt or persuading them to avoid whatever foods, technologies, or medical procedures are the current focus of those pushing unevidenced environmental theories. Such an article also risks damaging vulnerable people in the EHS community, buttressing an impression that their illness is caused by EMF despite the evidence to the contrary (Röösli, 2008). Such narratives are quickly adopted and difficult to counteract – we need only think of the notorious Wakefield Lancet MMR-autism paper, which continues to be a mainstay of the anti-vaccine community despite being long debunked and retracted (Nature Immunology Editorial,2008) to see how much havoc can be wreaked by bad science on emotive issues.

As scientists, we strongly believe we have a responsibility to maintain rigorous standards, and to help inform public discussion and policy. It is of course inevitable that some highly suspect material will slip through the net even in quality journals, but we have an obligation to rectify this when it occurs, and to take steps to ensure it does not happen again. Science should be perpetually self-correcting, and suspect claims should be investigated when they arise. It is our hope that these comments will assist reviewers, editors and authors to appraise whether the material they encounter is sound, and help guide discussions on the merits of submitted material.

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