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Physics in Canada
La Physique au Canada

Physics vs. Pseudoscience and Fake News

La physique face aux pseudosciences et aux fausses nouvelles

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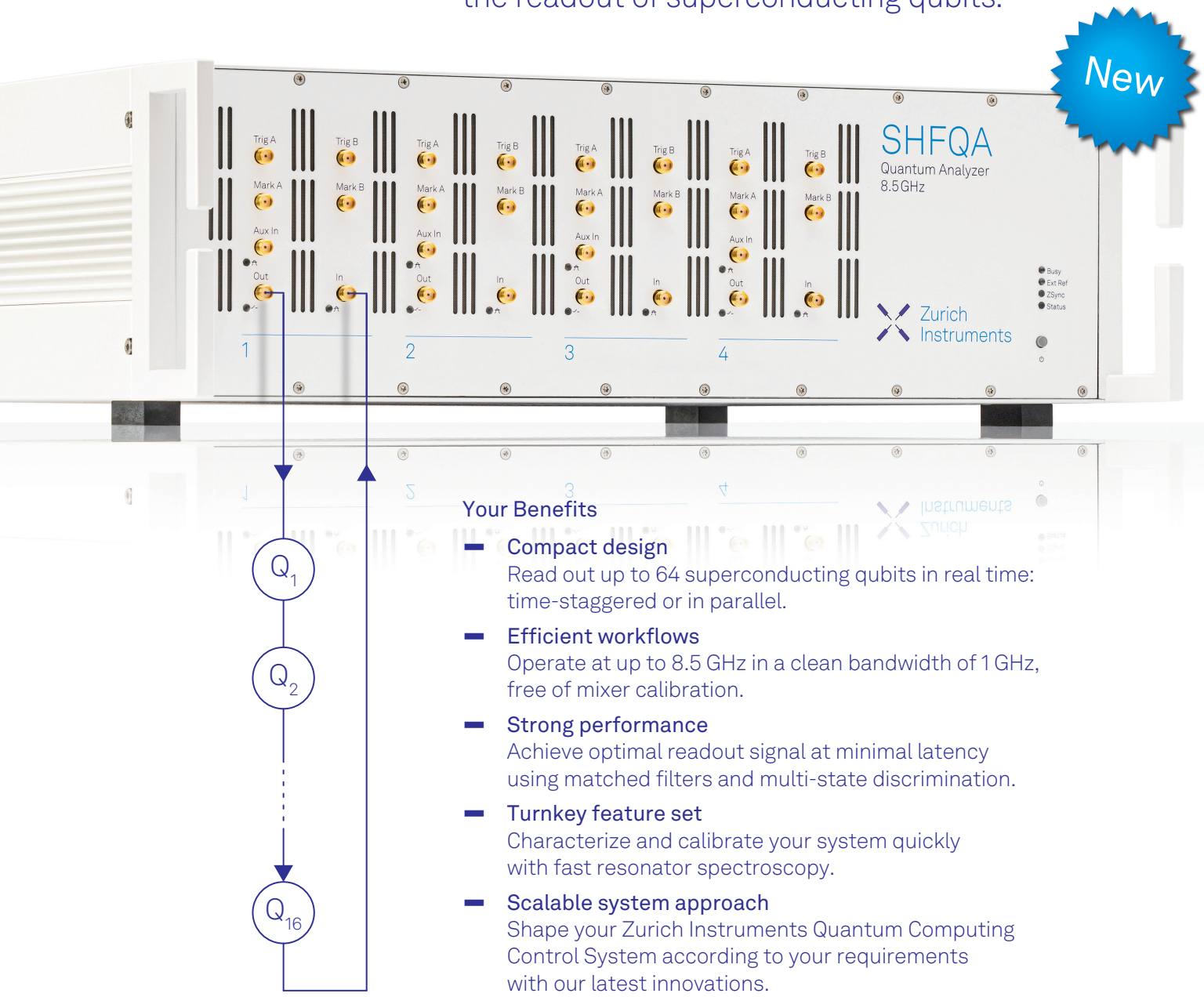

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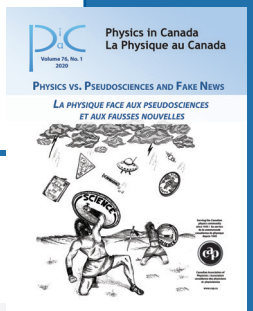

Nous remercions Maïlys Beroud, une artiste de la région de Clermont-Ferrand (France), pour avoir gratuitement offert de dessiner la page couverture. Maïlys est connue pour ses dessins et portraits noir et blanc, et a fait des expositions sous le nom de B-maï's Art.

We would like to thank Maïlys Beroud, an artist from the Clermont-Ferrand region (France), for offering to draw the cover page for free. Maïlys is known for her black and white drawings and portraits, and has made exhibitions under the name of B-maï's Art.

SECTIONS

Canadian Association of Physicists (CAP)
Association canadienne des physiciens et physiciennes (ACP)

The Canadian Association of Physicists was founded in 1945 as a non-profit association representing the interests of Canadian physicists. The CAP is a broadly-based national network of physicists working in Canadian educational, industrial, and research settings. We are a strong and effective advocacy group for support of, and excellence in, physics research and education. We represent the voice of Canadian physicists to government, granting agencies, and many international scientific societies. We are an enthusiastic sponsor of events and activities promoting Canadian physics and physicists, including the CAP's annual congress and national physics journal. We are proud to offer and continually enhance our web site as a key resource for individuals pursuing careers in physics and physics education. Details of the many activities of the Association can be found at http://www.cap.ca. Membership application forms are also available in the membership section of that website.

L'Association canadienne des physiciens et physiciennes a été fondée en 1946 comme une association à but non-lucratif représentant les intérêts des physicien(ne)s canadien(ne)s. L'ACP est un vaste regroupement de physiciens et de physiciennes oeuvrant dans les milieux canadiens de l'éducation, de l'industrie et de la recherche. Nous constituons un groupe de pression solide et efficace, ayant pour objectif le soutien de la recherche et de l'éducation en physique, et leur excellence. Nous sommes le porte-parole des physicien(ne)s canadien(ne)s auprès du gouvernement, des organismes subventionnaires et auprès de plusieurs sociétés scientifiques internationales. Nous nous faisons le promoteur enthousiaste d'événements et d'activités mettant à l'avant-scène la physique et les physicien(ne)s canadien(ne)s, en particulier le congrès annuel et la revue de l'Association. Nous sommes fiers d'offrir et de développer continuellement notre site Web pour en faire une ressource clé pour ceux qui poursuivent leur carrière en physique et dans l'enseignement de la physique. Vous pouvez trouver les renseignements concernant les nombreuses activités de l'ACP à http://www.cap.ca. Les formulaires d'adhésion sont aussi disponibles dans la rubrique « Adhésion » sur ce site.

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PHYSICS VS. PSEUDOSCIENCE AND FAKE NEWS

When I was approached to be the Editor of an issue of *Physics in Canada* on the general theme of false news and pseudoscience in the spring of 2019, I had not anticipated the increased relevance of the topic a year later, in the midst of a pandemic (I admit it: I put my crystal ball in the recycle bin when nothing happened with the Y2K). The purpose of this issue is to give you some arguments to use when discussing such topics with neighbours, friends, family, the general public, journalists, colleagues, etc.

Like many of you, I have been interested in the subject of pseudoscience for decades. I have even built a small library on the subject at home. Occasionally, I give presentations and interviews on the subject, and I complain to the media, governments or businesses. At parties, I sometimes come across as the grumpy skeptic or the narrow-minded scientist, but I readily accept the role.

Choosing topics for this issue was not easy: the potential list was endless. Some of the topics I dropped for lack of space include the anti-vaccination movement, homeopathy and alternative medicine, conspiracy theories, and so on. Topics, you will agree, that are now at the heart of our concerns. I shouldn't have followed the recommendations of my horoscope!

I thank Mona Nemer, Canada's Chief Science Advisor, for taking the time to write an editorial commentary on social media and the silos in science. Her message resonates with a whole new tone in the current situation. The public is suddenly thirsty for scientific information — it's up to us to respond. The door is open.

We all have a role to play, of course, but we must recognize that we also have to look at our own backyard. Who are we to believe when dubious scientific journals seem to emerge as if by spontaneous generation? Kelly Cobey and David Moher of the Centre for Journalology discuss predatory scientific publications and their impact on science and the public, as well as their efforts to stem this other pandemic. Greg Dick and Stephanie Keating of the Perimeter Institute are optimistic despite the challenges we face: perhaps we can use Artificial Intelligence to help us filter the information tsunami? Normand Mousseau of the Université de Montréal reminds us, however, that we also have a responsibility as researchers to explain the limits of the scientific process, not to exaggerate the conclusions we put forward and to accept that science is also a human activity.

Maintaining public trust, despite the inevitable failures of science, is more crucial than ever — and that is why the position of Canada's Chief Science Advisor is critical. Bonnie Schmidt and Karin Archer of Let's Talk Science ask the question: Is Science Under Assault? The statistics they share with us are disturbing (for example, 30% of Canadians only believe in science if it is consistent with their own beliefs!), but they are not without their positives. This is why education remains the best vaccine against obscurantism, helped of course by organizations like Let's Talk Science that bring us closer to people of all ages. Jonathan Jarry of the McGill Office for Science and Society examines the perils of believing in pseudosciences related to medicine, dangers to health, of course, but also to the wallet. One only has to Google homeopathy and covid-19 to realize the magnitude of the problem…

Speaking of spreading diseases, what about the one that physicist Sébastien Point examines: the electrohypersensitivity syndrome? We already see sites that propose a link with covid-19. In fact, as I write this, the BBC has just posted an article entitled "Coronavirus: Scientists brand 5G claims 'complete rubbish'"! The human brain is excellent at finding connections between things, and even better at inventing them... It's not just electromagnetic waves that are scary these days—the most extreme scenarios are also circulating around artificial intelligence. Stan Matwin of Dalhousie examines some of the myths related to AI - given the phenomenal growth of AI in physics and society in general, this article is timely.

Of course, some subjects do not seem to want to disappear, despite overwhelming evidence. Some absurdities even make a comeback, against all logic — for example, the flat earth. Ford Doolittle of Dalhousie tells us why he is not a creationist. The successes of the theory of evolution are such that it is hard to believe it is not universally accepted; perhaps its weakest point is the word "theory" which the public does not understand. Parapsychology is, according to James Alcock of York, the "search science left behind". As he so aptly put it, parapsychology is "belief in search of evidence rather than data in search of explanation". Obviously, this profound phrase can be used in connection with a multitude of other "para" fields!

Among the most tenacious of these is astrology, a subject that Ivan Kelly, from the University of Saskatchewan, and his colleagues James Dean (Western Australia) and Don Saklofske (Western), have been studying for a long time. For a physicist, the subject itself makes no sense. And yet. How many times have you had to discuss this subject with followers? Every physicist must be prepared to defend science in the face of this anachronistic subject. As I mentioned to Ivan, I have written hundreds of science columns for newspapers in my career; although I have covered evolution, abortion, the death penalty, and a whole variety of sensitive topics, the only one that has earned me complaints from readers is, yes, astrology!

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Before the current pandemic hit, the topic of the day was climate change. The topic that will define our future. Gordon McBean of the University of Western Ontario has been at the centre of this global issue for decades. He offers us a historical perspective that is, to some extent, ironically "chilling".

I hope that you will enjoy this issue, which is off the beaten path for *Physics in Canada*, and I want to thank all the authors once again for their outstanding work and enthusiasm, and the support of the *Physics in Canada* team. I would be remiss if I didn't end by renewing my call to action. Don't let the absurdities you are witnessing pass you by — in some cases, they can have dire consequences. And don't lose your sense of humour — it is often a formidable weapon. A good example is the one described by Richard MacKenzie, former CAP President, on his web page [1], which involves nothing less than a water-based cosmetic product with a magnetic charge!

Gary Slater, University of Ottawa
Guest Editor, *Physics in Canada*

[1] *https://www.webdepot.umontreal.ca/Usagers/mackenzr/MonDepotPublic/pagewebpers/LaMer/indexeng.html.*

Comments of readers on this Editorial are more than welcome.

Note to readers: The authors of the articles included in this issue were approached in the Fall of 2019. They submitted the first draft of their article around Christmas. Revised versions, following the peer review process, were submitted at the very beginning of the Covid-19 pandemic. Unfortunately, the exceptional situation that resulted from the pandemic delayed publication until mid-2021. As a result, many of the articles (including this introduction) should be read with these dates in mind; indeed, some authors would most likely have linked their topic to the pandemic if they had had the chance, while some articles may contain somewhat out-of-date material. We therefore invite the reader to take these factors into account when reading this issue. Thank you for your understanding.

LA PHYSIQUE FACE AUX PSEUDOSCIENCES ET AUX FAUSSES NOUVELLES

Lorsqu'on m'a approché pour être l'éditeur d'un numéro de *La Physique au Canada* portant sur le thème général des fausses nouvelles et des pseudosciences, au printemps 2019, je n'avais pas prévu la pertinence accrue qu'allait avoir le sujet un an plus tard, en pleine pandémie (je l'avoue : j'ai mis ma boule de cristal au recyclage lorsque rien ne s'est produit avec le bogue de l'an 2000). Le but de ce numéro est de vous donner des arguments à utiliser lorsque vous discutez de tels sujets avec des voisins, des amis, de la famille, le grand public, les journalistes, des collègues, etc.

Tout comme plusieurs d'entre vous, je m'intéresse aux pseudosciences depuis fort longtemps, et j'ai bâti chez moi une petite bibliothèque sur le thème. À l'occasion, je donne des présentations et des entrevues sur le sujet, et je porte plainte auprès des médias, des gouvernements ou des commerçants. Lors des fêtes, je passe quelques fois pour le sceptique grognon ou le scientifique borné, mais je m'assume.

Il n'a pas été facile de choisir des sujets : j'avais vraiment l'embarras du choix. Certains sujets que j'ai laissés tomber, faute de place, incluent les mouvements anti-vaccination, l'homéopathie et des médecines alternatives, les théories du complot, et j'en passe. Des sujets, vous en conviendrez, qui sont maintenant au cœur de nos préoccupations. Je n'aurais pas dû suivre les recommandations de mon horoscope!

Je remercie Mona Nemer, Conseillère scientifique en chef du Canada, d'avoir pris de son précieux temps pour nous écrire un commentaire éditorial sur les médias sociaux et les silos en science. Son message résonne d'une tonalité toute nouvelle dans la situation actuelle. Le public a tout à coup une soif d'information scientifique — c'est à nous d'y répondre. La porte est ouverte.

Nous avons tous un rôle à jouer, certes, mais il faut reconnaître que nous devons aussi examiner notre propre cour. Qui croire quand les journaux scientifiques douteux semblent voir le jour comme par génération spontanée ? Kelly Cobey et David Moher, du *Centre for Journalology*, nous parlent des publications scientifiques prédatrices et de leur impact sur la science et le public, et de leurs efforts pour endiguer cette autre pandémie. Greg Dick et Stephanie Keating, de l'Institut Périmètre, sont optimistes malgré les défis auxquels nous sommes confrontés: peut-être pourrions-nous utiliser l'intelligence artificielle pour nous aider à filtrer les informations qui circulent ? Normand Mousseau de l'Université de Montréal nous rappelle toutefois que nous avons aussi la responsabilité, comme chercheurs, de bien expliquer les limites du processus scientifique, de ne pas exagérer les conclusions que nous mettons de l'avant et d'accepter que la science est, elle aussi, une activité humaine.

Conserver la confiance du public, malgré les ratés inévitables de la Science, est plus crucial que jamais — et c'est pourquoi le poste de Conseillère scientifique en chef du Canada est critique. Bonnie Schmidt et Karin Archer, de *Parlons sciences*, se posent la

question : Is Science Under Assault ? Les statistiques qu'elles partagent avec nous sont inquiétantes (par exemple, 30 % des Canadiens ne croient la science que si elle est en accord avec leurs propres croyances!), avouons-le, mais elles ne sont pas dépourvues de points positifs. C'est pourquoi l'éducation demeure le meilleur vaccin contre l'obscurantisme, aidée bien sûr par les organisations comme *Parlons sciences* qui nous rapprochent des gens de tous les âges. Jonathan Jarry, du *McGill Office for Science and Society*, examine les périls de croire aux pseudosciences reliées à la médecine, notamment les dangers pour la santé, évidemment, mais aussi pour le portefeuille. Il n'y a qu'à chercher « homéopathie » et « covid-19 » sur Google pour réaliser l'ampleur du problème

Parlant d'épidémie, que dire de celle dont nous parle le physicien Sébastien Point : le syndrome d'électrohypersensibilité ? On trouve même des sites qui proposent un lien avec la covid-19. D'ailleurs, au moment où j'écris ces lignes, la BBC vient de mettre sur ses pages un article intitulé « Coronavirus: Scientists brand 5G claims 'complete rubbish' »! Le cerveau humain est excellent à trouver des liens entre les choses, et encore meilleur à les inventer Il n'y a pas que les ondes électromagnétiques qui font peur ces jours-ci — des scénarios extrêmes circulent aussi autour de l'intelligence artificielle. Stan Matwin, de l'Université Dalhousie, examine certains mythes reliés à l'IA — étant donné la croissance phénoménale de l'IA en physique comme dans la société en général, cet article arrive à point.

Évidemment, certains sujets ne semblent pas vouloir disparaître, malgré le poids des évidences contraires. Quelques absurdités font même un retour, contre toute logique — par exemple, la terre plate. Ford Doolittle de l'Université Dalhousie nous dit pourquoi il n'est pas créationniste. Les succès de la théorie de l'évolution sont tels qu'il est difficile de croire qu'elle n'est pas universellement acceptée; son point le plus faible, peut-être, est le mot « théorie » que le public ne comprend pas. La parapsychologie est, selon James Alcock, de l'Université York, la recherche que la science a laissée derrière elle. Comme il le dit si bien, la parapsychologie est une croyance à la recherche d'évidences, et non un ensemble d'évidences à la recherche d'une explication. On peut certainement utiliser cette phrase fort profonde à propos d'une multitude d'autres domaines « para »!

Parmi les sujets les plus tenaces se trouve l'astrologie, un sujet qu'Ivan Kelly, de l'Université de la Saskatchewan, et ses collègues James Dean (Western Australia) et Don Saklofske (Western), étudient depuis longtemps. Pour un physicien, le sujet lui-même n'a aucun sens. Et pourtant. Combien de fois avez-vous dû discuter de ce sujet avec des adeptes ? Tout physicien doit être préparé à défendre la science face à ce sujet anachronique. Comme je le mentionnais à Ivan, j'ai écrit des centaines de chroniques de science pour des journaux dans ma carrière; bien que j'aie écrit sur l'évolution, l'avortement, la peine de mort, et toute une variété de sujets délicats, le seul qui m'a valu des plaintes de la part des lecteurs est, oui, l'astrologie!

Avant que la pandémie ne frappe, le sujet de l'heure était les changements climatiques. Le sujet qui définira notre futur. Gordon McBean, de l'Université Western, est depuis des décennies au centre de ce dossier planétaire. Il nous offre une perspective historique qui, dans une certaine mesure, donne ironiquement « froid » dans le dos.

En espérant que vous apprécierez ce numéro qui sort des sentiers battus pour *La Physique au Canada*, je veux encore une fois remercier tous les auteurs pour le travail remarquable et leur enthousiasme, ainsi que le soutien de l'équipe de *La Physique au Canada*. Je m'en voudrais de ne pas terminer en renouvelant mon appel à l'action. Ne laissez pas passer les absurdités dont vous êtes témoins — dans certains cas, elles peuvent avoir de sinistres conséquences. Et ne perdez pas le sens de l'humour — c'est une arme souvent éloquente. Un bel exemple est celui décrit par Richard MacKenzie, ancien président de l'ACP, sur sa page web [1], et qui ne concerne rien de moins qu'un produit cosmétique à base d'eau possédant une charge magnétique!

Gary Slater, Université d'Ottawa
Rédacteur honoraire, *La Physique au Canada*

[1] *https://www.webdepot.umontreal.ca/Usagers/mackenzr/MonDepotPublic/pagewebpers/LaMer/index.html.*

Les commentaires des lecteurs sur cet éditorial sont toujours les bienvenus.

NOTE : Le genre masculin n'a été utilisé que pour alléger le texte.

(Note aux lecteurs : Les auteurs des articles inclus dans ce numéro ont été approchés à l'automne 2019. Ils ont soumis la première version de leur article autour de Noël. Les versions révisées, suite au processus d'évaluation par les pairs, ont été soumis au tout début de la pandémie Covid-19. Malheureusement, la situation exceptionnelle qui a résulté de la pandémie a repoussé la publication à juin 2021. En conséquence, plusieurs des articles (y compris cette introduction) doivent être lus en considérant ces dates; en effet, certains auteurs auraient très certainement fait le lien entre leur sujet et la pandémie s'ils en avaient eu la chance, tandis que certains articles peuvent contenir des éléments un peu périmés. Nous invitons donc le lecteur à tenir compte de ces facteurs en lisant ce numéro. Merci pour votre compréhension.)

Science, Silos and Social Media

The creation and expansion of scientific knowledge, throughout its history, has been aided by its dissemination. The broader a theory's circulation, the faster new knowledge has been founded upon it — and the more science's influence has grown. Today, scientific discoveries and advancements are taking place at an unprecedented pace. The same is true for communication technologies, which have ushered a new era for knowledge sharing and dissemination. However, rather than supporting science, some new communications technologies have begun to undermine its authority. It's a communication problem not of scientists' making, but it is ours to solve.

The earliest philosophers cultivated disciples who would travel to preach their ideas and communicate their discoveries. The rise of couriers and messengers made it possible for early scientific researchers to discuss findings and debate theories, sometimes sparking intense rivalries, always quickening the pace of discovery. Scholars at the early Modern universities of Europe, assisted by the printing press, were able to distribute their findings across vast distances to a growing community of scientists, who would replicate experiments and either advance worthy theories or propose alternatives.

By 1850 the number of scientists in Europe numbered over one million. It is no coincidence that, around this same time, scientific publications developed the practice of peer review, as a means of selecting the most vigorous research for publication. The vetting process has begun to change in recent years, with the aim of making it more transparent. But its basic principle — that scientists' methodologies and findings are open to scrutiny — remains vital.

In the era in which we now live and work, however, dissemination cannot stop within our field of expertise. Science has become more interdisciplinary than ever before: developments in physics impact subsequent discoveries and applications in chemistry, biology, medicine, engineering, computer sciences and beyond. These vectors of influence can run in practically any direction between specialties, none of which share the others' vernacular.

Meanwhile, the advent of social media has galvanized skepticism and even denial of scientific endeavour and its benefits. On topics such as vaccination, global

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Science, silos et médias sociaux

De tout temps, la diffusion des connaissances scientifiques a favorisé leur acquisition et leur enrichissement. Plus une théorie est diffusée largement, plus elle génère de nouvelles connaissances rapidement et plus l'influence de la science s'accroît. Aujourd'hui, les découvertes et les progrès scientifiques se font à un rythme sans précédent. Il en va de même pour les technologies de communication, qui ont marqué le début d'une nouvelle ère pour la mise en commun et la diffusion des connaissances. Cependant, plutôt que de servir la science, certaines de ces nouvelles technologies de communication ont commencé à miner son influence. C'est un problème de communication qui ne vient pas des scientifiques, mais il est quand même de notre responsabilité de le régler.

Les premiers philosophes formaient leurs disciples, lesquels voyageaient ensuite pour enseigner leurs idées et communiquer leurs découvertes. La venue des messagers a permis aux premiers chercheurs scientifiques de discuter de leurs découvertes et de débattre de leurs théories, ce qui suscitait parfois d'intenses rivalités et accélérait sans cesse le rythme des découvertes. Grâce à la presse à imprimer, les chercheurs des premières universités modernes d'Europe ont pu faire connaître leurs découvertes sur de grandes distances et à une communauté de scientifiques de plus en plus nombreuse, qui reproduisait des expériences, faisait progresser les meilleures théories ou en proposait de nouvelles.

En 1850, le nombre de scientifiques en Europe s'élevait à plus d'un million. Ce n'est pas un hasard si, vers cette même époque, les publications scientifiques ont commencé à faire l'objet d'un examen par les pairs, ce qui permettait de ne publier que les recherches les plus prometteuses. Dans un souci de transparence, les scientifiques ont commencé à modifier le processus d'examen par les pairs au cours des dernières années. Toutefois, son principe de base, soit l'examen des méthodes et des résultats des scientifiques, reste essentiel.

À l'époque où nous vivons et travaillons, la diffusion des connaissances ne peut plus s'arrêter à notre domaine de compétence. La science est devenue plus interdisciplinaire que jamais : les progrès réalisés dans le domaine de la physique ont une incidence sur les découvertes et les applications subséquentes notamment en chimie, en biologie, en médecine, en ingénierie et en informatique. Ces vecteurs d'influence peuvent s'appliquer à pratiquement toutes les spécialités, et ce indépendamment de leur jargon.

warming, and genetic crop modification, social media has helped to spread misinformation, champion unproven theories, and connect disbelievers to one another, sometimes endowing them with a collective identity of resistance.

The scientific community will need to respond to these challenges by galvanizing in turn, and that effort should begin by reaching out to one another across disciplines. Given how much of our work is interconnected, it is surprising that we do not do this more often, but it is largely a matter of habit.

Nothing prohibits any university department, be it physics, biology or any other specialty, from hosting a roundtable for other departments' faculty to learn about its latest discoveries and advancements. Roundtables are collegial, facilitating discussion in language that's not narrowly disciplinary: presenters are speaking to an engaged and educated audience, but one that is not necessarily familiar with their discipline's lexicon.

Interdisciplinary efforts should not be limited to campus. National associations' conferences could include panel discussions devoted to findings from other fields that impact their own. Their journals could include brief "roundups" of research from other disciplines. These kinds of initiatives represent a change from decades-old routines, yet they would not be arduous.

Scientists also need to engage more regularly with the broader public, and social media can be just as effective a communications tool for scientists as for skeptics. Some of us are more adept communicators than others, and those who are have already shown us the path. Communicating with the broader science community and with the public must be encouraged and valued by scientists, their institutions, and society at large.

Not every scientist can host a podcast or curate a feed, but not everyone needs to. All it takes is an effort to reach out and engage discussion beyond our communities of practice. Above all, we need to equip our fellow citizens with the understanding of the scientific method so they can sift through the deluge of information- and misinformation, and make informed decisions on issues that impact their lives. It's a commitment we all need to make.

Entre-temps, l'avènement des médias sociaux a exacerbé le scepticisme, voire le déni des travaux scientifiques et de leurs bienfaits. Sur des sujets tels que la vaccination, le réchauffement climatique et les modifications génétiques des cultures, les médias sociaux ont contribué à diffuser des informations erronées, à défendre des théories non prouvées et à rallier les sceptiques, les dotant parfois d'une capacité de résistance collective.

La communauté scientifique devra se mobiliser à son tour pour relever ces défis, et cet effort devrait commencer par un rapprochement entre les différentes disciplines. Étant donné qu'une grande partie de notre travail est interconnectée, il est surprenant que nous ne le fassions pas plus souvent, mais c'est surtout une question d'habitude.

Rien n'empêche un département universitaire, qu'il s'agisse de celui de physique, de biologie ou de toute autre spécialité, d'organiser une table ronde pour les professeurs des autres départements afin de s'informer sur ses dernières découvertes et avancées. Les tables rondes se déroulent dans un cadre collégial, ce qui facilite la discussion dans un langage qui n'est pas étroitement lié à la discipline puisque les présentateurs s'adressent à un public engagé et instruit, mais qui n'est pas nécessairement familier avec le jargon de leur discipline.

Les efforts interdisciplinaires ne doivent pas se limiter au campus. Les associations nationales pourraient organiser des tables rondes portant sur les résultats d'autres domaines qui ont une incidence sur les leurs. Leurs publications pourraient comprendre des résumés des recherches menées dans d'autres disciplines. Ce genre d'initiatives représente un changement par rapport à la façon dont les choses se passent depuis des décennies, mais elles ne seraient pas plus difficiles à mettre en place.

Les scientifiques doivent également communiquer plus régulièrement avec le grand public, et les médias sociaux peuvent être un outil de communication tout aussi efficace pour les scientifiques que pour les sceptiques. Certains d'entre nous sont plus habiles à communiquer que d'autres, et ceux qui le sont nous ont déjà montré la voie. La communication avec la communauté scientifique au sens large et avec le public doit être encouragée et valorisée par les scientifiques, leurs institutions et la société dans son ensemble.

Tous les scientifiques ne peuvent pas animer un balado ou gérer un fil sur les réseaux sociaux, et tout le monde n'a pas à le faire. Tout ce qu'il faut, c'est un effort pour communiquer avec les autres et engager la discussion au-delà de nos communautés de pratique. Il s'agit avant tout de permettre à nos concitoyens de comprendre la méthode scientifique afin qu'ils puissent faire le tri dans cette avalanche de bons et de mauvais renseignements et prendre des décisions éclairées sur des questions qui ont une incidence sur leur vie. C'est un engagement que nous devons tous prendre.

DEBUNKING SOME OF THE MYTHS SURROUNDING ARTIFICIAL INTELLIGENCE

BY STAN MATWIN[1]

Following a condensed history of Artificial intelligence the paper presents the personal views of the author about the common, somewhat pessimistic perspectives on Artificial Intelligence, encountered often in the media and supported by some visionaries.

INTRODUCTION

Artificial Intelligence (AI) is today on everybody's minds and lips. It has become part of the vocabulary of scientists, but also of engineers, physicians, business people, politicians, the media and visionaries. AI today attracts attention, money and people to an extent unprecedented in its short history. While I do remember meetings of neural networks researchers attended by some 200 participants in the early 2000s, the same meetings today sell 6000 registrations in a matter of minutes, or even offer a lottery to thousands of people willing to travel around the world to attend. Figure 1 illustrates this interest surge graphically by showing Google searches for the terms "Artificial Intelligence" and "Machine Learning" since 2012. Starting in 2015 the gradient of the latter is much sharper. A lot of this popularity is due to the obvious attractiveness of the idea of "automating intelligence". This current interest is due, at least in part, to a number of myths and misconceptions that have been created and supported by people from outside the field. This brief article attempts to de-bunk four such generally held and common beliefs present in the public sphere. The views presented below, while based on almost 40 years of experience in different areas of AI, represent a purely personal perspective many would not agree with. I believe, however, that in order to progress as a field, we need to be capable of introspective reflection.

SUMMARY

This brief article presents author's views about some of the claims concerning Artificial Intelligence, appearing often in the media and supported by certain visionaries. It debunks four such myths, based on misunderstanding and unwarranted extrapolation of the current technical developments in the field.

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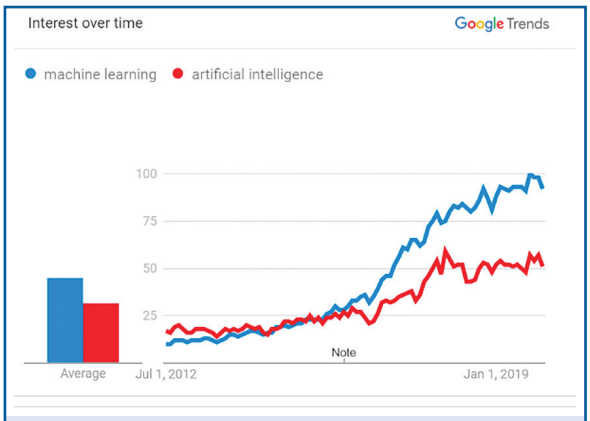

Fig. 1 Trends in Google searches for the terms "Machine Learning" and "Artificial Intelligence" since 2012. The y axis is the Google Search Volume Index, Google's proprietary measure for comparing relative popularities of search queries.

A VERY BRIEF HISTORY

AI, a child of the Cold War, was born in a DARPA workshop at Dartmouth College in 1956, where the late John McCarthy from MIT coined the term "Artificial Intelligence". To this day there is no general agreement on the definition of AI, but the one used operationally is that it is an area of science "researching and building systems capable of intelligent behavior". From its early days the field of AI consisted of a number of sub-fields. Knowledge representation and reasoning, natural language processing, machine learning (ML), computer vision (CV), and planning were the main sub-areas of AI. These fields were relatively disjoint and worked on different problems. It was quickly realized that almost all AI problems are intractable, or NP-complete: any algorithm to solve a particular problem would, for the hardest dataset for this problem, be no better than trial and error. The researchers therefore worked on heuristics that would not guarantee such optimal solutions but would nevertheless produce results close to optimal, and be sufficiently efficient to work on larger and larger data. Many of the successful solutions and progress milestones of the first twenty or

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Fig. 2 The wolf vs husky training set. From [4].

thirty years of AI were based on the community efforts that resulted in the development of specialized resources: large dictionaries summarizing a wealth of knowledge about languages (especially English), or benchmarking datasets allowing ML researchers to compare their algorithms in a methodological manner. Inadequate computational resources often stood in the way of progress, e.g., in artificial neural networks. When specialized "Lisp machines" and "Prolog machines" failed to solve AI in the mid-1980s, the second "AI winter" took place, lasting until the mid-1990s. Then, in the case of ML, robust ML methods slowly morphed into data mining, and advances in the theoretical foundations of ML (e.g., Support Vector Machines or boosting) put the field on a stronger footing. A breakthrough took place in 2012, when Geoff Hinton and colleagues from the University of Toronto showed [2] how their deep learning architecture could beat state-of-the art computer vision algorithms on the standard AlexNet image classification dataset by more than 5%, where standard incremental progress of the CV field over the years was on average 1% per year. People started paying attention to "deep learning" (many other elegant and powerful deep learning architectures, algorithms and representations ought to be at least mentioned here, e.g., autoencoders, embeddings, generative adversarial networks, etc. See [1] for an excellent, condensed introduction to Machine Learning with deep artificial neural networks). Moreover, advances in hardware democratized high-performance computing after 2010 through the availability of "for rent" cloud-based, parallel computing environments on the one hand, and off-the-shelf cheap GPUs processors on the other hand. Highly parallelizable deep learning computational tasks became solvable on generally available, inexpensive computing platforms. Ease of sharing data (and code) through the internet and managing it methodically with the use of open-source, high quality database software were other factors contributing to the Big Data revolution (more on the relationship between Big Data and AI below). AI researchers from all its subfields turned to Machine Learning for addressing specific tasks in their research. By 2018 the fields of NLP and CV became infused by ML, and planning has become by and large deep reinforcement learning. Machine Learning has taken over AI, and has attracted hundreds of thousands of young, creative minds from around the world. Investors are lining up to fund promising AI companies. Governments pour hundreds of millions of dollars, euros and yuans into AI research institutes[2]. Further progress in inevitable, but as argued below it might not be linear.

2. Canada, for once, is at the forefront of AI research. Among the three funding fathers of the Deep Neural Networks and Deep Learning: Y. Bengio, G. Hinton and Y. LeCun (recipients of the 2018 ACM Turing Award, generally believed to be the Nobel Prize of Computer Science), two (Yoshua Bengio at the Université de Montréal, and Geoff Hinton at the University of Toronto) are Canadian. Their research has survived all the AI winters in part due to the Canadian Institute for Advanced Research (CIFAR) that has steadily funded AI research in lean and fat years.

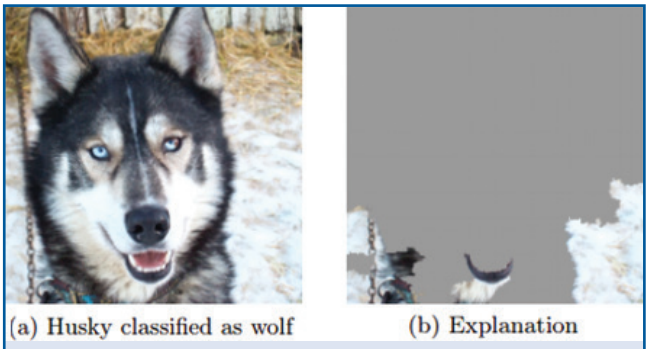

Fig. 3 (a) A new example (a husky) misclassified as a wolf and (b) the explanation (a "saliency map") for this classification. From [4].

MYTH I: AI CAN SOLVE ANYTHING

Hardly a week goes by without media headlines about new achievements of AI, how the discipline can solve problems until now tackled only by humans. "Intelligent Machines are Teaching Themselves Quantum Physics", "Artificial intelligence better than humans at spotting lung cancer" or "How AI understands passengers' emotions for in-car safety systems" are just a few examples. Such titles are often true only in a narrow sense: while the problem is general, the AI solution refers to a particular, simplified rendering or aspect of the problem, reducing it to, e.g., an image recognition or text classification task. Image classification and clustering is the area in which the advances of "new AI" are probably the strongest. However, as pointed by Melanie Mitchell in her recent book [3], the Convolutional Neural Network (CNN) algorithms at the basis of many such successful applications do not really understand the images the way humans do. Instead, they find hidden, often complex (non-linear) combinations of features whose presence or absence in a given image is characteristic of its "class" (e.g., presence vs absence of quantum phase transition in an image, or telling apart an x-ray of a healthy vs sick patient, or recognizing a dog's breed in a photo). The intrinsic lack of understandability of such "classification" is a major shortcoming of these solutions, especially if they were to be used to make decisions about humans. As an example, let us consider an experiment in which a CNN was trained on a dataset of images of dogs, in which each image contained either a wolf or a husky. The "training" images of wolves also contained, on purpose, snow in the background (Fig. 2). When the result of Machine Learning — a trained CNN — was asked to classify a husky image in the centre of Fig. 3a, it declared it to be a wolf. As for an explanation, the system pointed to the snow in the picture: in fact, in the training set there was an overwhelming evidence of snow in all the wolf pictures (Fig. 3b), and therefore the CNN targeting recognition of wolf images was optimized to detect large white areas, without learning anything about dogs. This is what we mean by the correlational nature of Machine Learning. As long as a task can be reduced to identifying patterns in data, preferably continuous, "smooth" data such as images or sound, and there is a very large set of annotated "instances" whose classes are known, we can obtain a good solution with modern Machine Learning. But trusting this solution, e.g., with a patient diagnosis, incarceration decisions or a school admission policy recommendation based on the student's expected academic performance is a different question. AI systems outperform humans in tasks which are often associated with a "high level of intelligence" (e.g., playing chess, or GO), but are not anywhere near human capacity in other tasks in which humans are very good without any training (e.g., telling jokes). It is because we all have an enormous knowledge base, known as "common sense", which we are still unable to circumscribe, let alone codify and feed into AI systems. Attempts in that direction have been made over many years, but are generally believed to come far short of the expected results (e.g., the CYC system, www.cyc.com). AI will continue solving some difficult problems better than humans, but is a long way from solving others at which even children excel.

MYTH II: AI WILL SURPASS HUMAN INTELLIGENCE BY 2045

It has been predicted by eminent contributors to AI that systems "surpassing humans" will take place before 2050. Ray Kurzweil's "singularity" prediction from 2005 said that in 2045 "machine intelligence will be infinitely more powerful than all human intelligence combined" [5]. Yet this prediction is based on the belief that the current growth of AI, characterized as exponential, will continue as such for the next 25 years. This is highly unlikely, as barriers will almost certainly arise on the way. One such barrier is the complexity of AI systems: some of the modern networks trained on very large data contain billions of parameters. The complexity of these systems, and a lack of understanding of the adverse interaction of their features, will make it very difficult to engineer larger systems from function-specific components. It is difficult to see how such components can be assembled and connected without understanding how to set them up for a given task. A lack of any serious results in the standardization of fundamental tools that advanced AI uses (e.g., data representation and description languages) is another likely barrier. Finally, a scarcity of the annotated ("labeled") data necessary to train the "supervised" (i.e., the most powerful) ML algorithms is another. While the Big Data movement brought focus to the questions of collection, management and analysis (using ML) of large, heterogenous and constantly growing data, the question of annotation of massive (order 10^6 or 10^7 instances) datasets is still open. A practical solution used today is the global crowdsourcing of data annotation, with its non-scaling cost, difficult quality assurance issues and the unsolvable questions of hidden cultural and demographic biases in annotating certain types of data. There is also the difficult question of data ownership: much of the promising data that, combined, could potentially lead to breakthroughs in a number of society-level issues belongs to several major players known as GAFA (Google, Amazon, Facebook, Apple) and is treated as a proprietary asset by these organizations. Given all these issues and the lack of a convincing perspective for addressing them in the fragmented,

competitive data ecology, makes it almost certain that hurdles will appear in the growth path of AI. Even if some of the challenges outlined in Myth I were solved, others will no doubt appear. No technology has continued its progress forever without reaching a plateau at some point. The exponential growth of AI will not continue eternally, and as it is the central argument for surpassing human intelligence, singularity is not certain.

MYTH III: AI WILL HARM HUMANS

The fear of AI revolting against its human creators has long left the safe territory of science fiction and has been repeatedly brought up by thinkers and visionaries. On the one hand there are no technical or scientific arguments substantiating these beliefs. Some such doomsday scenarios have been presented by people who are thought leaders in science or human history — e.g., Stephen Hawking and Yuval Harari, but do not necessarily have in-depth, technical understanding of AI as it is today. On the other hand, strong technical arguments have started appearing that argue the impossibility of such a "robot revolt". In particular, a recent book [6] by Christof Koch, Chief Scientist and President of the Allen Institute for Brain Science argues that it will not be possible to construct artificial (computerized) conscience. Koch presents an analytical, scientific argument about the impossibility of "artificial consciousness". For robots to differentiate themselves from humans, let alone attack them, self-conscience would be necessary. This is not to say that we do not need to think about the ethics of AI — we do, because AI systems make decisions that concern practically all of us, and that will grow even further. But from seeing a path from transparency of specific decisions to autonomous intelligence that may evolve the goal of harming humans is a far fetched conclusion.

MYTH IV: AI WILL ELIMINATE JOBS AND MAKE HUMANS SECOND-CLASS CITIZENS

This myth has different versions. In some, it is similar to the luddite movements from the 19th century where people were destroying textile machines because they were threatening pre-industrial revolution jobs. In its much more refined version, discussed e.g., in Harari's 2017 book "Homo Deus" [7], humans will become inferior members of a society, with all the higher-level intellectual decision-making powers reserved for AI systems. I have a different view of the effects of AI on human work. It is clear that some very common jobs will most likely be eliminated by AI within the next 10 years. According to Statistics Canada, driving a truck for a living is the second most frequent occupation among men in Canada, and yet most of these jobs will be likely replaced by autonomous vehicles before the decade is out. Other jobs, e.g., even some positions in the legal profession, are also likely to either be eliminated or greatly scaled down. But does that mean massive unemployment and the universal need for a Guaranteed Basic Income? I believe that new jobs, which we cannot even imagine and articulate today, will appear, just like we could not predict in 1980 that hundreds of thousands of people will make a living from adding value to the internet (e.g., webpage and app design), because the internet concept or even the name itself did not exist at that time. Similarly, new technologies will appear and will create new kinds of jobs. It is often raised that these jobs will require much higher levels of math and science than those existing today. That is most likely true, but I believe that significantly raising the level of universal training in mathematics and science is not impossible. Most of the population was illiterate before the industrial revolution, but once this revolution happened and literacy of the workforce has become a must, societies have been to be able to build educational systems in one generation. This is the challenge we are facing today. And here is also a fascinating opportunity for AI. Artificial Intelligence may be a major tool and enabler in creating better ways of individualized, engaging and thorough ways of training our youth in mathematics, physics and science through simulation, visualization and interaction, and one-on-one conversations, with the student making the material relevant to their personal interests. In that way, the jobs that AI will take away will be replaced by new jobs that AI will train people for. There is no reason to believe that humans will be degraded to intellectual slaves.

CONCLUSION

The four myths discussed above are far from an exhaustive list. I do not pretend that my answers to these myths are complete, as any opinion based on a prediction with significant uncertainty, may turn out true, or perhaps not. Many others remain — e.g., are AI systems capable of true creativity, in the sense of inventing new concepts as described in Kuhn's seminal book "The Structure of Scientific Revolutions"? Our society needs to discuss these issues in a perhaps more thorough, systematic manner than is the case today. More participation by scientists, particularly from the field of AI, is needed. "Aucun n'est prophète dans son pays", but we need to try.

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Syndrome EHS : une grave épidémie de croyances

par Sébastien Point

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Sommaire

Le syndrome d'éléctrohypersensibilité, ou syndrome EHS, peut être, en première approche, décrit comme un ensemble de symptômes ressentis par un individu et dont la cause est attribuée aux ondes électromagnétiques de l'environnement. C'est, pour certains, la maladie du 21ème siècle. Pour d'autres, il s'agit d'une maladie imaginaire. Quelle réalité se cache derrière le syndrome EHS ?

UN SYNDROME ÉMERGENT

D'après le site Rassemblement Électrosensibilité Québec (RESQ), la prévalence[1] du syndrome EHS serait comprise entre 3% et 10 % de la population, soit au minimum 240 000 personnes au Québec [1]. L'incidence[2] serait en augmentation. Selon le Pr. Dominique Belpomme, considéré par certains comme un spécialiste du diagnostic et du traitement du syndrome EHS, le nombre de personnes affectées sera de « *50% dans les cinquante ans qui viennent* »[3]. Effectivement, les résultats de plusieurs études montrent, depuis 1985, une augmentation forte et constante du taux de personnes souffrant du syndrome EHS, bien que des études récentes ne montrent pas une poursuite de cette tendance [2]. Le syndrome EHS se caractériserait par la survenue chez les individus atteints d'un certain nombre de symptômes en présence d'ondes électromagnétiques de faible intensité. L'Organisation Mondiale de la Santé (OMS) mentionne « *des symptômes dermatologiques (rougeurs, picotements et sensations de brûlure), des symptômes neurasthéniques et végétatifs (fatigue, lassitude, difficultés de concentration, étourdissements, nausées, palpitations cardiaques et troubles digestifs)* » [3], auxquels on peut rajouter, entre autres choses, et suivant la description faite par un certain nombre d'associations de soutien aux malades, des troubles du sommeil, des sifflements dans les oreilles, des saignements de nez, des troubles de l'humeur, des douleurs articulaires, des altérations de la vue et même des membres qui « *dorment* (…) *et peuvent être comme morts durant le sommeil* » [4]. Les symptômes sont ainsi très nombreux, variés et non spécifiques. Yves le Dréan, chercheur pour l'institut national de la santé et de la recherche médicale (INSERM) et spécialiste des effets biologiques des rayonnements non-ionisants, en comptabilise 80 [5]. Ces symptômes sont typiquement reliés au syndrome EHS par autodiagnostic [6,7] mais des méthodes de diagnostic scientifiques auraient été développées : d'après l'Association pour la Recherche Thérapeutique Anti-Cancéreuse (ARTAC), il existe des signes cliniques (concomitance des symptômes avec l'exposition aux ondes, antécédents d'expositions, accumulation de symptômes, alliages dentaires pouvant faire « antenne » …) et des marqueurs biologiques, dont la diminution du flux sanguin cérébral à l'encéphaloscan et l'augmentation des taux sanguins des protéines Hsp27, Hsp70, et S100B [8] …

Enfin, outre les symptômes physiques, une des conséquences du syndrome EHS est un isolement social. En effet, la recherche d'une « zone blanche », les tentatives de faradisation[4] de leur environnement domestique, et le désinvestissement des lieux de sociabilité dans le but de fuir les ondes conduisent de nombreux malades à un repli sur soi [9].

ÉCONOMIQUEMENT ET POLITIQUEMENT INTÉRESSANT

La généralisation de la téléphonie mobile et des technologies communicantes d'une part, et l'augmentation du nombre de cas de personnes se déclarant malades des ondes d'autre part, font du syndrome EHS un sujet médiatique vendeur et donc désormais récurrent. On ne compte plus les articles de presse grand public relatant l'enfer vécu par les électrosensibles, et leur recherche désespérée d'un endroit ou d'une méthode leur permettant de retrouver une vie normale. De nombreuses associations ou collectifs se créent, à travers le monde, pour défendre, à coup de pétitions et de manifestations, le droit des personnes électrosensibles et faire reconnaître la maladie. De nombreux litiges opposant des opérateurs de

1. La prévalence est, à un moment donné, le nombre total de cas d'un trouble rapporté à l'effectif total d'une population.
2. L'incidence est, sur une période donnée, le nombre de nouveaux cas d'un trouble rapporté à l'effectif total d'une population.
3. Cité par le site lemieuxêtre.ch [48].
4. Action de protéger un espace des ondes électromagnétiques au moyen d'une cage de Faraday.

téléphonie mobile ou des exploitants de compteurs communicants se règlent devant les tribunaux, avec une tendance non négligeable de l'appareil judiciaire à donner raison aux plaignants, sur la base de certificats médicaux attestant de la nécessité d'un éloignement immédiat de toutes sources d'ondes électromagnétiques. En Italie, par application d'une décision de justice, l'état doit ainsi réaliser une campagne d'information sur les risques sanitaires et environnementaux qui seraient liés aux appareils de téléphonie mobile [10]. En France, dans une ordonnance en référé en date du 26 septembre 2016, le tribunal d'instance de Grenoble, devant statuer sur la plainte d'une personne déclarant être devenue malade après l'installation d'un compteur d'eau communicant sans fil, a considéré qu'il résultait des nombreux certificats médicaux versés aux débats que la plaignante présentait « *une hypersensibilité aux champs électromagnétiques* » nécessitant « *impérativement sa mise à l'abri d'un maximum de sources électromagnétiques même de faible intensité, sous peine d'atteinte à sa santé sous forme d'une détérioration cérébrale sévère*» [11]. Autre exemple frappant, toujours en France, le feuilleton « Linky », ce compteur électrique communicant d'ENEDIS (société gérant le réseau d'électricité en France) qui déchaîne les passions et pousse les particuliers à barricader leurs installations électriques pour en interdire la pose, par crainte notamment des ondes [12,13] … et cela en dépit des résultats de mesure communiqués par l'Agence Nationale des Fréquences (ANFR) montrant que ce compteur, qui fonctionne par voie filaire, n'émet pas plus d'ondes qu'un petit appareil électroménager [14].

Face à ce « fléau » qui touche une partie de l'électorat, le **corps politique** réagit. Comme par exemple, en France, Stéphane Le Foll, ex-ministre de l'Agriculture et maire du Mans, économiste de formation, qui considère que l'hypersensibilité aux ondes est une réalité [15]. Ou encore Michèle Rivasi, députée européenne écologiste, qui cherche « *une zone blanche dans laquelle reloger* » les électrosensibles et milite pour une recherche européenne afin d'identifier les bio-indicateurs du syndrome EHS [16]. **Côté administration**, un processus de reconnaissance a démarré. D'après une information du site AiretVie, en 2011 [17], la commission des droits de la personne et des droits de la jeunesse du Québec confirmait le statut des électrosensibles dans une lettre adressée à l'association pour la santé environnementale du Québec, en précisant que « *la définition du motif handicap dans la Charte des droits et libertés de la personne* » était suffisamment large « *pour que les personnes qui souffrent d'hypersensibilités environnementales puissent invoquer ce motif* ». En France, en 2014, c'est la Maison Départementale des Personnes Handicapées (MDPH) de l'Essonne qui a accordé une aide financière à une personne électrosensible afin qu'elle équipe son logement de dispositifs anti-ondes [18] …Car **côté affaires**, les besoins de cette population de malades ont engendré l'apparition d'une nouvelle offre commerciale, celle des divers objets censés les protéger des méfaits des ondes. En Ontario par exemple, la société *technoscente* aide ses clients à éliminer les risques et les souffrances associés aux rayonnements par une évaluation personnalisée qui détermine la solution de protection qui leur convient le mieux [19]. En France, une apicultrice de métier a choisi de développer sa gamme de vêtements high-tech anti-ondes tissés de fils d'argent, seule matière d'après elle « *qui atténue aussi bien les hautes que les basses fréquences* » [20]. La firme *petit-bateau* a mis sur le marché, par principe de précaution nous dit-elle, des bonnets et couverture anti-ondes pour bébé [21]. On trouve facilement dans les boutiques de commerce en ligne des caleçons, des foulards, des chapeaux anti-ondes et même des chaussures cloutées pour se relier à la terre. Il est également possible d'occulter les fenêtres de sa maison par des rideaux anti-ondes, de couvrir le matelas de son lit d'un surmatelas anti-ondes et de draps reliés à la terre ou encore d'installer dans les différentes pièces de vie des générateurs de bulles de protection... La liste est en réalité bien longue et nous renvoyons le lecteur à un autre article [22] de l'auteur qui dresse un inventaire à la Prévert de tous ces gadgets.

MAIS TRÈS PROBABLEMENT D'ORIGINE PSYCHOLOGIQUE

Une incidence en augmentation, des symptômes handicapants, une « prise de conscience » par le monde politique, administratif et judiciaire, des méthodes de diagnostics « sophistiquées », des objets anti-ondes. Tout cela paraît si convaincant qu'il pourrait sembler incongru de mettre en doute la réalité de l'électrohypersensibilité. Et pourtant, il se pourrait bien que le syndrome EHS relève en réalité du champ de la psychopathologie. Voyons pourquoi.

Du côté des mécanismes biologiques à l'origine des symptômes, certains évoquent des cristaux de magnétite qui seraient contenus dans nos cellules et se mettraient à "vibrer" sous l'action du champ électromagnétique [23] ; d'autres font le lien avec une forte concentration en minéraux ou en métaux lourds dans les fluides organiques qui entrainerait une plus grande sensibilité aux inductions électromagnétiques [24,25]. Mais il n'existe en réalité aucun mécanisme scientifiquement reconnu qui permettrait de lier les symptômes et marqueurs décrits précédemment avec l'exposition aux ondes électromagnétiques de faible intensité… D'ailleurs, les évolutions de plusieurs marqueurs biologiques mis en avant dans le diagnostic de l'EHS peuvent être expliquées par des mécanismes physiologiques impliqués dans la réaction de stress, comme nous le verrons plus loin. Quant à la pertinence et l'efficacité de l'encéphaloscan, elles n'ont jamais été validées scientifiquement, comme l'a rappelé le Conseil de l'Ordre National des Médecins, dans le cadre d'une plainte déposée en France à l'encontre du Pr. Belpomme pour manquement à la déontologie [26]. Par contre, ces dernières années, face à l'ampleur du phénomène, plusieurs études de provocation[5] ont été menées et ont apporté un éclairage original de la situation [27-36]. Une analyse [37] de ces études a été faite

5. L'objectif de ces études est de mettre en évidence, en conditions de laboratoire, donc contrôlées, une possible relation de cause à effet entre l'exposition aux ondes et le niveau d'inconfort des personnes EHS, par rapport à des conditions d'expositions factices et par comparaison avec une population témoin.

par van Rongen et ses collègues qui concluent qu'une relation causale entre l'exposition aux rayonnements et les symptômes ressentis n'a pas été démontrée et suggèrent que des facteurs psychologiques tels que l'attente consciente d'effets sur la santé peuvent jouer un rôle important. Cette conclusion est partagée par Szemerszky et ses collègues [38] qui ont suggéré la formation dans l'esprit des personnes EHS d'un cercle vicieux basé sur la somatisation, l'amplification somatosensorielle, la causalisation et l'erreur d'attribution. Dans un article récent [39], j'ai moi-même proposé une approche cognitive de l'EHS en l'identifiant à un trouble anxieux. Nous y renvoyons le lecteur et me bornerai ici à dresser les grandes lignes du mécanisme proposé, avant d'en venir aux implications d'une telle hypothèse.

Le facteur biologique[6] joue un rôle majeur dans de nombreux modèles d'anxiété, notamment le modèle biopsychosocial de Jones et Barlow du stress post-traumatique [40] et le modèle de panique de Clark [41]. Dans ce dernier modèle, les personnes souffrant de troubles panique sont excessivement sensibles à certaines perceptions corporelles normales ou pathologiques, qu'elles considèrent comme une menace. Ces perceptions jugées comme menaçantes peuvent déclencher une attaque de panique, dont la manifestation biologique (palpitations cardiaques, hyperventilation...), associée à une focalisation de l'attention, peut amplifier la perception de la menace lors de l'exposition à l'objet de la phobie et favoriser plus tard le développement d'une anxiété anticipatoire et d'un comportement d'évitement. Dans une approche cognitive du syndrome EHS, nous avons proposé l'existence d'une vulnérabilité biologique comparable chez les patients électrosensibles. Cette vulnérabilité biologique conduirait les malades à confondre leurs symptômes d'anxiété avec un effet biologique des ondes électromagnétiques. Un focus attentionnel sur la perception physique pourrait conduire à une amplification somatosensorielle et renforcer le sentiment de danger. Lorsqu'une stratégie d'évitement ou de défense est mise en place, la réduction du niveau de stress[7] (liée à la croyance que la stratégie est efficace) et des symptômes associés, renforce la conviction du malade que les rayonnements électromagnétiques sont bien à l'origine de son mal-être. L'exposition aux ondes — qu'elle soit réelle ou non — jouerait ainsi le rôle de stimulus conditionnel d'un mécanisme phobique que viendrait renforcer un biais de confirmation basé sur le focus attentionnel et la réussite des stratégies d'évitement.

Le mécanisme que nous venons brièvement de décrire ici appelle bien entendu des confirmations expérimentales supplémentaires. A son avantage, un modèle cognitif du syndrome EHS tel que nous le proposons peut s'appuyer sur des mécanismes biopsychologiques déjà à l'œuvre dans d'autres types de phobies, et ne fait pas appel à des mécanismes biologiques encore inconnus. Cette hypothèse n'est pas non plus incompatible avec l'évolution de certains marqueurs biologiques donnés comme caractéristiques du syndrome EHS : l'augmentation du taux d'Hsp27, marqueur d'un stress oxydatif que certains attribuent à un hypothétique effet des ondes, peut bien plus simplement résulter d'un stress oxydatif lié à une hyperoxie, un excès d'oxygène dans le sang qui accompagne les hyperventilations fortes [44] dont nous avons vu qu'elles sont une manifestation physiologique des troubles anxieux. Idem pour la protéine Hsp70 qui intervient pour protéger les cellules contre le stress oxydatif. Et d'après certaines études (par exemple [45]), la protéine S100B est le marqueur d'un stress psychogénique induit par la reconnaissance d'une menace.

Tous ces éléments appuient donc bien l'hypothèse psychosomatique. Dans cette hypothèse, quels effets aurait, sur les électrophobes, le contexte informationnel actuel dans lequel le lien de causalité entre syndrome EHS et ondes électromagnétiques est affirmé par des politiques, des militants, des médecins et même des juges et relayé sans discontinuer par les médias de masse ? Concernant les **médias de masse**, leur rôle serait fondamental dans l'initiation du trouble. Le traitement médiatique pourrait favoriser l'attention des personnes prédisposées sur les divers émetteurs de radiofréquences existants dans leur environnement, et aux perceptions physiques lorsque ces personnes les rencontrent ou les utilisent, et contribuer ainsi largement à transformer les ondes en stimulus conditionnel de l'électrophobie. Les **médecins** ont aussi un rôle social majeur. Sur les sujets de santé, leur parole fait autorité, y compris lorsqu'ils s'expriment parfois en dehors de leur domaine de compétence. Dans l'hypothèse d'un trouble anxieux, quelles conséquences les certificats de médecins attestant de l'électrosensibilité aux ondes auraient-ils sur le trouble lui-même ? Selon nous, ces prises de positions sans fondement médical seraient de nature à renforcer le biais de confirmation des personnes électrophobes et à les conforter dans la croyance que les ondes sont réellement dangereuses. Les **objets anti-ondes** auraient également un impact déterminant. En effet, ils font partie des stratégies de défense et d'évitement mises en place par les personnes électrophobes. Comme toute stratégie d'évitement mise en place par un patient phobique, les objets anti-ondes semblent efficaces sur le moment puisqu'ils contribuent à diminuer le niveau d'anxiété, y compris le niveau d'anxiété anticipatoire, et favorisent le retour du patient phobique vers un état de plus grand calme. Par conséquent, ces objets contra-phobiques peuvent conforter le patient phobique dans la croyance que les ondes sont bien responsables de ses symptômes (puisque qu'il constate qu'un objet anti-ondes a pu diminuer son mal-être). Les mécanismes à l'œuvre seraient donc une rétroaction négative sur l'état de stress et une rétroaction positive sur le biais de confirmation. Les objets anti-ondes seraient ainsi, dans une approche psychologique du syndrome EHS, de nature à maintenir et amplifier le syndrome d'EHS. Enfin, nous pensons que les différents mécanismes de reconnaissance du syndrome EHS par des

6. D'après certaines études [42], un volume anormal de l'hippocampe pourrait être à l'origine de cette vulnérabilité biologique.
7. Il a en effet été montré que les personnes atteintes du syndrome EHS disent retrouver un meilleur niveau de confort lorsqu'elles mettent en place des stratégies d'évitement des dispositifs émetteurs d'ondes [43].

associations, des **administrations**, ou même des **tribunaux**, participeraient aussi à maintenir le trouble EHS en contribuant à créer une identité d'EHS et en légitimant le combat « anti-ondes » aux yeux de tous. Ce contexte informationnel est ainsi à rapprocher de la notion d'exposition socio-cognitive aux ondes, notion développée par Marc Poumadère et Anne Perrin [46], pour qui l'exposition à des informations préoccupantes et aux controverses associées aux ondes de téléphonie mobile pourrait constituer un stresseur chronique et favoriser notamment la génèse d'un effet de type *nocebo* (apparition de symptômes par exposition à des agents inactifs).

UNE THÉRAPIE À INVENTER

En se basant principalement sur les témoignages de personnes dites « électrosensibles » qui, du point de vue scientifique, constituent un très faible niveau de preuve compte tenu des différents biais cognitifs propres au fonctionnement du cerveau humain, de nombreux acteurs de nos sociétés, médecins, juges, administrations, militants, se trompent sur la nature et l'étiologie du syndrome EHS. Les études de provocation, conduites en laboratoire en double aveugle, aléatorisées et contre-balancées, ont en effet démontré que les personnes « électrosensibles » ne détectent pas plus la présence d'ondes dans leur environnement qu'une pièce que l'on jouerait à pile ou face. Pire, des symptômes insoutenables ont été ressentis au cours de ces expériences par des personnes « électrosensibles » lors des conditions d'exposition fantômes, c'est-à-dire en l'absence d'onde, signe que leur cerveau semble capable de construire la sensation de douleur lorsqu'ils se croient exposés : selon toute vraisemblance, le syndrome EHS est une maladie psychosomatique caractérisée par une peur irrationnelle des ondes électromagnétiques. L'électrosensibilité serait donc en réalité une électrophobie. Sous cet éclairage, on comprend que les conséquences des prises de positions affirmant un lien réel entre syndrome EHS et exposition aux ondes électromagnétiques sont lourdes à l'heure de l'information instantanée et massive. A la fin du 19ème siècle, Gustave Le Bon, en pionnier de la psychologie des foules, décrivait le mécanisme de propagation des croyances au sein d'une foule psychologique, c'est-à-dire une communauté de pensée, plus ou moins éphémère, reliée par les même sentiments ou croyances, comme le constitue aujourd'hui, nous semble-t-il, la communauté des électrophobes. Selon Le Bon [47], « *lorsqu'une affirmation a été suffisamment répétée, et qu'il y a unanimité dans la répétition (…) il se forme ce que l'on appelle un courant d'opinion et le puissant mécanisme de la contagion intervient. (…) C'est surtout par le mécanisme de la contagion, jamais celui du raisonnement, que se propagent les opinions et croyances des foules* ». Ces mécanismes de contagion d'une croyance sont, selon nous, le véritable moteur de l'épidémie d'EHS. Il est urgent de comprendre que l'hypothèse psychologique est l'étiologie la plus probable de ce trouble, et que dans cette hypothèse, chaque information véhiculée par les médias, chaque jugement ou avis médical certifiant l'« électrosensibilité » d'une personne, enfonce un peu plus les malades dans leur phobie et en contamine d'autres. Cette prise de conscience que nous appelons de nos vœux doit permettre, au plus vite, la mise en place de dispositifs d'accompagnement et de prise en charge des malades dans le cadre de thérapies cognitives comportementales spécifiques qui restent à inventer.

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FAUSSE SCIENCE; SCIENCE BIDON : LE RÔLE DE LA COMMUNAUTÉ SCIENTIFIQUE DANS LA PROPAGATION DE CES IDÉES

PAR NORMAND MOUSSEAU[1]

Le sommaire de l'article [1] est sans équivoque : il n'existe aucun niveau de consommation d'alcool qui soit sans risque pour la santé. Cette conclusion est résultat d'une compilation de milliers d'articles par des centaines d'auteurs, financée par la *Bill et Melissa Gates Foundation* et publiée dans la prestigieuse revue *The Lancet.* S'appuyant sur cette analyse, les auteurs demandent aux directions de la santé publique de par le monde de revoir dès à présent leurs recommandations. Sans surprise, les conclusions de cet article, qui bousculent les discours dominants depuis quelques années, ont été reprises par les grands médias à travers la planète incluant Radio-Canada, le *National Post*, le Monde, la BBC et bien plus.

Pour quiconque suit, même de loin, le dossier, des résultats aussi catégoriques soulèvent des questions. Comment cette nouvelle méta-étude peut-elle arriver à une conclusion en opposition aussi marquée avec les études précédentes ? La taille démesurée de cette étude pouvait-elle faire apparaître des corrélations ratées auparavant ? Un coup d'œil à l'article, au-delà de la lecture seule du sommaire et des conclusions, ne pointe pas dans cette direction. La structure de l'article est, en elle-même, étonnante : contrairement à la coutume dans les méta-études, on ne retrouve pas de grands tableaux récapitulatifs ; les chiffres mentionnés dans le texte sont difficilement interprétables et les figures restent assez peu claires. Toutefois, en se concentrant sur ces rares données (figure 2, en particulier), on constate rapidement que malgré un nombre d'auteurs qu'on ne retrouve normalement qu'en physique des particules, un commanditaire prestigieux et une revue de première ligne, les chiffres ne supportent pas la conclusion [1].

SOMMAIRE

Le processus de production et de diffusion scientifiques est, par sa nature humaine, imparfait, comme le savent les chercheuses et chercheurs qui pratiquent la science au quotidien. Trop souvent, toutefois, ces limites et biais sont occultés lorsqu'on intervient auprès du public. Et si cette fausse représentation de notre activité contribuait à la diffusion de la science bidon ?

Il s'avère que l'information la plus pertinente ne se trouve que dans le communiqué de presse. Selon le blogueur David Spiegelhalter [2], c'est à la demande des chargés de communication de la revue *The Lancet*, et non de ses éditeurs, que les auteurs ont fourni les estimations de risques absolus. Le communiqué de presse nous montre donc que si on ne boit pas une seule goutte d'alcool, les risques de développer une maladie normalement associée à l'alcool sont d'environ 914 sur 100 000 (0,9 pour cent). À un verre d'alcool par jour, ces risques passent, selon l'étude, à 918 sur 100 000, une augmentation de 0,004 pour cent ou de 0,5 % plus grande que sans aucune boisson. Quelqu'un peut-il croire réellement que l'on peut mesurer la consommation d'alcool avec une précision qui s'approche de cette valeur ? Une médecin de ma connaissance me disait qu'elle doublait systématiquement la consommation avouée de ses patients pour ses dossiers.

Et que se passe-t-il lorsqu'on augmente notre consommation d'alcool ? Les risques, pour deux verres par jour, sont multipliés par 15, à 977 sur 100 000 ou de 0,6 % en moyenne de plus que pour quelqu'un qui ne boit pas. Lorsqu'on inclut les marges d'erreur présentées par l'étude, on voit qu'il est possible que, jusqu'à 2 verres par jour, l'alcool puisse même être bénéfique pour la santé.

Cette étude, que les auteurs ont largement moussée dans les médias et auprès de divers organismes de santé publique, est un exemple flagrant des limites du processus de validation scientifique, dont on vante pourtant si souvent le fonctionnement. En effet, parmi les centaines d'auteurs de cette étude se trouvent plusieurs chercheurs reconnus par leurs pairs; le manuscrit a été révisé par les éditeurs et des arbitres anonymes; et le tout publié dans une revue de premier plan. Cet article est donc passé par les filtres traditionnels et a respecté toutes les normes de notre communauté. Il ne s'agit pas d'un article rédigé par des scientifiques douteux sorti dans une revue placée au ban de la communauté. Et pourtant, il est

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évident que cette étude, aux conclusions biaisées qui ne reflètent pas les données recueillies, n'aurait pas dû être publiée.

Ce type de situation, s'il n'est pas commun, n'est pas rare, à proprement parler. Une étude récente portant sur les risques de l'exposition aux ondes électromagnétiques émises par les téléphones cellulaires est du même acabit [3] : si les données présentées dans l'article semblent honnêtes, les conclusions et la publicité faite autour de celles-ci dépassent de loin ce qu'il est possible de conclure, malgré l'importance des efforts : 8 cohortes de 100 rats, quatre de mâles, quatre de femelles, exposés à divers niveaux d'ondes électromagnétiques. Selon le sommaire, si on ne trouve aucune corrélation entre l'exposition au rayonnement micro-onde et le cancer chez les rats femelles, les rats mâles soumis à divers niveaux de rayonnement micro-onde sont plus susceptibles de développer un cancer du cœur. Ce qui n'est pas dit, toutefois, est que le taux de mortalité sur la durée de l'expérience (2 ans) est beaucoup plus élevé chez les rats mâles non-exposés! En effet, seulement 25 des 90 rats non-exposés survivent 2 ans, alors qu'entre 43 et 60 rats mâles survivent dans les 6 cohortes exposées à divers niveaux de radiations, une différence qui n'est pas discutée, même si elle est beaucoup plus grande que les niveaux de cancer observés.

Ici encore, la mauvaise science est présentée par des institutions tout ce qu'il y a de crédible — on parle ici du *National Institutes of Health* — et la publication du rapport a été précédée du processus attendu de révision par les pairs. La critique traditionnelle de la pseudoscience ou de la science bidon ne s'applique donc pas ici ; tout au plus, peut-on contester la promotion faite par les instituts de recherche au sujet de ce rapport, lorsqu'on tient des importantes lacunes de celui-ci. Comment espérer, dans ces conditions, que le citoyen non-expert puisse faire la différence entre science bidon, pseudoscience et mauvaise science ?

UNE SCIENCE VENDUE COMME PARFAITE

J'ai retenu ces exemples car j'ai eu l'occasion de les critiquer sur la place publique; ils ne sont pas les seuls, et les mauvaises études qui concluent au faible risque de la consommation d'alcool ou à l'absence d'effet sur la santé des micro-ondes existent aussi — ce n'est pas parce que les conclusions sont correctes que les travaux qui les soutiennent sont bien faits!

Ces exemples soulignent bien, toutefois, un aspect relativement peu discuté de l'apparition et de la survie de la pseudoscience dans le débat public : l'absence d'une discussion honnête et publique sur les limites réelles du processus scientifique. Trop souvent, le blâme est jeté sur le citoyen, à qui on reproche son manque de connaissances scientifiques générales ou son insistance à croire malgré les évidences scientifiques solides [4]. Il ne s'agit pas de nier les conclusions de ces travaux, tel que le démontre, par exemple, le débat sur les changements climatiques causés par l'activité humaine, mais plutôt de montrer également la part de notre responsabilité collective, en tant que communauté scientifique, dans cet égarement.

Traditionnellement, la communauté scientifique, comme toute autre corporation — des médecins aux ingénieurs, en passant par les avocats et les journalistes — tend à défendre son fonctionnement, ses règles et son intégrité face à ceux qui n'en font pas partie, mais aussi lors de la formation de nouveaux membres. Tout manquement aux normes proférées est alors soit caché — les exemples d'université traitant très discrètement des fraudes et des malversations sont trop nombreux pour que je les cite ici — soit présenté comme une faute rarissime et anormale. Le message officiel offert tant à la communauté elle-même qu'au reste du monde est, qu'à l'exception de ces cas presque uniques, la science est fondamentalement au-dessus de tout soupçon, grâce au désintérêt des chercheurs et de leurs institutions, à la rigueur des arbitres et à la probité des éditeurs et des organismes de financement. Les hagiographies des grandes et des grands scientifiques offrent un visage humain à cette machine parfaitement huilée, ce qui rend le message plus facilement assimilable par le public et par notre communauté.

Lorsqu'on accepte cette fabulation, il est difficile de comprendre comment un citoyen possédant une formation scientifique minimale ou acceptant la domination de la raison puisse adhérer à la propagande des pseudosciences. L'origine de ce phénomène est donc clairement extérieure à nous, scientifiques, ce qui nous décharge de toute responsabilité quant sa montée.

UN SYSTÈME TOUT CE QU'IL Y A DE PLUS HUMAIN

Pour quiconque pratique la science sur une base régulière, maintenir le crédo officiel de la communauté exige pourtant une capacité de dissociation proche de la schizophrénie. Quelle fraction des arbitres anonymes évaluant nos propres manuscrits trouve grâce à nos yeux ? De mon côté, si l'ensemble des évaluations que je porte sur le travail de mes collègues est, bien sûr(!), du plus haut niveau, les critiques de mes travaux sont presque systématiquement le fruit d'imbéciles ignares qui ne semblent même pas avoir lu la première phrase du sommaire avant de porter leur jugement. Et qu'en est-il des comités qui révisent mes demandes de subvention ? J'en aurais long dire sur leur étroitesse d'esprit et leur manque de vision.

Les discussions régulières avec mes collègues m'ont confirmé que je ne suis pas le seul à observer cette dichotomie. La plupart d'entre eux tiennent également un discours très critique quant au fonctionnement de la science aujourd'hui, que ce soit dans l'obtention des fonds, le choix des sujets, les contraintes à la recherche ou la publication des résultats. Et je ne parle pas des pressions à la publication, de l'évaluation superficielle des dossiers de chercheurs à l'aide de l'indice H ou du nombre de citations, et bien plus.

Or, la poursuite de la science est une activité humaine et, comme telle, est imparfaite, biaisée et sujette à la malversation. De par sa nature institutionnelle, elle est possiblement plus propre que bien d'autres disciplines, particulièrement lorsqu'elle se déploie dans des domaines éloignés de l'industrie, mais plus propre ne veut pas dire impeccable, comme le montrent les diverses études qui se penchent sur ses travers (voir, par exemple, Réf. [5]). Ces études tendent à cibler les aspects les plus problématiques de

notre profession, telles que les fraudes, mais ignorent généralement des imperfections plus banales, mais dont les effets sont possiblement plus grands.

Revenons à nos exemples. Dans les deux cas, les études sont importantes tant par la taille de leur financement que par celle des équipes de chercheurs. La pression est donc forte pour que les résultats soient à la hauteur. Pas question de fausser les données, bien sûr. Par contre, on peut mousser un peu leur interprétation, choisir les bons termes et placer dans le sommaire et les conclusions de l'article des phrases alarmistes qui permettront de démontrer aux organismes de financement qu'ils en ont pour leur argent. Cette orientation facilitera d'ailleurs le renouvellement des subventions essentielles au fonctionnement des laboratoires et à la poursuite des recherches. Pour préserver l'honnêteté — et faciliter le financement futur — il suffit d'ajouter à la conclusion alarmiste une phrase qui souligne la nécessité de poursuivre les recherches sur cette question et le tour est joué!

Si les équipes à l'origine de ces études ont peut-être poussé la manipulation des résultats beaucoup plus loin que ce qui est habituel, elles ne sont pas les seules à le faire, dans un contexte de compétition mondiale pour des postes, du financement et l'accès aux revues renommées.

CONSTRUIRE SUR LES LACUNES DE LA SCIENCE

Reconnaître les limites et les travers de l'activité scientifique veut pas dire rejeter, comme le fait Bruno Latour, par exemple, la valeur des résultats ou n'en faire qu'un récit, à mettre sur un pied d'égalité avec les autres croyances humaines. En effet, au-delà même des exemples ci-haut, la nature profonde la recherche implique une perte d'impartialité. Ainsi, on ne peut demander à une chercheuse ou un chercheur ayant consacré 20 ans de leur vie à démontrer un phénomène d'évaluer froidement l'importance de leur découverte. C'est plutôt leur biais profond qui leur a donné la motivation de faire le travail.

Mettre de l'avant le fonctionnement réel de la science permet donc de mieux expliquer le processus de la découverte, l'origine des débats et leur nécessaire évolution, à la lumière de l'avancement des connaissances, de ses contradictions et de leur résolution.

Le fonctionnement humain de notre communauté n'est pas à honnir. On doit plutôt se réjouir que celui-ci ne soit pas le reflet de l'image d'Épinal que l'on présente normalement, pour toutes sortes de raisons qui viennent autant de l'intérieur que de l'extérieur, mais qui démontrent l'aspect social de cette activité. Expliquer ces travers ne signifie pas les accepter ou, encore moins, les défendre tous. Cela signifie simplement les reconnaître.

Cette reconnaissance formelle est essentielle pour permettre au public d'évaluer à sa juste mesure les résultats qui sont présentés et les scientifiques qui les génèrent. Expliquer les limites du système d'évaluation par les pairs et la chasse à la citation des grandes revues, par exemple, permet de mieux faire comprendre comment de mauvais articles peuvent passer les barrières, s'ils ont des chances d'attirer l'attention médiatique. Faire connaître la difficulté de financer sans promesses démesurées facilite également l'esprit critique face aux annonces à répétition de traitement contre le cancer ou la maladie d'Alzheimer. Exposer la monomanie de certains chercheurs explique comment ceux-ci parviennent à des révolutions envers et contre tous, mais aussi comment ils surestiment souvent, et sans malice aucune, l'impact de leurs travaux.

En dévoilant les limites du fonctionnement de la science, notre communauté ne fera pas disparaître la pseudoscience. Il est même probable que l'on complique la discussion, en brouillant les frontières entre l'évidence scientifique et le farfelu. Malgré ce risque, il reste préférable pour la communauté scientifique de jouer cartes sur table, en reconnaissant et en expliquant son fonctionnement réel plutôt qu'en perpétuant un conte de fées. Il faut que les chercheurs présentent plus souvent les biais de notre profession, les pressions du système de financement, de promotion et de reconnaissance.

Cette ligne de conduite, qui rappellera à tous le caractère profondément social de l'activité scientifique, nous forcera à débattre plus ouvertement des faits et des données plutôt que de recourir à l'appel à l'autorité et au consensus scientifique. Ça ne réglera pas tout, bien sûr, mais cela permettra peut-être de mieux faire comprendre le processus scientifique et, ainsi, de repousser au moins légèrement les avancées de la pseudoscience.

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PREDATORY JOURNALS THREATEN THE INTEGRITY OF SCIENCE

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"Greetings for the day! We wrote to you previously, but you have not responded. You're invited to submit your manuscript to a journal [insert topic entirely not related to the work you do], and if you send us your paper now, we will publish it within 4 days. Your paper will be peer reviewed quickly and our journal has a very high Index Copernicus Impact Value. We are impatiently waiting for your response."

Researchers unacquainted with the term "predatory journal", may none the less experience e-mail solicitations like the (fictitious) example given above multiple times a day. These e-mails are sometimes quite non-sensical and can be riddled with spelling and grammar errors. Other times the solicitation e-mails are more professional, grammatically correct, and even mention legitime work the recipient has recently published. We know that even senior scientists can be duped by these types of predatory journal invitations [1]. In what follows, we discuss our program of research on predatory journals and provide a commentary on what predatory journals are, what actions we feel could be taken to stop them, and a discussion of the consequences of not addressing predatory journals. Efforts to understand and address predatory journals extend well beyond considering their e-mail solicitations. Indeed, addressing the challenge of predatory journals relates to a broader effort to improve the reporting quality of research, and to ensure research is transparent, reproducible, and useable [2-4].

WHAT IS A PREDATORY JOURNAL? REACHING A CONSENSUS DEFINITION

As part of a line of research addressing predatory journals, we recently worked with an international team including researchers, librarians, funders, publishers, and patients to develop a consensus definition of predatory journals. Without agreement within the scholarly community on the definition of a predatory journal, or how to characterize predatory journals, it is difficult to study the phenomenon. An agreed definition also serves as a starting point to develop educational outreach and support tools. In the absence of a definition we have seen the problems that can result. Consider a recent study one of us (DM) was involved in which systematically reviewed checklists to detect predatory journals. Checklists, often produced by librarians, provide 'red flags' to look out for when selecting a journal. Such lists have obvious appeal, but the study found that there were a total of 93 unique checklists available in the published literature, on library websites, and even on YouTube [5]. Multiple and competing lists create confusion for those looking for guidance. These findings illustrate the need for a consensus definition to develop standardized educational resources. A consensus definition is also a necessary starting point to craft meaningful publication policies that can be implemented and audited.

The consensus definition reached was: "*Predatory journals and publishers are entities that prioritize self-interest at the expense of scholarship and are characterized by false or misleading information, deviation from best editorial and publication practices, a lack of transparency, and/or the use of aggressive and indiscriminate solicitation practices*. [6]"

This definition built upon a few other studies we were involved in. The first was a scoping review of the literature on predatory journals. There are many opinion papers about predatory journals, but little of the discussion on this topic is evidence-based. Through a systematic search we identified 334 articles discussing predatory journals, of which just 38 described research studies. Using only the empirical studies, we derived a corpus of potential characteristics of predatory journals. In total, we found 109 unique characteristics, some of which were in direct conflict. For example, we extracted the following three conflicting journal characteristics: Journal article processing charges (APCs) clearly stated"; "Journal does not specify APCs"; and "Journal has hidden APCs or hidden information on APCs" [7]. As is the case with the

SUMMARY

This paper addresses the impact of predatory journals on the integrity of science. We outline our Centre for Journalology's recent collaborative program of research to define predatory journals, and map solutions to addressing the problems they create. We discuss stakeholders impacted by predatory journals, including the public.

abundance of online checklists to identify predatory journals, this study illustrates the inconsistency in research-based descriptions of what characterizes a predatory journal.

With a synthesis of the literature conducted, we felt it cogent to present the results of this work to a broad group of stakeholders. To do so, working with a team of colleagues, we organized an international 2-day summit meeting on predatory journals. In preparation for this meeting, we conducted a Delphi survey [8] in which we surveyed summit attendees, as well as additional stakeholders, about predatory journals. This was done in an effort to narrow down potential characteristics as we worked to establish a definition. Our survey contained 18 questions and 28-sub questions, and we required 80% agreement on an item to consider consensus among the group to have been reached. The final round of the Delphi survey was conducted in person at the Summit, and ultimately led to the consensus definition stated above. An important point to stress with respect to the consensus definition developed is that it does not specify that predatory journals use a particular publication model. Some researchers confuse open access publishing with predatory publishing. While it is true that many predatory journals take advantage of the open access publication model, where it is common for journals to take in fees for accepted articles, it is conceivable for a journal to meet the definition of being predatory using another publication model.

MOVING FORWARD WITH A DEFINITION

Now that a consensus definition of predatory journals has been established, we need to operationalize the definition in a way that is meaningful and practical for the research community. We will need to agree upon the metrics used to represent the four characteristics: (1) false or misleading information; (2) deviation from best editorial and publication practices; (3) a lack of transparency, and (4) the use of aggressive and indiscriminate solicitation practices. It may be that multiple measures are combined for each of these four characteristics, and that we could create a composite overall score for a given journal. Some characteristics will be easier to assess than others. For example, the fourth characteristic 'use of aggressive and indiscriminate solicitation practices' may not be easy to measure when viewing a journal website but may be a useful characteristic to consider when you receive an e-mail invitation to submit an article from a journal, such as the one at the beginning of this paper.

An interesting challenge in operationalizing the four agreed characteristics of predatory journals is that even journals considered to be legitimate and of high quality tend not to operate particularly openly or transparently. For the most part editorial and peer review still takes place in a black box. While some journals have adopted an open peer review system where authors and reviewers are known to one another and reviews are posted alongside the published paper, this is unfortunately not the norm. Further, there is little transparency, even at journals that post reviews with published work, about the decision-making and review process related to work that the journal rejects. Changes in the scholarly landscape are in an ongoing flux; as change occurs, the metrics used to assess predatory journals, and the consensus definition itself, will require reviewing.

In addition to agreeing on a consensus definition of what a predatory journal is, attendees at our Predatory Journal Summit created a roadmap of actions they agreed would be useful in addressing predatory journals. Actions include a 'one-stop-shop' website of resources on predatory journals. This would host materials such as summary documents of the definition, educational resources, policy guides, and non-technical summaries. In recognition of the global nature of the threat, and the importance of raising awareness and educating a diverse group of scholars, where possible translations of all resources developed and hosted in the one-stop-shop will be created. We are also working to develop a digital journal authenticator tool. Our vision for this tool is that it could be downloaded as a plug-in, and that when a user is viewing a journal website, they could click on the tool to obtain information about it, and whether it meets the consensus definition of 'predatory' or not. To develop the tool, we would employ a user-centered design strategy, in which stakeholders work interactively to develop a tool that meets their needs [9,10]. Our hope is that this tool could safeguard researchers and members of the public, as well as other stakeholders, from interactions with these journals and the low-quality information they may contain.

A NOTE ON JEFFREY BEALL AND ON PREDATORY JOURNAL LISTS

The term "predatory journal" was coined by Jeffrey Beall. Beall, who worked as a librarian at the University of Colorado-Denver, identified dubious journals in the scholarly landscape that he felt preyed upon researchers in an effort to make money from publishing their articles. He subsequently began curating a list of suspected predatory journals and a list of suspected predatory publishers on his personal blog website [11]. Beall played a significant role in increasing awareness of predatory journals. We benefited from using Beall's lists in several of our research studies. However, Beall's lists faced several criticisms, including the methods he used to identify and evaluate journals [12]. Beall was also criticized for his bias towards journals from the global south which may have fewer resources to support publishing [12].

At first glance, the idea of a list of 'bad' journals to avoid is appealing. It provides a practical tool for stakeholders, such as researchers, to reference when selecting a journal to publish in. In practice, we can't see how such lists would ever substitute for direct journal evaluation. One concern is that journal practices change over time, another is that new journals are created all of the time. How would a list of supposed legitimate journals respond to these temporal changes? How would new journals, which are often not indexed, even be identified? It would seem

that as soon as a 'bad' journal list was created, that it would need updating. A study by Strinzl and colleagues [13] showed that there was overlap between apparent lists of 'good' and 'bad' journals, and inconsistency within various 'good' and 'bad' lists. Based on these and other concerns, we favor the development of the aforementioned journal authenticator tool as a means to identify predatory journals.

WHAT ARE THE CONSEQUENCES OF FAILING TO ADDRESS PREDATORY JOURNALS?

The advent of predatory journals has created a novel threat to the integrity of science. This threat mirrors related societal concerns about the nature of truth such as uncertainties about the production and impact of 'fake news'. Predatory journals sow confusion and draw scrutiny on the scientific system itself. The analogy of an evolutionary arms race is appropriate: as stakeholders impacted by predatory journals adapt to thwart their impact, the self-interested predatory journals create counter-adaptations. The threat is discipline agnostic. While there may be nuances in natural sciences that differ from our own area of biomedicine, we feel that a concerted action to address the overall phenomena is the best way forward. For example, physical sciences have a long history of use of preprints; in medicine this practice is only really beginning. With implementing preprints in medicine, there may be unique ethical considerations not pertinent to physical sciences, such as considerations of potential harms to patients related to disseminating unvetted health research. We can nonetheless learn from actions taken across various disciplines to recalibrate and challenge existing norms in publishing in order to take actions that promote responsible scholarly communication. Addressing the problem of predatory journals will require funding to understand how the journals operate and who publishes in them. Work we and others have conducted surveying authors who have published in predatory journals suggests diverse motives, and diverse experiences among authors of presumed predatory articles [14,15]. Collaborative efforts to develop and implement standardized tools, resources, and policies need to be undertaken.

Failure to address predatory journals means they will continue to erode the integrity of scholarly publishing. The impact of predatory journals is multi-faceted and effects diverse stakeholders [16]. From a researcher perspective, predatory journals pollute the scholarly landscape with journals and articles that are unlikely to meet expected best practice standards. This requires additional effort from researchers to carefully vet journals they are considering submitting to, or articles they are considering reading, using, peer reviewing or citing. The onus should be placed on genuine journals and publishers to increase their transparency and practices to facilitate journal evaluation. Errors in journal assessment contribute to waste and inadequate communication. This issue is of a global nature: counter to the prevailing view that predatory journals are a problem only in lower income nations, work we conducted with colleagues suggest that researchers all over the world are publishing in predatory journals, including in high income nations [17]. A recent preprint reported that predatory journals tend not to be cited as much as legitimate journals [18]. Based on their analysis the authors concluded that predatory journals therefore have very little impact. This conclusion is problematic for a number of reasons. Though we would not expect predatory journals, which are not always indexed, to obtain as many citations, this is a poor assay to their overall potential impact. Further, when legitimate work ends up in predatory journals [1], if it is not found, read, and cited, this contributes to publication bias.The conclusion that predatory journals have little impact based upon low citations also fails to consider how stakeholders beyond researchers are negatively impacted by predatory journals. For example, funders presumably do not want to support work that ends up in predatory journals. This work is unlikely to be optimally disseminated as it is often not indexed. This contributes to fiscal waste, often paid from tax dollars. We anticipate that the amount of money that is spent on conducting and publishing work in predatory journals will continue to increase unless actions are taken to stop predatory journals. When one considers spending globally, this is not an insignificant amount of money. An estimate from Italy suggest that about 5% of Italian scholars CVs contain predatory publications [19].

Like funders, research institutions presumably do not want to promote publishing in predatory journals. However, if institutions consider number of publications as a metric in hiring or promotion, they may inadvertently reward predatory publishing. Some institutions require a minimum number of publications as part of doctoral training. This is increasingly recognized as a perverse system that results in predatory publishing and that does not support high quality research [20]. Ongoing reconsideration of the system of rewards and incentives used in academia is an essential action to minimize publications in predatory journals. If metrics like transparency, reproducibility, and reporting quality were valued in academia, predatory journals would be less attractive to those knowingly publishing in these outlets.

Finally, and perhaps most importantly, predatory journals have the potential to create negative consequences for the public. In our own area of biomedical research, there is the potential for unvetted predatory journal publications to end up in the hands of the public, or their care providers, and for them to use this information to inform health care decisions [21]. As researchers we feel we have the responsibility to make research openly available and accessible to the public and to communicate the issue of predatory journals. Our experience including patient partners in our research on predatory journals has very much enriched our perspective and approach to measuring and addressing this phenomenon. More broadly, predatory journals may negatively impact the public's perception of science or lead to questions about the scientific system itself. Predatory journals may contribute to the misinformation that leads portions of the public to express skepticism towards science.

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WHAT'S THE HARM IN EMBRACING PSEUDOSCIENCE?

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SUMMARY

Pseudoscience can appear harmless to the casual observer, but it tends to harm the people who buy into it both financially and physically.

When I'm interviewed by journalists on the topic of pseudoscience, I am inevitably asked some version of the question, "but what's the harm?" The journalist here is doing their job in getting me to communicate to the public that this nonsensical intervention is not without risk. But many people not particularly interested in whatever bit of pseudoscience I am criticizing will lob the same question at me in a rhetorical manner. "If people want to try it", I will essentially be told, "they're free to do so. Why should you care?"

While freedom of choice should be defended, these choices need to be well informed. When they are contaminated by misinformation, it's the consumer who ends up paying the price. Combatting pseudoscience thus has a strong consumer protection angle. There are people out there, either deluded or manipulative, ready to sell the masses on game-changing technology, ancestral knowledge, and cure-alls based on little more than powerful testimonials and cherry-picked data. And this pseudoscience is never harmless.

PSEUDOSCIENCE HARMS YOUR WALLET

Fifteen years ago, I consulted a chiropractor. I was under the impression back then that a chiropractor was a medical doctor who had specialized in back care. That is not the case [1]. Suffice to say that none of the sessions I had were free. I had to pay for the initial X-ray, which inevitably revealed a "chiropractic subluxation" (a fictional change in your spine that actual radiologists can't see... because it's not there); I had to pay for the frequent acute care sessions I was told I needed; and I then had to pay some more for "maintenance" sessions. We wouldn't want that spine to get back out of alignment, would we? It turns out that the mild, temporary benefit I was gaining from these sessions was entirely due to the pre-back-cracking portion of the intervention when I was laying down with a hot compress around the painful area. When the chiropractor personally called me to know why I hadn't booked a new appointment, I told her I could do the laying down and the heat at home for free. She was not happy.

Because the idea of wellness is particularly trendy these days, an impressive industry has been built to offer products, services, books, apps, and interventions to allegedly make you happier and healthier. Hollywood actress Gwyneth Paltrow is now infamous for starting a wellness brand called "goop" and selling porous vaginal jade eggs under the pretense of aspirational living and female empowerment. These eggs and their pseudoscientific siblings (a medicine bag full of rocks, crystals in water bottles, books written by a guy who claims to be receiving medical information from a supernatural spirit from the future), they cost money.

There are even more insidious ways of losing money on unproven wellness gimmicks. Some essential oil companies function as multi-level marketing operations. They recruit people to buy their product, sell it, and recruit more people under them, who will themselves recruit more people. While promises of lavish lifestyles are flaunted quite liberally, it turns out that 92% of the sales force for one such essential oil company, Young Living, makes on average $1 a month [2]. But because they have to buy the products they are selling, and because there only so many potential customers out there, they all lose on average a little over $1,000 [2].

The wellness industry alone is worth 4.5 trillion dollars [3]. Someone has to pick up the tab.

PSEUDOSCIENCE HARMS YOUR PHYSICAL HEALTH (AND CAN SOMETIMES KILL YOU)

Makayla Sault was 11 years old when she died. She had a type of cancer known as acute lymphoblastic leukemia, and her chances of survival were estimated at 72-75%... with chemotherapy. But the treatment was putting a strain on her body, and a naturopath by the name of Brian Clement, who operates a pseudoscientific health resort in Florida, came to talk to her community in Ontario about the evils of medicine and why they should instead embrace a raw vegan diet to cure cancer. So Makayla stopped chemotherapy and her parents paid thousands of dollars to fly to Florida to receive these alternative "treatments". She eventually died of a stroke a few months later [4].

Vulnerable people dealing with acute and chronic illnesses make for ideal prey. Turning to tempting, unproven and often disproven pseudoscientific "remedies" often means delaying proper medical treatment, which has real consequences on our health. Even when the modality is termed "complementary" (meaning that it's meant to accompany proper medical treatment and not replace it), there is some evidence (in a fairly small study so far) that it does lead to delaying medical interventions [5]. How? For example, a patient may decide to get surgery for their cancer and complement it with a pseudoscientific intervention, but *also* refuse the chemotherapy that is recommended. Thus the pseudomedical intervention would be labelled "complementary" to the surgery, but it is in fact an alternative to chemotherapy. And these patients, on average, tend not to survive as long.

The pseudoscientific interventions themselves can also be responsible for directly harming the body. Ear candles can cause burns and perforations inside the ear [6]. Herbal products have been implicated in heavy metal poisoning and kidney and liver damage due to adulteration and accidental contamination [7]. And the swift neck rotations performed by chiropractors have been associated with a number of cases of physical injury, mostly through the tearing of an important blood vessel in the neck which can be lethal [8,9].

There has also been a clear worldwide rise in parents declining vaccination for their children or choosing an "alternative vaccination schedule" that is not evidence based, and this growing movement is fed in large part by the pseudoscience of anti-vaxxers, who have found kinship with alternative health practitioners such as homeopaths and chiropractors [10-12]. Falsehoods such as "the measles-mumps-rubella vaccine has been linked to autism" and "children are receiving too many vaccines, too soon" spread like uncontrollable fires on social media and give a legitimate-looking anchor to the fears of new parents. For these reasons, vaccine hesitancy was named one of ten threats to global health in 2019 by the World Health Organization [13].

Even innocuous-looking pseudosciences like homeopathy — essentially the sale of sugar pills to treat any condition — carry risks to physical health. Many homeopaths have embraced an alternative to vaccines called "nosodes" in which diseased tissue, blood, feces, urine, or a respiratory discharge is diluted theoretically out of existence and sold as an all-natural immune booster. Embracing these preparations leaves children vulnerable to acute infections like mumps, rubella, and whooping cough.

THERE IS VALUE IN TRUTH

Believing in pseudoscience can be clearly harmful to you in very practical ways, but there's also a more philosophical reason for wanting a bit of light in the darkness: there is great value in believing true things. The universe does not care about your beliefs and opinions. It simply exists according to rules that we can begin to understand using the tools of science. I found it personally enriching to walk out of the darkness of intuition and supernatural thinking and to find the guiding light of science to show me the wonders of our world. The more we understand the universe, the better prepared we will be for its quirks. We are free to believe whatever we want, of course, but at the end of the day, if we think sugar pills and mystical energy transfers will save us, the universe will still kick us in the rear.

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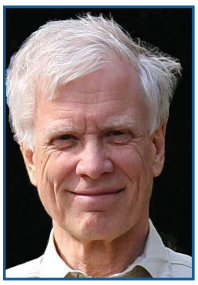
PARAPSYCHOLOGY: THE SEARCH SCIENCE LEFT BEHIND

BY JAMES E. ALCOCK



Direct mind-to-mind, "extrasensory," communication with others no matter where they are in the world (telepathy). Seeing the future before it occurs (precognition). Moving an object simply by wishing it (psychokinesis). Changing the present by going back in time to modify the past (retro-psychokinesis). Improving task performance today by practising tomorrow (retro-causality). Leaving and returning to one's body (out-of-body experiences). These and other putative "paranormal" (or "psi") phenomena are the subject matter of parapsychology.

Parapsychologists consider themselves scientists conducting careful investigations of mind-matter interactions, and indeed, formal parapsychology has many of the features of normal science: professional organizations, journals and conferences; a large research literature; researchers with doctorates in traditional scientific fields; and courses offered in a few universities where some even award PhDs [1]. Moreover, a number of distinguished scientists have been involved in parapsychology across the decades, among them physicists Sir William Crookes, David Bohm, Robert Jahn (former Princeton University Dean of Engineering) and Nobel laureates Lord Raleigh, Wolfgang Pauli and Brian Josephson. Josephson turned to string theory to explain extrasensory perception (ESP) in terms of shared 'thought bubbles' generated out of a mental vacuum state [2]. However, it is important to note that none were drawn to the study of the paranormal by theoretical considerations or observations or anomalies emerging from their work as physicists. And just as important, none were trained to deal with the complexities and pitfalls of conducting research with human subjects.

Yet, even though parapsychologists have many times produced what they consider to be confirmatory evidence, they have never persuaded the larger scientific community that their phenomena actually exist. To understand this impasse, one must go back to the beginnings of modern science and its rejection of supernaturalism.

SUMMARY

Parapsychologists claim to have established the reality of paranormal phenomena. However, because of fundamental problems with theory, methodology, and data interpretation, and the inability to provide a single demonstration replicable by neutral scientists, it is no more worthy of scientific status now than when science rejected it a century ago.

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THE RISE OF MODERN SCIENCE

Belief in the supernatural has played an important role in every civilization throughout history. In medieval Europe, God, heaven, soothsayers, witches, astrology, curses and charms were all part of a common worldview. At the same time, dogma, both sacred and secular, was generally accepted without challenge, and philosophers philosophized through logical analysis unencumbered by the constraints of actual data. It was in this context that modern science took its first steps in the 16th century when Copernicus' heliocentric model, supported by data gathered by Galileo with his crude telescope, ultimately triumphed over the geocentric pronouncements of Aristotle, Ptolemy and the Roman Catholic Church. This ushered in a new approach to understanding nature in which systematic observation and logic were used to form theories which were then tested against data, with anomalous data playing the role of disruptor [3]. The 1687 publication of Isaac Newton's *Philosophiae Naturalis Principia Mathematica* went a step further, demonstrating that there is a logical order to the world and that complex phenomena can be described in precise mathematical language corresponding with observation [4].

As modern science continued to develop, supernaturalism in its many forms — deities, discarnate spirits, mind-body dualism — was gradually expunged, resulting at times in pitched battles with religious orthodoxy. Science and organized religion eventually reached somewhat of a truce (although one might wonder, given contemporary efforts to ban the teaching of evolution from biology classes in some parts of the United States). Parapsychology is a remnant of the breakup between science and supernaturalism; its persistence reflects a continuing effort to demonstrate that "mind" can act independently of the brain and does not necessarily extinguish with the dying of the flesh.

SCIENCE AND THE PARANORMAL

Scientific discoveries in the 19th century, Darwin's theory in particular, challenged biblical truths about the centrality of human beings in creation, and this roiled the minds of many scholars who had been reared with religious beliefs. Two paths diverged in the wood, but which to follow? Religion with its recognition of the soul and

post-mortem survival, or the materialistic, soulless, worldview offered by science?

The Society for Psychical Research (SPR) offered a middle road. It was launched in England in 1882 as a *scientific* organization dedicated to the exploration of paranormal phenomena and post-mortem survival. Its formation was very timely, for the Spiritualist movement was in its heyday, producing startling demonstrations of apparent communication with the dead that called out for serious appraisal. There was nothing particularly unscientific at the time in subjecting these reports to scientific scrutiny. After all, this was an era of astonishing discoveries of previously undetected energies, such as Roentgen's X rays, Hertz's radio waves, and Becquerel's radioactivity, and it was conceivable that other as yet undiscovered energies could account for mediumistic communication, telepathy, psychokinesis and other paranormal events.

The SPR was attractive to those who, like its founding president Cambridge philosopher Henry Sedgwick, were disillusioned with the mythological aspects of religion and yet distressed by the implications of the materialistic scientific worldview. (This conflict was experienced by other prominent figures in parapsychology down through the years, including Joseph Banks Rhine, the "grandfather of American parapsychology." Rhine viewed finding proof of telepathy as a stepping-stone towards proving the existence of the soul). Rather than standing in opposition to science, parapsychologists sought to operate *within* science. Thus, one foot in empiricism, the other in supernaturalism, parapsychology has from the beginning sought a sort of "secular" soul unfettered by mythological deities and demons.

The SPR began its work with the analysis of accounts of paranormal experiences, but anecdotal reports prove too unreliable to be useful, for whenever they could be checked against objective information, the errors of memory were obvious. Similarly, studies of mediums and other supposedly "gifted" individuals failed, most often because the individuals were caught cheating. In the 1930s, the obvious weaknesses of such naturalistic evidence pushed parapsychologists, led by Joseph Banks Rhine, into the laboratory in the hope that science — and the methodology of experimental psychology in particular — could finally establish the reality of paranormal phenomena.

However, because parapsychologists claim that paranormal influence cannot be blocked in any way, the use of traditional control groups is not possible. In their place, success in guessing experiments is compared with what would be expected by chance alone. A significant deviation, either positive or negative ("psi missing") is taken as evidence of paranormal influence. However, to automatically consider the cause to be paranormal is unjustifiable; statistical significance is silent as to its cause and one cannot distinguish between the effects of paranormal processes, flaws in the methodology, or even the intervention of some hypothetical deity.

What was gained by the move into the laboratory? Increased control over experimental conditions and data collection. What was lost? The emotionally-compelling and seemingly paranormal personal experiences that intrigued so many people were replaced by monotonous guessing tasks, with success determined by statistical deviations from chance expectation. And at the same time, parapsychologists had climbed onto a one-trick pony, seeking only evidence of the paranormal while ignoring psychological and neurological research into perception, memory and consciousness related to how such experiences can be understood in terms of normal brain processes [5]. Nonconscious cues, automatic causal associations, the distorting effects of coincidence on information processing, the influence of emotion on cognition, the inability of the conscious brain in certain circumstances to distinguish between information from the outside world and information arising from parts of the brain itself — such influences are likely at some time in each of our lives to produce powerful and strange experiences that seem paranormal.

PARAPSYCHOLOGY'S FAILED QUEST

Although parapsychologists strongly reject this conclusion, their efforts to find scientific evidence of paranormal phenomena over the past 150 years have been a dismal failure, and the evidence for the paranormal is as unconvincing now as it was in the 19th century. No reliable data have been produced. No consistent pattern of research findings has emerged. No well-articulated theory has been developed. And while every area of normal science shows progress over time — constructs, methods and procedures are refined, and effect sizes grow as a result of improved methodology — no such advancement has occurred. Methods once proclaimed to have demonstrated the reality of the paranormal have since been abandoned as inadequate. New methodologies emerge, often every decade or so, promising the long-awaited breakthrough, until they too eventually prove futile. Guessing tasks involving decks of cards and dice-rolling machines are replaced by random event generators driven by electronic noise or radioactive decay; or participants are placed in a sensory deprivation situation assumed to isolate the brain from extraneous sensory stimulation, supposedly improving the capability to respond to paranormal influence. Whatever the methodology, the goal of establishing the reality of paranormal is never reached. And while meta-analyses have become popular in recent years, they cannot overcome the methodological weaknesses of the studies upon which they are based.

There are a number of important reasons why parapsychologists' evidence has failed to persuade mainstream science [6]:

Negative definition of phenomena: Unlike any area of normal science, putative paranormal phenomena are only *negatively* defined: they are said to be observed only when all normal explanations can be ruled out. However, one can never be certain that all normal explanations — methodological shortcomings in

particular — have been identified and eliminated. In addition, constructs are so poorly defined that parapsychologists admit that they cannot always distinguish between them. For example, an event supposedly *foreseen* through precognition may have instead been *caused* by psychokinesis.

No limits, no boundaries: Parapsychologists inform us that paranormal influences are pervasive, unstoppable and have no limits. No physical means has ever been found to influence or block them. People cannot simply switch their ability on and off for the benefit of researchers, for paranormal processes can continue to act subconsciously. The effects can apparently manifest themselves just as strongly across tens of thousands of miles as across a room and operate backwards or forward in time as well. Their successful use requires no effort or training, nor even knowledge of a target or its location. And such powers can be wielded not only by humans but by animals and insects as well.

When *nothing at all* appears to modulate statistical deviations from chance in what are essentially guessing tasks, this suggests that there is no phenomenon to be studied, that these statistical "successes," unaffected by situation or context, are what one might expect if they are simply due to methodological flaws [7]. And methodological weaknesses there are aplenty.

Methodological weaknesses. Despite the determined efforts of some researchers, methodological weaknesses continue to plague parapsychological research. Given the very small effect sizes produced over what is typically a very large number of trials, even minor methodological flaws are capable of producing significant departures from chance.

My own detailed analysis of a wide range of parapsychological research reports (including virtually all of that conducted by physicists Helmut Schmidt and Robert Jahn [8]) has not found any study free of important methodological flaws. And then there is the recent publication in a mainstream psychology journal of a major paper by Daryl Bem [9] reporting experiments trumpeted by many as clearly demonstrating the reality of the paranormal. This research was so riddled with blatant methodological flaws that it established nothing except the mystery of why it was ever accepted for publication [10].

The critic is often asked how one can be so critical if one has not carefully analyzed whatever is the very latest research paper. However, to examine each new research paper is extremely time-consuming and, even then, there is often insufficient detail to allow for the detection of methodological flaws and weaknesses. For example, a series of studies on "remote viewing" (a variant of telepathy) conducted by physicist Russell Targ and engineer Harold Puthoff [11] was presented as confirmatory evidence of paranormal phenomena. Weaknesses in the procedure were not evident in the paper itself, and it was only several years later that information was obtained that exposed methodological flaws so serious that they later were shown to account for the reported paranormal effects [12].

Lack of replicability: Unlike any other research area deemed to be scientific, parapsychologists have never been able to provide even a single demonstration of a paranormal phenomenon that is replicable by neutral scientists. Undaunted, this huge failing is explained away in terms the *psi experimenter effect*, a convenient feature of the paranormal. If a neutral scientist cannot replicate a paranormal effect, this failure is attributed to the scientist, for it is claimed that any lack of confidence or any skepticism about the reality of the phenomenon interferes with its manifestation. Some go even further and suggest that ". . . *the nature of the phenomenon may be intrinsically unsuitable for detection under controlled conditions* [13]." The claim that outcomes are influenced by the attitudes and wishes of the researchers should be reason enough to conclude that parapsychology, whatever it is, is not a science.

Moreover, this lack of replicability increases vulnerability to fraud, allowing it to go undetected much more easily than in normal science. And fraud is a significant problem for parapsychology. One recent example: one quarter of the papers in a large meta-analysis [14] supposedly claiming to demonstrate paranormal influence, were authored by a parapsychologist who had earlier been caught red-handed with doctored data [15,16].

Lack of theory: Not only has parapsychology failed to produce reliable data, it has developed no coherent theory of its own. However, parapsychologists are drawn both to the "spookiness" of quantum mechanics [17] and the counter-intuitiveness of relativity theory in the hope that they will provide justification for paranormal claims. The Heisenberg uncertainty principle is taken to indicate that the mind of the observer interacts with matter directly, in line with parapsychological claims. Simultaneity in the theory of relativity is interpreted as allowing effect to precede cause, thereby enabling precognitive abilities. And it has been argued that the fundamental laws of nature do not have a preferred direction of time, and so this too allows for perceiving the past and the future with equal ease. Quantum entanglement and non-locality are interpreted to allow that information can be instantaneously transmitted from one part of the universe to another, as is claimed for telepathy. Such theoretical adventures can seem tantalizingly impressive, especially to the non-physicist, and the gainsaying of these claims by mainstream physicists falls upon deaf ears.

Wisdom dictates that before trying to explain a phenomenon, one should first be sure that there is a phenomenon to explain [18]. In the absence of reliable evidence of the paranormal, seeking theoretical explanation is at the very least premature. But this is not the kind of prematurity that can trigger a scientific revolution, for the "anomalies" of which parapsychologists speak never present themselves to anyone but parapsychologists.

Another strike against parapsychology is its failure to jibe with science at large. There is nothing in physics that violates the basic principles of biology. The science of genetics is not inconsistent with chemistry. Neurological findings do not conflict with physics. Parapsychology, on the other hand, is completely inconsistent with well-established principles in other areas of science. In fact, as psychologist Arthur Reber and I [19] have pointed out, paranormal phenomena are impossible if the current scientific worldview is correct. For example, paranormal phenomena apparently pay no heed to the laws of thermodynamics, given that minute biological brain activity supposedly can, through psychokinesis, bring about movements in physical objects that require significant amounts of energy. Further, parapsychologists claim both that distance has no effect on either telepathic transmission or psychokinetic processes, and that some currently nonexistent future state can physically influence the brain of a participant in a precognition experiment. (We recognize that scientists are often uncomfortable with describing the paranormal as "impossible," and yet there is no such discomfort in regard to the impossibility of perpetual motion machines, or the "memory" of water in extremely highly diluted homeopathic preparations, or chemicals that convert lead into gold, or levitation during transcendental meditation).

And then there is the gross incompatibility with neurology and psychology. As one example, verbal communication is an extremely complex process mediated by a number of centres in the brain. Its mastery requires years of learning, and damage to any of the components of this complex system results in serious degradation. Telepathy apparently requires no such apparatus or training. And while deterioration in your functioning can lead to the disintegration of memory and personality associated with dementia, parapsychologists argue that "mind" is able to separate itself from the physical brain altogether and fully experience the world as though all of the brain's sensory and cognitive functions are intact.

Such "impossibility" does not trouble parapsychologists, for as has been noted:

> *"... parapsychology remains tied to its historically conditioned adversary relationship with the natural sciences ... Achievements in the field therefore are important just to the extent that they are incompatible with, and as a result have revolutionary implications for, the modern scientific world picture."* [20]

THE SEARCH GOES ON…

Science turned its back on parapsychology because of lack of evidence that its subject matter is real. Physicists in the course of their normal research using ultrafine measurements of extremely delicate phenomena never report "paranormal" anomalies, nor are such anomalies predicted by physical theory. Why then does the search for the paranormal survive when searches for other questionable phenomena end for lack of evidence? No modern scientist pursues alchemy. Phrenology, a supposed science based on measuring mental traits by examining bumps on the skull, died away for lack of empirical evidence. Interest in ether as the medium in which light is propagated dwindled away following Michelson and Morley's failure to find supportive evidence. Yet, parapsychology continues.

Convinced that their phenomena are real, parapsychologists consider their research pursuits to be true to scientific ideals and feel ill-treated by the rejection of their claims by the supposed gatekeepers of scientific righteousness. They belong to a passionate community of like-minded researchers who share the reassuring perspective that minds and personalities are much more than mere epiphenomena of brain function that will vanish with the dying of the flesh. They are not flummoxed by the failures and inconsistencies in their research but instead explain them away in terms of ad-hoc effects. They are undeterred by criticism, even when it is from initially supportive colleagues. Consider this: A century ago, several distinguished experimental psychologists, after failing to find persuasive evidence of psi phenomena despite significant investments of time and effort, left the field, concluding that the phenomena do not exist. This had no impact on other researchers and their failures to find evidence were explained away. And in recent times, when physicist Stanley Jeffers [21] abandoned parapsychology after his failed attempts at replicating physicist Robert Jahn's paranormal findings (with Jahn's cooperation and support), this too had no impact on the field, and his failures were also explained away. And when psychologist Susan Blackmore, once a leading and highly valued parapsychologist, left the field after coming to doubt the existence of paranormal phenomena, this too had no effect. Instead, her credibility was questioned.

As a result, the parapsychological belief system is virtually unassailable, and parapsychology in one form or another is likely to endure, for it is belief in search of evidence rather than data in search of explanation [22]. New methodologies will be applied; fresh attempts to link the paranormal to quantum mechanics or other physical theories will be made; further claims of confirmatory evidence will be issued; and the quixotic quest will continue to capture the interest of a small number of dedicated researchers who strive to revolutionize science through their efforts. And their claims will continue to resonate with much of the public who, unaware of the myriad ways in which their own brains sometimes produce seemingly inexplicable experiences, find a paranormal explanation preferable to no explanation at all. *Plus ça change, plus c'est la même chose.*

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ASTROLOGY FOR THE PHYSICIST

BY IVAN KELLY, GEOFFREY DEAN, AND DON SAKLOFSKE

To an astronomer or physicist the stars and planets are balls of plasma, gas or rock with interesting physical properties. For example Venus is both our nearest neighbour and the nearest thing to hell, with the solar system's thickest (90 bars) and hottest (470 ºC) atmosphere of mostly carbon dioxide laced with sulphuric acid. They can also be a source of beauty and wonder (think of Saturn's rings or the Crab nebula's crab-like filaments). But the one thing they definitely don't have is a particular meaning. No astronomer or physicist can look through a telescope and believe that Venus is harmonious, Mars is martial or Jupiter is jovial.

But to an astrologer it is the other way round. The only thing that matters is not physical properties but *meaning* based on metaphor and mythology. No astrologer can look at a birth chart and not see Venus as harmonious, Mars as martial or Jupiter as jovial [1].

AS ABOVE SO BELOW

In antiquity astrology and astronomy were lumped together into judicial astrology (judging the future) and natural astrology (evaluating heavenly bodies). In due course the former became today's astrology and the latter became the science of astronomy and astrophysics.

Today's astrology rests on the classical occult idea that events in the visible world are a reflection of events in the unseen world. More specifically, whatever is born at a particular moment, be it a person, dog, event, nation, company or question, will manifest the quality of that moment, which can be conveniently seen in the heavens. So there will be a correlation between the heavens and terrestrial affairs. Or *as above so below*.

In the spirit of political incorrectness we might ask why the heavens should in some mysterious way be ordered for our personal benefit. But in the centuries before the invention of telescopes the idea made perfect sense and was a central feature of man's intellectual and social existence.

SUMMARY

There are no known physical ways (gravity, magnetism, radiation) that astrology could work. But there are many psychological ways, all supported by empirical tests.

Whatever we may think of astrology today, it occupies a legitimate and important place in our history.

But right from the start astrology had its own problems. It was complicated, took a long time to learn (today just the basics takes a year part-time), fundamental disagreements were common, and calculating a birth chart was so time-consuming that large samples were impractical. So the hardest things to find in astrology were facts and clear outcomes. Anecdotes yes, facts no.

But the advent of home computers changed everything. Chart calculation and analysis were no longer a barrier to proper investigation. Dozens of charts could be calculated while you coughed. Judgement Day had come at last.

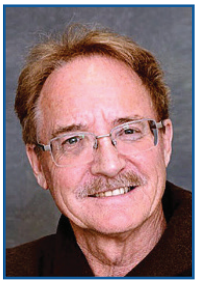
ASTROLOGY TODAY

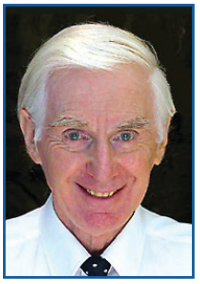
Sun sign columns are the most visible form of today's astrology because they are easy to commercialise — just follow the money. Critics rightfully dismiss them as nonsense; as do serious astrologers, albeit not as nonsense but because a birth chart (Fig. 1) contains so many factors that focusing on sun signs is like pulling tomato from a pizza and declaring it to be tomato pie.

But there is much more to astrology than sun signs. For the rest of us it can be entertaining, beautiful, dangerous, lucrative, or a load of codswallop. But always challenging, because half the population (more in Eastern countries) believes in it [2], skeptics deny it, vested interests distort it, and astrologers tend to disagree on mostly everything including what planets and which zodiac to use.

This challenging confusion exists in various forms from national astrological organisations in over 45 countries (in some of which conferences can attract a thousand people) to commercial practices and cosmic religions. It is the subject of over 100 periodicals, hundreds of websites, and about 3000 book titles in print of which about half are in English. In Western countries roughly 1 person in 10,000 is studying or practising serious astrology, of which roughly 1% make a living from it.

Important here is astrology's Golden Rule, the only rule that serious astrologers have ever agreed on, namely that all relevant factors must be weighted and combined before any chart is interpreted. But having agreed on the rule,





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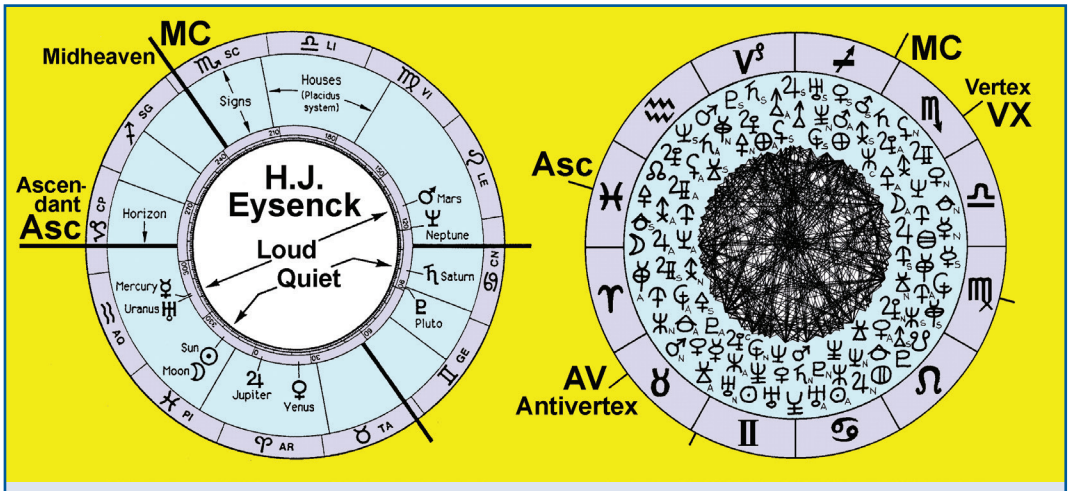

Fig. 1 Birth charts show the sky at the moment of birth. Left: psychologist H.J. Eysenck's with a traditional mix of chart factors (planets, aspects, signs, houses) plus our brief interpretation. Right: some of the modern factors seriously proposed for general use.

astrologers immediately disagree on how it should be applied and on what factors are relevant in the first place. Which then allows them to fit almost anything to any chart after the event, which is a feature they firmly deny but (as we shall see) controlled tests confirm.

MORE THAN BEING TRUE OR FALSE

Astrologers see that birth charts seem to fit the person or event (what matters is the fit, not whether it is better than a control or the result of artful selection), and are thus convinced that astrology works. Clients find the fit to be meaningful and helpful in understanding themselves and their lives, as in "his Mars on yours explains why you and your boyfriend get on" (or don't get on). So they invariably end up satisfied, which then reinforces the astrologer's belief that astrology works.

But notice how the client's satisfaction may merely reflect the undivided personal attention they are getting, so the chart may be working only as a means of changing the subject. So there may be more going on than meets the eye [3]. In other words (and this is the crucial bit) there is more to astrology than being true or false, which is a point missed by most critics.

For many centuries there was a tradition of defending astrology by physics [4] as in theories about rays emitted by different planets. Eventually it became clear that authentic physical phenomena — gravity, magnetism, radiation — could not defend astrology (if they did then scientists would have rushed to be the first to discover how it worked) whereas *as above so below* worked in unknowable ways that put astrology above criticism. To astrologers it was a valuable bonus.

Today they vigorously defend astrology despite having no clear idea about why it works. When in 2007 Liz Greene, a Jungian psychoanalyst and a famous leading astrologer, was asked by Danish ethnographer Kirstine Munk why astrology worked, she replied: "I really have no idea. I explain to a client how I am going to interpret a chart ... but why it works I don't think anyone knows. ... But this doesn't stop me from using it. I don't know why my car works either" [5].

Students of automotive engineering might wonder at this. As might students of psychology, who these days will know two very good reasons why astrology seems to work.

REASONS WHY ASTROLOGY SEEMS TO WORK

The first good reason is the many biases in thinking that people are normally unaware of (we call them hidden persuaders). They make astrology seem to work when in fact only hidden persuaders are working — astrology is merely a misdirection. Most were unknown before the rise of experimental psychology in the previous century, and they remain unknown to most astrologers in the present one. They are also surprisingly numerous. Here are just a few:

- Barnum effect *(reading specifics into generalities)*.
- Cognitive dissonance *(seeing what you believe)*.
- Confirmation bias *(remembering only the hits)*.
- Dr Fox effect *(blinding you with jargon as in this list)*.
- Illusory correlation *(seeing meaning where none exists)*.
- Immunity from disconfirmation *(nonfalsifiability)*.
- Social desirability *(I'm firm, you're obstinate, he's ...)*.

There are more than 30 others [6]. Each can create the illusion that astrology works, and all lead to client satisfaction.

The second good reason is the surprising range of excuses that can be called upon should an error occur. They include:

– Stars incline and do not compel.
– Birth time is unreliable.
– Client does not know herself.
– Potential shown is unfulfilled.
– The manifestation is untypical.
– Other factors are interfering.
– Astrologers are not infallible.

Which together *unfailingly* explain away all conceivable errors of interpretation. It means that astrology must always work even if all input data are wrong, which is why astrologers and clients are so easily convinced that astrology works (we say more about this later), and why astrologers could never learn from experience in the same way that repairmen could never learn to make repairs if faults could never be identified [7].

Other biases include artifacts of *astronomy* (sun spends more time in Cancer than in Capricorn), *demography* (monthly birth rates vary between and within countries), *age incidence* (selection by performance at a given age and date, e.g., junior ice hockey teams will tend to pick births longest at that age), and *data* (think of statistical variations). All have led to arguments about astrology.

A NEVER-ENDING SHOUTING MATCH

Astrology has always been a never-ending shouting match in which each side shouts from entrenched positions. Part of the conflict arises because astrologers usually judge astrology by how *helpful* it is, while critics usually judge it by how *true* it is, so they can reach opposite conclusions from the same evidence. The following examples show how little has changed:

Arguments attacking astrology

Few predictions are accurate. *Many are successful.*
Time twins do not lead similar lives. *Some do.*
Signs ignore precession. *Precession is not important.*
Tests are negative. *Better tests may be positive.*

Arguments defending astrology

Researchers are biased. *Many were astrologers.*
Has great antiquity and durability. *So has superstition.*
Extraterrestrial influences exist. *None are relevant.*
Astrology works. *Same claim was made for phrenology.*

Which side should we believe? Even after 2000 years and a literature too enormous for anyone to read in their lifetime (the largest astrology collections fill over 200 shelf-metres, internet book finders typically return over 1000 new or used titles in English and in stock), the arguments leave us none the wiser. But why have arguments when you can have tests?

A BITTER LESSON FOR CRITICS

As Jonathan Swift put it in 1720: "Reasoning will never make a Man correct an ill Opinion, which by Reasoning he never acquired" [8]. So critics are largely wasting their time if they challenge cherished but wrong beliefs. Once the human mind is made up it resists being confused by evidence. Nevertheless empirical tests have failed to find support commensurate with the often grandiose claims made by astrologers. Here the key word is *commensurate* – a useless effect size may be statistically significant but it is still useless. Yes, astrology may seem to work, but it comes from seeing faces in ambiguous clouds of never-ending chart symbolism, not from *as above so below*. The next three figures illustrate this point.

In Fig. 2 odd-numbered signs starting from Aries are said to be extraverted, the rest are said to be introverted. When the results of sun-sign-vs-extraversion studies are plotted (left), they seem to support this. But controls (right) show they are due to knowledge of astrology. Ask Sagittarians (said to be sociable and outgoing) a question related to extraversion such as "do you like parties" and astrology might tip their answer in favour of yes rather than no, and vice versa for Capricorns (said to be shy and solitary). The effect may seem like astrology but it has a non-astrological explanation. The mean effect size is uselessly small (0.062) but it has inspired psychologists to explore the effects of such knowledge on their own personality tests.

In Fig. 3 left, red dots show the effect size and sample size for 69 studies in which astrologers had to match birth charts to various objective criteria such as case studies, occupation, or responses to questionnaires. Light blue circles simulate the astrologers in each test making 100 judgements at random, so each red dot has 100 light blue circles at the same sample size

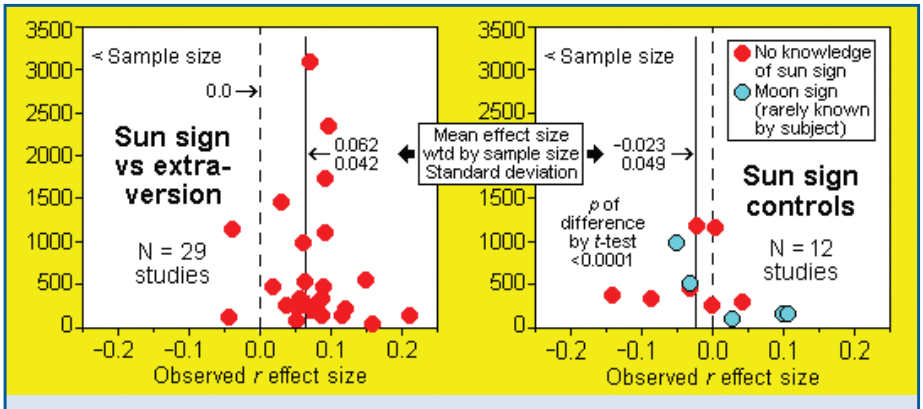

Fig. 2 Astrology's most replicated effect. See text for details.

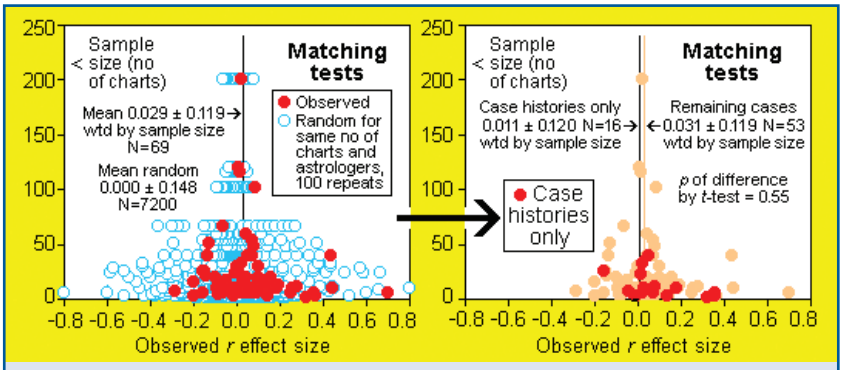

Fig. 3 Validity of astrologers' judgements. See text for details.

over a range that depends on the number of astrologers. Here duplicated circles appear as single circles.

As the sample size increases, the scatter due to sampling errors decreases and the results converge on reality, so the plot resembles an inverted funnel. Red dots are generally engulfed by light blue circles, which suggests that the observed effect sizes are due to sampling error. Meta-analysis confirms this — the variance due to sampling error is 0.041, nearly three times the observed variance of $0.119^2 = 0.014$, so the scatter is entirely explained by sampling error, which leaves nothing for astrology to explain. Especially as effect sizes for hidden persuaders can be much larger, for example the acceptance of Tarot readings increases with their Barnum content and social desirability, the effect size r being about 0.3 in each case [9].

In theory the red dots should be symmetrical about the mean, but more are on the far right than on the far left, indicating the presence of publication bias against negative results (which of course is a problem in any area of study, not just astrology).

Right: In their textbooks astrologers routinely deal with case histories, which suggests that studies based on case histories should give the best results. But if anything they are slightly worse. Such selection can be repeated to test particular criteria of interest including the effect of removing low quality studies, which in this case happens to make little difference [10, p. 21].

Data accuracy and criterion validity are crucial for the tests in Fig. 3 but are not always easy to establish, thus leaving room for the return of shouting matches. That is the bad news. The good news is that such things no longer matter in tests of astrologer agreement — in fact it would make no difference if all birth charts were invented and all calculations were wrong, because the test is now about *agreement between astrologers* and not about *agreement with reality*. Thus if all astrologers agreed that cats were black they would show perfect agreement ($r = 1.00$) even if cats were actually white. A related advantage exists when giving several chart readings to clients to see if they can pick their own. Both approaches are tested in Fig. 4.

Figure 4 left: As before, the plot is shaped like an inverted funnel, but the observed mean effect size r is barely 0.1, showing there is almost no agreement between astrologers on what a birth chart means. It is also a long way from the 0.8 generally recognised as desirable for psychological tests applied to individuals (as astrology is). It shows how different astrologers can see different faces in the same cloud. So a second opinion on your birth chart it is likely to differ substantially from the first.

Furthermore most of the studies were conducted not by hostile critics but by astrologers anxious to demonstrate the value of their craft, so the studies cannot be dismissed as biased. But if astrologers cannot even agree on what a birth chart *means* then their entire practice is reduced to absurdity.

Right: Clients are unable to pick their own chart reading from several (typically 3-5) when cues such as sun sign meanings (which many people are familiar with, such as *Leos are generous*) are absent. They are more successful when cues are present, so success is due to cues and not astrology [10, p. 22]. Remove cues and the client's success at seeing their own face in their own clouds disappears. The agreement results are even more telling in the variation of this test described next.

TESTS OF WRONG CHARTS

The information conveyed by astrology can be anything from assurances like "women who have Mars with the Moon are all

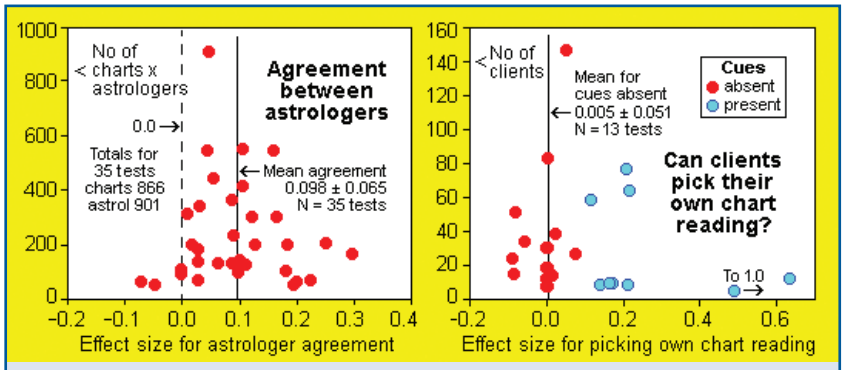

Fig. 4 Left: Agreement between astrologers interpreting the same birth chart. Right: Ability of clients to pick their own chart reading from several. See text for details.

right", which was personally guaranteed by the early Italian astrologer Jerome Cardan, to modern psychological insights like "Moon-Saturn suggests early problems in childhood with your mother". According to astrology textbooks, right answers can come only from right charts, i.e., charts based on correct birth data. But should we believe it? Is it actually true?

The idea might seem difficult to test — what astrologer would willingly read *wrong* charts — but it happens by accident and is surprisingly common. The birth chart can be wrong by hours, days or years, yet on receiving a bona fide interpretation (typed, spoken, or recorded) from the unknowing astrologer, the unknowing client still accepts it without question. Indeed often with high praise for its penetrating insight and accuracy. Which agrees with the earlier results and confirms that:

– Astrology doesn't work (at least not factually) otherwise astrologers would get wrong answers from wrong charts.
– Charts are superfluous but are still necessary for astrologers and clients to believe in the system.
– Astrology is a useful fiction if the focus is on meaning and not facts.

Faced with the above results astrologers usually respond by claiming astrology is above empirical tests even though this denies they could know anything about astrology in the first place. But the results are supported by veteran US astrologers Zip Dobyns and Nancy Roof who famously complained that "astrology is almost as confused as the earthly chaos it is supposed to clarify" [11]. And by Austin Prichard-Levy, then owner of Australia's largest computerized birth chart calculation service, who commented: "I often get the feeling, after talking to astrologers, that they live in a mental fantasy world, a kind of astrological universe where no explanations outside of astrological ones are permissible, and that if the events of the real world do not accord with astrological notions or predictions, then yet another astrological technique will have to be invented to explain it" [12].

EXPERIENCE RULES OK?

The above reactions show how completely astrologers have been persuaded by their experience and their ignorance of hidden persuaders that astrology really works. Indeed, their experience of astrology is so convincing that they tend to automatically dismiss all negative findings. But tests have consistently shown that the *as above so below* links claimed by astrologers do not exist. Venus is not harmonious, nor is Mars martial or Jupiter jovial. Seemingly meaningful outcomes from chart readings are entirely explained by hidden persuaders and by seeing faces in clouds of astrological symbolism.

But does it matter? Many people find spiritual comfort and guidance in astrology. Astrologers tend to be caring people who provide support regardless of what a chart says. *It is the astrologer that matters*. But astrology alone is not counselling. People with problems need to learn coping skills, which will not happen unless the astrologer is trained to do so. Helping is a powerful process that is all too easy to mismanage.

THE PICTURE SO FAR

To recap, there are no known physical ways (gravity, magnetism, radiation, quantum effects) that astrology could work, but there are well-known ways (at least to psychologists and sociologists) that explain both why people believe in astrology and why it seems to work. Except there is a snag:

Many empirical studies have been published in obscure books and journals that may never be accessible on line. Their retrieval would require personal visits to foreign collections at a cost far beyond what any university department could justify. So any critical survey of astrology including this one will suffer from incomplete empirical data. That is the snag.

CASE FOR AND AGAINST ASTROLOGY

However, since the mid 1970s a dedicated pro bono team has been retrieving these elusive empirical studies from libraries and astrological collections around the world. It has taken over forty years, but the results have just been published in a large thick book *Understanding Astrology: A critical review of a thousand empirical studies 1900-2019* [13].

As it happens the results confirm our conclusions. They also suggest a social solution to the puzzles re *Gauquelin's planetary effects* (links between occupation and the diurnal position of visible planets, but only for eminent professionals and only for occupation). The effect size was trivial (typically $r = 0.04$) but was independently replicable, and contrary to all expectation was larger for less-precise birth times, which is like saying the more we tune our radio the worse the reception. Such puzzles had challenged our earlier 1990 review [14, pp. 63-70], and had become a last-ditch defence of astrology, but all are consistent with social effects [13, pp. 165-196]. So we can at last summarise the case for and against astrology:

The case for astrology is that it can provide meaning for human existence, at least for those who find it hard to accept the world revealed by the sciences. The case against astrology is that it has the potential to mislead those who believe in it. It is also literally untrue. Meaning, yes. Truth, no. Your choice. But before proceeding to a conclusion we need to provide better evidence for our reliance on seeing faces in clouds:

CHALLENGING THE FACES-IN-CLOUDS IDEA

In 1983 the idea that astrology is seeing faces in clouds was directly challenged by a $US5000 "superprize" competition sponsored by astrology groups from four countries including Canada: "The superprize will be awarded for convincing [i.e., convincing to the eight judges] evidence that the

accuracy of chart interpretations cannot be explained by non-astrological factors [i.e., hidden persuaders and other artifacts]" [15].

The interpretation could be of any kind but subjects had to be typical of those who visit astrologers. To win $US5000 — then the world's biggest astrology prize — entrants had to show that astrology worked when artifacts were controlled as in matching tests. If it did then the idea of faces in clouds would be publicly discredited and astrologers could trumpet this result from the rooftops. It was an offer no astrologer should refuse.

News of the superprize appeared in astrology journals everywhere and probably reached 250,000 readers in the USA and over 5000 elsewhere. Over 60 intentions to enter were received from a total of 14 countries and were encouragingly diverse — the breakdown of topics was roughly one third personality, one third events, and one third other relevant areas such as compatibility and divination.

In due course 34 entries from seven countries were received totalling over 1500 pages plus several in book form, but only one entry was successful. Unknown to the judges this was a 17-page control disguised as a genuine entry (it reported positive results from tests of transits) and was designed to address hostile views that the superprize was unwinnable due to supposed bias among the eight judges (who were mostly academics). It was not flawless — too good a result might have aroused suspicion — but it was good enough to merit approval from an impartial judge. In fact the judges gave it unanimous approval except for one (an astrologer) who remained silent.

In other words this international response to the world's then biggest astrology prize failed to disconfirm a very simple hypothesis — that astrology is the result of artifacts like hidden persuaders, not the result of *as above so below*.

Today substantial prizes are on offer from more than twenty skeptic groups around the world for empirical confirmation of paranormal claims including astrology. In their own local currency they include *Quebec Skeptics* $100,000, *Australian Skeptics* $100,000, *James Randi Educational Foundation* $1,100,000, and *Indian Skeptics* Rs100,000. The latter began in 1970 as a Rs100,000 challenge to astrologers by Dr A.T. Kovoor, president of the Sri Lankan Rationalist Association. In 2010 former astrologer Rakesh Anand offered Rs1,000,000 (about $US20,000) to any Indian astrologer who could show under controlled conditions that astrology works [16].

To date none of these prizes have resulted in empirical support for astrology commensurate with the claims. If astrology really worked then such a result is hard to explain.

CONCLUSION

The findings from half a century of empirical research explain two key observations that any modern discussion of astrology must address before proceeding further:

- The universal personal experience of astrologers that astrology seems to work.
- The failure of astrology to work when artifacts and biases are controlled.

The findings indicate that astrology is simply a time-honoured cover for the operation of artifacts that better explain the outcomes. In effect astrology is seeing faces in clouds.

So the claim that astrology involves *as above so below*, or psychic powers or transcendental mental faculties or special links with the divine or other mysteries, achieves no more than smokescreen status. One final question:

DOES ASTROLOGY HAVE A FUTURE?

Arguably astrology has little to contribute to human understanding except fantasy. Yes, it is undeniably part of our past, but why should it be part of our future? That some people feel astrology works for them is hardly a problem for the rest of us.

But here we can learn from phrenology, a system of reading character from head shape that began in the 1800s. It shared the same aims as astrology ("know thyself") and in 1896 *The British Phrenological Year Book* said it was "so plainly demonstrated that the non-acceptance of phrenology is next to impossible" (p. 64). By the 1830s about 1 person in 3000 was studying or practising phrenology, making it more popular than astrology is today. It was accepted because, like astrology, it seemed to work. But character is unrelated to head shape [14, pp. 60-61]. Like astrology, phrenology had historical importance but no truth. By the 1900s it was effectively dead

Nevertheless, in 1898 Alfred Russel Wallace FRS, one of the most eminent scientists of his time and a prominent supporter of phrenology, predicted "phrenology will assuredly attain ... one of the highest places in the hierarchy of the sciences". Ironically it was almost identical to the prediction made in 1971 by John Addey MA, the leading UK astrologer of his time, that astrology "seems destined to assume an almost central role in scientific thought... its impact will be felt in the next twenty years" [14, pp. 76-77] This was based on his many years of heroic empirical testing. But nearly 50 years later, no such impact is apparent. Could this be telling us something?

That said, astrology could hardly be better suited to the scientific study of pseudoscience. In terms of longevity and ongoing popularity it has a clear edge over other questionable beliefs. For every student of pseudoscience, astrology would seem to be a good place to start.

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Using Science to Restore Faith – in Science

by Greg Dick and Stephanie Keating

ONLINE REALITY

Memes — those pithy captioned images that fill our social feeds with humour, politics, and sometimes vitriol — simplify complex ideas into emotion-inducing caricatures of reality.

In his book "Thinking, Fast and Slow," Nobel Prize-winning Professor of Psychology Daniel Kahneman described how our brains default to one of two processes when confronted with new situations.

The first process, which Kahneman calls "System 1," is lightning fast. Information is taken in and immediately placed within a person's existing mental constructs linked to emotions like danger, fear, happiness, or joy. System 1 thinking allows us to go efficiently about our day, making assumptions quickly, quietly re-enforcing our worldview, minimizing the need for profound alternations to our thought patterns, and reducing anxiety. It also comes in handy when you are confronted by a bear in the deep woods, or crossing the street against the lights.

The second process, "System 2," is slow, methodical, and nuanced. System 2 is what allows us to make impactful decisions, like buying a house or planning out a healthy diet for the coming week. Using this process, we employ logic, weigh evidence, question inconsistencies, and dig deeper in search of a more complete picture. It's a powerful process, one that consumes significantly more calories and is more mentally taxing than System 1, and is usually reserved for more intentional activities [2].

Combined, the two processes provide us with an effective means for getting through our days, instinctively reacting most of the time with little energy cost and reserving the more energy intensive mental efforts for those few activities that truly warrant.

Summary

The need for deep societal trust in science is now poignantly clear as COVID19 ravages the earth. This article, written before the onset of the pandemic looks to science as one means to regain this trust. The tension between humorous social memes and the torrent of misinformation they propagate are now in stark relief.

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A meme is the perfect tool to engage System 1, often triggering a laugh as your thumb continues to keep the scroll alive. The longer you scroll, the more ad revenue your favourite feed will generate.

Fear and anger seize your System 1 thinking with an even tighter grip — and this is where a problem begins to emerge. There is a strong financial incentive to keep you scrolling, so social media algorithms fill your feed with customized content that will trigger you most deeply — either emotionally reinforcing existing beliefs and biases or directly contradicting them. The result is a stream of questionable content being absorbed via System 1, repeatedly reinforcing your unconscious biases.

Most of us want to believe we are not affected by the stream of memes, but the evidence suggests we are [2]. Next time you are thumbing through your social feeds, engage System 2 by fact-checking each meme that would otherwise make you smile in agreement. But, before you start, predict how many memes you will get through before you abandon the task. My over-under was 3. I ended up down a deep rabbit hole on the first one, which is directly counter to the social network's advertising strategy.

Source: https://www.teepublic.com

AN EROSION OF TRUST IN SCIENCE

Another, and perhaps more insidious, result of having our biases consistently bolstered is the erosion of the role of the expert. Experts understand phenomena deeply, carefully teasing out nuance from the most complex relationships. Science, and scientists, are at an elevated risk in this environment.

Science is incredibly creative, powerful, and has shaped and reshaped society for generations. Science is also slow, methodical, careful, risk averse, incredibly nuanced, and fallible. Scientists know that every interpretation of data comes with some amount of inherent error. Scientists are very careful to ring-fence what is within their study and what is not, what the results imply and what is not clear, lost in the experimental error. This naturally cautious approach, and recognition of error limits, is lost in a nuance-free, System 1-thinking, meme-filled world.

What's worse, the concept of error is often misunderstood. This, combined with a lack of mathematical literacy (think lottery tickets) and misunderstanding of scientific rigour, means that scientific findings are lowered to the same level as "opinion." When new evidence is discovered that renders a previous theory or hypothesis incorrect, too many see this as proof that science "doesn't really know." In fact, this is the process of science working exactly as it should, moving our understanding of the natural world forward one small step at time.

The challenge is significant. Economic incentives prejudice our online lives to swirl in a sea of bias-reinforcing, critical thought-undermining, emotional System 1 thinking. Exposure to this, day after day, week after week, and year after year is undermining scientific authority, which is not guaranteed to keep its place.

Society has advanced by utilizing science, but there are points in history where science was lost, like the European Dark Ages, where the science and medicine of the ancient Greeks was all but forgotten. In his latest book, philosopher Robert Crease [1] shares his view that a fall of scientific authority is a real threat, and offers thoughts on how it might be brought back.

Our climate crisis further raises the stakes: good science and popular trust in science will surely be needed as we enter what will be a fate-determining decade for the long-term survival of our species.

CHIMING IN WITH A SOLUTION

What if the solution to the steady erosion of scientific trust could come from science itself?

Imagine an algorithm that could sift through the continuous flow of data through Facebook, Instagram, and TikTok. What if, in real time, we could rank the veracity of content, fact-check memes, and link to original sources? Layer on blockchain technology to provide content with credible chain of custody tracking, and a user could reliably see whether they are consuming science content generated by NASA or a misinformation troll farm.

An example can already be found in Canada's award-winning CHIME telescope, which uses algorithms to sift through a torrent of data in real-time to pick out the relevant signals. The CHIME collaboration is looking for peculiar astrophysical phenomena called "fast radio bursts," (FRBs) — ultrabrief blips of radio waves that can easily be lost amid the countless other signals traversing the night sky.

Prior to CHIME, only several dozen FRBs had been detected over the decade since their discovery. Thanks in large part to its sophisticated software, CHIME has discovered 13 new FRBs over a period of just two months during its pre-commissioning phase, running at a fraction of its full capacity.

USING ARTIFICIAL INTELLIGENCE TO BOLSTER HUMAN INTELLIGENCE

Another solution may lie in oft-touted realm of artificial intelligence (AI).

Headlines about AI breakthroughs seep into our news feeds with increasing frequency. Yet, according to neuroscientist Gary Marcus, these are so far only "microdiscoveries." They may broaden the potential applications of AI to more complex pattern-matching tasks, but will never move the field forward into the almost mythical promised land that the faithful believe artificial intelligence holds [4].

Since then, advances have been made in understanding how machine learning models, such as neural networks, "think" [3]. These results move machine learning and AI away from being simple "black box" tools and push them towards being "a true source of inspiration in science." Additionally, Judea Pearl and Dana Mackenzie offer insight on how AI can progress toward true reasoning via a three-rung "Ladder of Causation."

Rung one is *seeing*: sifting through masses of data in unique and creative ways in order to find hidden associations and correlations. Imagine an owl recognizing the movement of grass blades that reveal a well-camouflaged mouse scurrying through a field.

Rung two is *doing*: connecting disparate observations into an intervention. For example, a drug store might ask, "What will happen to our floss sales if we double the price of toothpaste?" Assume this change has never before been tried, so no data exits to draw from. An answer to this question would require connecting data that have never been considered together before.

Rung three is *imagining*: the act of wondering what if something was different than it currently is. "What if you didn't take that aspirin, would your headache still have gone away?" To answer

this, we must go back in time and consider a fictitious set of new "facts" that cannot ever be in the original data [5].

Pearl and Mackenzie place the current state of machine learning firmly on the first rung of the causation ladder, where they believe it will remain until the new science of *causal inference* is incorporated into the algorithms. A handful of scientists, including some at Perimeter Institute, are beginning to work at this new interface between artificial intelligence and causation, with optimistic early results.

Artificial intelligence empowered by the emerging science of causation may usher in the benevolent version of AI's promise, enabling society to grapple with our unprecedented access to information of wildly varied veracity.

OPTIMISM FOR THE FUTURE

These are just two examples of where foundational physics could be laying the groundwork for answers to help get us back to a place where information can be trusted, experts are valued, and science can progress unhindered by the repercussions of a society that thinks it doesn't work at all.

Do not mistake these futuristic musings, as accurate depictions of the current or even future state of AI, blockchain, or computer-centric astronomy. The intent is simply to illustrate some of the many sources of our unfailing optimism for humanity's future by highlighting just a few of the current, cutting-edge science advances that may have the power to positively shape our world, if we have the continued courage to trust the rigour and process of science.

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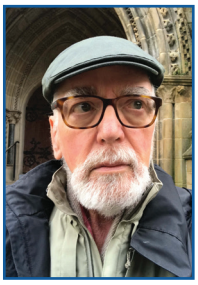
WHY I AM NOT A CREATIONIST: THE DEVIL IN THE DETAILS

BY FORD DOOLITTLE



Gary Larson's smoking dinosaur cartoon entitled *The Real Reason Dinosaurs Became Extinct* has always been one of my favorites. Three dinosaurs furtively puffing on cigarettes with a pterodactyl flying overhead nicely illustrate some of the points I want to make here, in what will be a very personal essay, by which I mean I have not done any of the background reading that would be necessary if this was to be a thorough and scholarly account. What's relevant about the cartoon is that there are facts of the matter about smoking causing cancer, about the availability of cigarettes in the Mesozoic, about why the dinosaurs went extinct, and about how they came to be in the first place. If creationists are willing to accept detailed naturalistic explanations about the first and second, they should also be willing to accept them in the third and fourth. The methods by which we go to find out those facts, and the richness and diversity of the data that support them, are not different.

We seem to be relatively immune to the critiques of creationists here in Maritime Canada, and the few encounters I've had with them after lectures elsewhere have been remarkably civilized. Indeed, unfailingly those I've encountered have been polite and knowledgeable, able to quote from sources (including my own papers) I'd forgotten. Clearly, to them, the facts of biology provided support for their beliefs. All I could say to them, and all I can say here, is that the particular facts of the history of Life, that is to say the facts that evolutionary biologists accept, seem much more easily and fruitfully interpreted as the product of natural selection and chance than intelligent design and divine intent. But if they as individuals have some other compelling personal reason to believe in God or some higher power that intervenes in daily events (the particulars of Life's history), then I can offer no proof of the *absence* of such intervention, though I'd want to know the detailed causal story in each case. Creationist explanations are seldom detailed and must, almost in principle, resort to miracles that defy explicit natural explanation. Most biologists are committed to naturalistic explanations, causal stories in fine detail. Indeed, evolutionary biology can and has been practiced by some committed theists, who seek to know in detail *how* God effected His plan, even if His plan remains hidden. In any case, what believers cannot do, I think, is use the facts of biology – *at the scales at which they are usually understood* – in any principled way to justify their belief.

SUMMARY

Darwin offered a naturalistic alternative to intelligent design which has the advantage of being experimentally accessible, and wherever so accessed provides satisfactory explanations for Life's diversity and adaptedness. One cannot use these phenomena alone as evidence for the existence of God.

Before Darwin that's just what most educated people in the English-speaking world *did* do. Natural theologians like William Paley saw the adaptedness of organisms (the exquisite refinements of the vertebrate eye fitting it for seeing) as analogous to the workings of a watch, and if the last needed a designer (a watchmaker), so must the former (God, from Paley's Christian perspective). I suspect that many creationists still hold such a view, but Darwin claimed it to be unnecessary. Not only was the watchmaker blind, "he" was the immutable natural force of natural selection operating iteratively on chance variations thrown up by populations – nothing divine or intelligent here at all [1].

It's important to realize that this is simply true, logically [2]. In any situation in which we find reproducing entities that bear traits affecting their likelihood of reproducing (their "fitness"), these traits being variable within large enough populations and to some extent heritable (passed down from parent to progeny), natural selection *will* ensue. Ancient Greeks already knew something about this: what Darwin added was the realization that such a process repeated generation after generation, and especially when there is competition among entities, could produce complex structures like the vertebrate eye. Adaptedness bespeaks adaptation. Again, this is logically true and many intelligent design creationists such as Michael Behe accept the principle. What is at issue is how often there are entities with those properties and whether the diversity and adaptedness of living things is adequately explained by this principle. Natural selection is a "how possibly" not a "how actually" theory, at least when it comes to explaining the past, and so there is an epistemological question here: how can we know that selection has been responsible in any particular instance, let alone in all instances?

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ID (intelligent design) creationists, including Behe [3], like to point out areas in which evolutionary biologists are not in agreement about exactly what happened in the history of Life, and of course there will be many, small and large. We *are* an argumentative lot. Three areas that are worth discussion are the origin of Life, complexity, and consciousness. The first provides a good example of how science makes progress. Life as we know it needs DNA to make proteins and proteins to make DNA, posing a chicken-and-egg problem, seemingly insoluble, and generalizable to "information" and "metabolism". In the 1980s, a "how possibly" solution fell out of experiments aimed at isolating proteins responsible for excising unwanted parts of RNA ("introns") from longer molecules. It turned out that no protein was needed [4]. The RNA could catalyse its own removal, so chicken = egg. We now have a well-elaborated "RNA-world" theory in which the first entities capable of showing heritable variation in fitness were RNAs. While Darwin of course had no conception of self-replicating molecules, the RNA world theory fits his vision of natural selection driving an increase of complexity over time. Clever biochemists have evolved such RNAs in the lab and are working on membranes to encapsulate them. When we will have "life in the test-tube" if we don't already, depends on how we define "life", a philosophical question, really. So we have a good "how possibly" story that does not require divine intervention. We will never have a fully proven "how actually" story, though. The history of Life, just like the history of our own civilization, will always have its mysteries, but we should be no more sceptical or more inclined to invoke the supernatural in the former than the latter.

In the second area, critics such as Behe make much of the "irreducible complexity" shown by multi-subunit complexes (the bacterial flagellum, for instance) whose parts must have evolved individually, but seem to have no function except when together. In the case of the flagellum, "how possibly" stories gradually yield to "how actually" explanations, as analysis of the genome databases come to show how its several components evolved and laboratory experiments demonstrate the functionality of many of them in their particular original genomic and cellular settings [5]. The self-assembly machinery of flagella, for instance, is homologous to (shares a common ancestor with) genes known to be involved in injecting toxins into other cells.

Consciousness, that of our traits making us seem closest to God, is a far thornier issue, and both philosophers and biologists remain divided as to whether it's really a thing at all, as opposed to an illusion [6]. Unquestionably, our minds and their contained thoughts are the products of millions of years of biological evolution and thousands of years of cultural evolution, in part under the direction of natural selection whose concern is only differential reproduction of genes or memes. Mapping to external reality may be a good but not a necessary feature, more relevant to survival and reproduction at the mesoscale of other organisms that we might eat or be eaten by than at the microscale of atoms or the macroscale of the cosmos. Clearly we do not yet understand consciousness, and we may never, but there is a natural, evolutionary, explanation for that, too. Just as my dog cannot figure out where her treats have gone when I hold them behind my back, I am intellectually limited. There may be room for God in these gaps in comprehension, but we don't need Him to explain mesoscale phenomena such as the extinction or origin of the dinosaurs.

At the mesoscale, many of our "how possibly" explanations have become believable "how actually" stories as we have learned more of Life's history. There is likely no particular event in the history of Life that demands a supernatural explanation – that will not yield to Darwin's principle or ordinary chance, stuff that "just happened". As evolutionary biologists, our job is to explain these individual events according to such principles, not to prove the principles. Elsewhere I have argued that we need no grander "evolutionary synthesis" and have made ourselves unnecessarily vulnerable to creationist critiques by pretending that we do [7,8]. What the theory of evolution is, in practice, is the claim that the diversity and adaptedness of existing organisms can be explained through the operation, over four billion years, of ecological, population genetic, and gene-level processes of the sort we already largely understand. If we want higher-level theory, supposing for instance that the mere existence of Life has implications in the same sense as the existence of something rather than nothing has spiritual meaning, the evolutionary toolkit is inadequate to the purpose. Evolutionary biologists can — at least in principle — tell how any particular event in Life's history might have happened and what natural forces might have been at play. If God were responsible, we can tell you *how* he (likely) fulfilled that responsibility, but not *why*. Most of us don't think there *is* a why, but that's another matter.

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Is Science Under Assault?

by Bonnie Schmidt and Karin Archer

At the 2019 meeting of the Royal Society of Canada, there was ongoing discussion about the perceived decline in public trust in science, the apparent assault on science and the role of scientists in addressing these issues. Over the past few years an anti-science movement appears to be growing. We set out to look at the evidence and, in this article, share results from recent surveys. We point to the ongoing importance of engaging youth in STEM [1] with the goal that, as adults, they will be better equipped to participate as informed citizens and for work in a world that is increasingly underpinned by STEM [2]. We highlight potential barriers that may be keeping youth from pursuing STEM in general, and physics, specifically. Despite the importance of physics to the global technological transformation now underway, only approximately 15% of Canadian high school students complete grade 12 physics [3], a rate that has not changed in decades. Finally, we close with an overview of Canada 2067, a recent initiative led by Let's Talk Science that generated strong national interest in, and alignment about, shaping the future of STEM learning.

Assessing the level of public trust in science is complicated. Emotionally charged media coverage of issues such as the impact of vaccines and negative or confusing headlines about the evolution of scientific knowledge point to a growing mistrust of science. Furthermore, product marketing that makes inappropriate scientific claims and the rapid rise in the availability of false information online can also foster skeptism. Results of a 2018 survey conducted by the Ontario Science Centre [4] indicated that 54% of Canadians believe that Society is turning away from science in favour of ideas that lack evidence or data. A 2019 study [5] by the Pew Research Center shows a positive trend in the American public belief that scientists generally mean well, but wariness exists over questions of scientific integrity, transparency and bias.

Summary

Assessing evidence about the current state of public trust in science indicates that it may be declining. However, in Canada, science skeptics remain the minority, and public support for science continues to be strong. Thanks to a growing outreach ecosystem, it is an excellent time to (re)build trust and public engagement.

At the same time, there has been an unprecedented global show of public support for science through initiatives such as March for Science and the climate strikes inspired by Greta Thunberg. In Canada, the inclusion of science advisors at different levels of government and programs [6] that provide opportunities for scientists to become policy fellows in government indicate a growing intent to include scientific data when developing public policy.

In September 2019, 3M released its State of Science Index [7], an international poll conducted by Ipsos, which garnered headlines about the erosion of trust in science around the world and catalyzed discussion at many events. While there was some evidence validating the negative headlines, a deeper look at the results indicate that science skeptics are still the minority in Canada. Public doubt has grown since the previous survey, however, nine out of 10 respondents said they still trust science with 85% indicating that they believe in scientific claims. However, about one third of respondents reported being skeptical about science and a shocking 30 per cent of Canadian respondents said they (24% somewhat and 6% completely) only believed science that aligned with their personal beliefs! It is not clear from the presentation of data whether the skeptics and believers are the same people, making this contradictory information even more difficult to reconcile.

Despite some skeptism, the results indicated positive attitudes and a strong interest in encouraging young people to pursue science. This may in part be the result of significant effort over the past decade to draw public attention to the importance of engaging youth in science for future employment.

Canadians appear to be more positive than the global average. Seventy-six per cent of Canadian respondents said that "curious" best described their perspective about science, while 11% said "intimidated". Further, 86% of Canadian respondents said they were optimistic about science in the next 20 years. Ninety-two percent responded that science was now somewhat or very important to their lives. Eighty-four percent of Canadian respondents said they trusted scientists. Similarly, positive results have been found by Let's Talk Science [4] and the Ontario Science Centre [4].

Despite the overall belief that science was very important, specific fields including physics, math, engineering and computer science continue to be unpopular (perhaps

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misunderstood), with very few respondents believing that they would lead to satisfying careers [7]. These beliefs likely contribute to the low school participation rates, with fewer than 15% of Canadian high school students graduating with a senior physics credit [3]. Disengaging from STEM courses at the senior level limits future education and career options.

There clearly is work to be done to reverse declines, improve public attitudes towards science, and increase participation in science, including physics, but a positive foundation upon which to build does exist. Change is possible. For example, over the past twenty years, concerted attention to improving the performance of girls in science has yielded positive results [8]. As indicated in results of PISA [9] 2015 and 2018, the gender gap in science and math performance has closed. PISA 2018 again showed that more top performing girls aspire to STEM careers than boys, however they lean towards life and health sciences.

It takes time, focused attention and investment to impact issues that are largely related to culture. When Let's Talk Science launched as a small project in 1991, very few scientists were engaged in outreach and even fewer publicly admitted to it. Thankfully, attitudes about the importance of public communication amongst scientists and engineers (and the granting councils) have changed significantly within the span of one generation. There now exists a STEM education and outreach sector, which is starting to show signs of maturity. With respect to physics education, the Perimeter Institute is known globally for its outreach. The Canadian Space Agency supports youth engagement. Physics and astronomy departments across Canada regularly invite the public to observatories. Canadian Nobel laureates all support and engage in public awareness activities. Last year, about 30% of Let's Talk Science's volunteer outreach workshops alone addressed physics.

Understanding root causes of attitudes and key barriers to participation offers insights about changes that are most likely to be successful. For example, science skeptism may be rooted in a general lack of public understanding about the nature of scientific inquiry (i.e., how science works). Too often, school science focuses on presenting scientific outcomes and facts rather than engaging students in developing a deeper understanding of inquiry processes. If most people disengage from science education well before high school graduation and lack understanding about the nature of science, then it shouldn't be surprising that skeptism sets in when scientific advancements are made and the facts change.

Key barriers [10] to STEM participation by youth include:

(i) lack of perceived relevance of STEM;
(ii) lack of understanding of post-secondary pathways and career opportunities;
(iii) teachers who lack resources and training to teach STEM in meaningful and experiential ways; and
(iv) lack of diverse role models.

These barriers were identified by the OECD in 2006 as part of an international study into the (then) trend of declining enrolment in post-secondary science studies. The barriers continue to be relevant today although gains are being made in each of them. In addition to these barriers, we know that parents can have a significant influence on their children's high school course choices. It is important to provide parents with access to the information on educational pathways and the importance that STEM plays in those pathways [3].

Let's Talk Science's research and evaluation efforts continue to validate the importance of understanding the role these barriers play in shaping youth attitudes and intentions. For example, several years ago, we conducted a small case study into the impact of select online articles on the attitudes of early teens. Teachers selected the articles, stating that the content was highly relevant for their classroom needs (e.g., one article was about antibiotic resistance for use in a health science class). During the class in which the article was used, student rating of relevance varied widely with some commenting that it was *not at all* relevant — the reason being that they were not ill themselves at that time! This simple example underscores the importance of beginning with a good understanding of audience perspectives as outreach initiatives are designed.

Let's Talk Science is committed to being a change agent by striving to address the barriers and working with the STEM community to offer a robust approach to STEM engagement across Canada. For example, we partner with 50 post-secondary education sites to mobilize thousands of inspiring role models, the majority of whom are women in STEM. With a goal of building science literacy, we offer 'citizen science type' classroom projects that are relevant and highlight the nature of scientific inquiry. We showcase diverse people in diverse STEM careers that follow different post-secondary pathways, including university, college, and apprenticeships. Importantly, we help early years to Grade 12 educators develop their abilities to support student learning in STEM. Students need to be engaged from a young age, made aware of the many diverse career opportunities, and provided with relevant and timely post-secondary and career pathways information.

Let's Talk Science programs are making a positive impact on participants. In a recent survey approximately 78% of school-aged youth who participated in Let's Talk Science Outreach programming responded that they have a better understanding of the role STEM plays in their lives; 75% reported they were more likely to pursue optional STEM courses in high school and 75% said it increased their desire to have a career that uses STEM. After participating in a professional learning session, teachers report gains of more than 33% in their confidence using an inquiry stance in their classrooms. A recent evaluation of the impact of our career profiles showed a 12% gain in student awareness and interest in STEM careers.

As the pace of global change accelerates, Canadian schools are under increasing stress. Canada's network of provincial/

territorial public education systems was established over the past 150 years to address the demands of a largely agrarian, and then industrial economy. Now, faced with demands to provide more personalized learning that develops new skills, Canadian schools are evolving — albeit too slowly. With the goal of driving continued change, during 2016-2018, Let's Talk Science spearheaded Canada 2067 [11], an ambitious initiative to collaboratively develop a national vision and recommendations for the future of education, starting with STEM learning.

Canada 2067 began with a review of global policy initiatives [12] that focused on STEM learning. Six common areas of focus were identified and used to frame subsequent discussions and surveys. These common areas are:

- How we learn (pedagogy, curriculum and assessment)
- How we teach (teacher pre-service education and professional learning and development)
- What we learn (skills and competencies)
- Who's involved (stakeholders, partnerships, leadership and coordination)
- Where education leads (career information and education guidance)
- Equity and Inclusivity (learning opportunities for all students)

Then, over the course of approximately 12 months, input to these pillars was gathered through:

- five summits with Grades 9/10 students [13];
- six Global Shapers hubs across Canada engaging millennials through roundtable discussions [14];
- a unique national leadership conference [15] that brought together provincial and federal deputy ministers with education, community and corporate leaders; and
- online surveys and polling that garnered over 500,000 inputs

The resulting Canada 2067 vision is "*All students develop the full range of skills needed to navigate an increasingly complex world and have equal opportunity to study and pursue diverse career paths*". Overall, 18 overarching recommendations anchor the Canada 2067 Learning Roadmap [16] (in total, more than 80 recommendations were documented from all audiences). All Canada 2067 audiences identified the importance of engaging youth in relevant, issues-based learning that integrated subject areas and prioritized skill development over content memorization.

In conclusion, there appears to be strong alignment about what is needed to evolve STEM learning in Canada and a growing ecosystem of partners ready to support the necessary transformation. The world needs science to solve critical global issues. And science needs people. We must build upon research, our collective experiences, and the current foundation of public trust and curiosity to continually build understanding and engagement.

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THE INFLUENCE OF DENIER'S SCIENCE ON NOT ADDRESSING CLIMATE CHANGE

BY GORDON MCBEAN

UN SECRETARY-GENERAL ANTÓNIO GUTERRES – CLIMATE ACTION SUMMIT

The UN Secretary-General A. Guterres called on all national leaders to come to New York on 23 September 2019 for the Climate Action Summit to enhance action on greenhouse gas emissions reduction and stated [1]: "*Climate change is the defining challenge of our time.*" When the Climate Change Conference COP25 ended in December 2019 without agreements on moving ahead with emissions reductions, the Secretary-General stated: "*I am disappointed with the results of COP25. The international community lost an important opportunity to show increased ambition on mitigation, adaptation and finance to tackle the climate crisis.*" [2] Why do governments not act when there is strong scientific climate change evidence that emissions of greenhouse gases are driving the warming and there are major implications for global societies? Governmental responses are usually motivated by political support. Will actions on climate change be supported by voters in the next election?

Is the influence of climate change deniers and their "fake" science an important factor in reducing the motivations of governments to take actions? When climate change became the issue with the policy focus on reducing emissions of chemicals into the atmosphere to reduce the changes in the greenhouse effect, climate change denial information began to be conveyed through media and other sources to the global community to influence the actions that would be taken. Science-based knowledge on the globally changing climate and its societal implications is strong and based on highly credible sources. There are some questions that need to be further investigated but these issues are clearly not justification for inaction.

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SUMMARY

This essay examines science and pseudoscience, and its sources, addressing climate change that has been provided to the public and policy makers through assessments, reports and websites, and how this has influenced action.

This article draws my personal involvement in the climate change science and policy from the 1980's to the present and on many reliable sources in the literature and the valuable and consistent information in five books, whose titles are indicative: Bowen (2009) [3] *Censoring Science: Inside the political Attack on Dr. James Hansen and the Truth of Global Warming*; Mann (2012) [4] *The Hockey Stick and the Climate Wars*; Oreskes and Conway (2011) [5] *Merchants of Doubt*; Powell (2011) [6] *The Inquisition of Climate Science;* and, focussing on the Canadian scene, Hoggan and Littlemore (2009) [7] *Climate Cover-Up: The Crusade to Deny Global Warming* .

CLIMATE CHANGE – NOT A NEW SCIENCE ISSUE

The scientific basis [8] for understanding the climate system and its variability goes back over millennia, building on fundamental understanding of the physics and chemistry of the climate system. About 200 years ago, Fourier [9] developed the understanding of the greenhouse effect where the visible light from the Sun heats up the Earth and the greenhouse gases (water vapour, carbon dioxide, methane and others) absorb some of the Earth's outgoing radiation and send energy back down to the surface, further warming the Earth. Arrhenius (1896) [10] concluded that doubling the CO_2 in the atmosphere would raise the Earth's global temperature some 5-6 °C.

Over the following half-century there was further research on the issues of changing greenhouse gases leading to climate change. The International Council of Scientific Unions (ICSU) (now the International Science Council [11]) organized the International Geophysical Year (IGY) [12] (July 1957 to December 1958) to initiate the systematic measurements of carbon dioxide and ozone and other chemical components of the atmosphere, which continue. On October 4, 1957, Sputnik [13] was launched, leading the development of satellites to see Earth from space.

In 1979, World Meteorological Organization [14], ICSU and UN Environment Programme [15] jointly convened the first World Climate Conference, raising climate change to a higher political level. To scientifically address the concerns, the World Climate Research Programme (WCRP) [16] was

created to determine: "*the predictability of climate*"; and "*the effect of human activities on climate*". The words predictability and human activities highlight the policy concerns. With the rising international concerns about climate change and related issues of global environmental change, plus emerging discussions on sustainable development, ICSU founded, in 1986, the International Geosphere-Biosphere Programme (IGBP) [17] to: "*study earth system science and to help guide society onto a sustainable pathway during rapid global change.*"

THE 1980'S – NEW SCIENCE, ATTACKS ON IT AND THE CREATION OF THE IPCC

On June 23, 1988, Dr. J. Hansen, Director, NASA Goddard Space Institute gave testimony [18] to a U.S. Senate committee that "*the global warming is now large enough that we can ascribe with a high degree of confidence a cause and effect relationship to the greenhouse effect*", increasing public awareness of climate change [19]. This "*ignited public discussion of global warming and moved the controversy from a largely scientific discussion to a full blown science policy debate*" and marked "*the official beginning of the global warming policy debate*" [20]. What followed were political attacks on Hansen, as documented in Bowen's book and those of Mann, Powell and Oreskes and Conway.

In the mid-1980s there were other climate change science meetings and one report, chaired by Professor B. Bolin (Sweden), noting that greenhouse gases were increasing rapidly due to human activities, agreed on a concluding statement: "*Many important economic and social decisions are being made today on long-term projects, all based on the assumption that past climatic data, without modification, are a reliable guide to the future. This is no longer a good assumption.*" [21]

There were raising political concerns and several countries, led by the United States, expressed concerns about climate change assessments, prepared by independent scientists, having far-reaching implications for national and global economies. The Intergovernmental Panel on Climate Change (IPCC) [22] was created through a process led by Canadian J.P. Bruce [23]. The IPCC does not do research, but assesses and synthesizes the relevant results of peer-reviewed published research and other credible and open sources. The reports are to be policy-relevant but not policy-prescriptive. The IPCC is structured with three Working Groups. Working Group I "*examines the physical science underpinning past, present, and future climate change and uses a global network and participation of scientists to regularly assess the rich body of scientific literature, contributing to an ever-strengthening understanding of how the climate system works, and how it is changing in response to human activity.*" Working Group II assesses the impacts, adaptation and vulnerabilities related to climate change and Working Group III focuses on climate change mitigation, assessing methods for reducing greenhouse gas emissions and removing greenhouse gases from the atmosphere. The author teams for each chapter are appointed based on their scientific excellence and knowledge. The assessments identify where there is agreement in the scientific community on topics related to climate change and where further research is needed. The process has several steps, each with reviews, for objectivity and transparency. The assessment report chapters are the responsibility of chapter's lead authors and the draft Summary for Policy Makers is prepared by lead authors and approved, or modified, by governmental representatives at the formal IPCC Sessions.

IPCC ASSESSMENTS AND THE IMPACTS OF DENIAL

The advancements in science, the increased concentrations of greenhouses and the warming of the climate system have been reflected in the IPCC's assessments. The IPCC First Assessment Report (FAR, 1990) was presented to the Second World Climate Conference in 1990 and states: "*The observed increase (in temperatures) could be largely due to natural variability; alternatively this variability and other man-made factors could have offset a still larger man-made greenhouse warming.*"

The IPCC Second Assessment Report (1995) was presented to the Climate Convention Conference of Parties (CoP2) in 1996, in Geneva, and then conveyed to CoP3 in 1997 in Kyoto (Kyoto Protoco[l]). There was major debate on the question of whether climate was changing and the influence of human activities. The scientific analysis of Dr. B. Santer [4] of the US Department of Energy's Lawrence Livermore National Laboratory was key, leading to the original proposed wording: "*balance of evidence suggests an appreciable human influence on climate*" which raised concerns of oil states. In the end, the compromise was: "*the balance of evidence suggests a discernible human influence on climate*". Later that year, the governments held their formal meeting[1] to review the summary for policymakers and this phrase was further debated. The representatives of the Global Climate Coalition [24] attended, as observers, and encouraged oil country representatives to collectively object to this terminology. IPCC Chair B. Bolin proposed, and it was agreed, that a footnote be added that said which countries objected to this wording. As the meeting was ending and it was clear that this version with the footnote would be published, the objecting countries formally asked that the footnote be withdrawn.

The "*attacks*" against Dr. Santer [25] ratcheted up dramatically following the Plenary Session which formally approved the Second Assessment Report. The Global Climate Coalition and the George C Marshall Institute [26] (founded by Professor F. Seitz and others and funded by industry; it was converted, in 2015, to be the CO2 Coalition [27]), circulated reports in Washington and in the media accusing Dr. Santer of abusing the peer review system and "*political tampering*" and "*scientific cleansing*". The IPCC chair and

1. G. McBean was the Canadian representative at the IPCC meeting, as then an Assistant Deputy Minister, Environment Canada.

co-chairs supported Santer, asserting that all proper IPCC procedures had been followed in producing the chapter.

IPCC THIRD ASSESSMENT REPORT (2001) AND THE "HOCKEY STICK"

The IPCC Third Assessment Report (TAR) concluded that: "*There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.*" The crucial scientific papers were three co-authored journal papers, with Mann (2012) as lead author. The graph of northern hemisphere average temperature was nick-named the "*hockey stick*" due to its shape. The IPCC's conclusions were attacked by a Canadian academic [28, 29] and a mining industry executive [30] (who created the blog called Climate Audit [31]). They claimed that the hockey stick shape was scientifically incorrect and its shape was not statistically significant. An independent assessment of Mann's hockey stick (Wahl, 2007) [32] confirmed the principal results that the warming trend and temperatures over the last few decades were unprecedented over at least the last 600 years.

In 2002 (with a new version in 2007), two Canadian academics published a book *Taken By Storm* [33] *in which they state:* "*We have shown, page after page, that certainty on the subject of the future direction of climate is impossible ... that anyone who thinks we can predict the climate only courts the laughter of the gods...*" They continue to speak out on these issues, including in a June 2019 opinion article [34] entitled: "*This scientist proved climate change isn't causing extreme weather — so politicians attacked. And so, many scientists who have the facts and know the truth remain silent."* The article was mostly quoting an American academic [35] who denies [36] the role of climate change in causing more weather disasters.

IPCC 4TH AND 5TH ASSESSMENT REPORTS

The IPCC Fourth Assessment Report (2007) stated: "*Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations*." The IPCC Fifth Assessment Report (2013-14) concluded: "*Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.*" And that: "*Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, in global mean sea level rise, and in changes in some climate extremes. This evidence for human influence has grown since AR4 (2007). It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century*."

CANADIAN SCENE

As noted, there have been active climate change deniers in Canada. The Friends of Science [37], as an example, has as its goal: "*To educate the public about climate science and through them bring pressure to bear on governments to engage in public debates on the scientific merits of the hypothesis of human induced global warming and the various policies that intend to address the issue*". They state that: "*It is our opinion that the Sun is the main direct and indirect driver of climate change.*" Their publications and presentations continue to deny climate change caused by human activities and to attack climate scientists. An active member of Friends of Science, T. Ball, has many publications denying climate change and has been involved in lawsuits [38, 39]. A columnist [40] for the Financial Post has consistently argued against climate change as an issue and against any action addressing it. On December 13, 2019 he suggested that "*the UN's climate catastrophe scenarios are way off the mark*" [41] and on October 17, 2018, he wrote about "*why-insurers-keep-hyping-climate-risks-that-don't-materialize*" [42].

The role of governments in supporting or controlling science is analysed by Turner (2013) in his book *The War on Science* [43] where he described the muzzling of science on the climate change and other issues.

In April 2019, the city of London, Ontario, declared a climate emergency with a strong positive vote (12-3), joining with other Canadian cities, including Halifax, Kingston and Vancouver, in making similar declarations [44]. On November 25, 2019, the City Council's Strategic Priorities and Policy Committee met to discuss the Climate Change Emergency Update. Three days earlier (November 22) Councillor M. van Holst [45] submitted a motion, quoting the Global Warming Prediction Project [46], "*There is no convincing scientific evidence that human release of carbon dioxide, methane, or other greenhouse gasses is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate. Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the Earth*". He went on to say: "*If this (demonized and shouted down) Carbon-dioxide-is-good narrative is true, then we will be wasting a great deal of time and money on actions that will produce nothing of value and set us back greatly in our goal to tackle the more tangible problems with which we are plagued.*" After some discussion, the motion to refer the report back to the staff for reconsideration was defeated, 11 votes to 2 [47] and the community's Climate Emergency Action Plan [48] is moving ahead. The CBC News in London interviewed four scientists (including the author of this article) about the scientific credibility of the Petition and all agreed that its climate claims were "*false or misleading*" [49].

THE EARTH'S CHANGING CLIMATE AND NEED FOR ACTION

In view of the preceding information on climate change and denials, what is the situation now regarding climate science and actions. The importance of and calls for action on climate change have been based on highly-credible, science assessments, including the: United In Science High-level synthesis

report [50] of latest climate science information from the contributing agencies, including the: World Meteorological Organization (WMO); United Nations Environment Programme (UNEP); Intergovernmental Panel on Climate Change (IPCC); and Future Earth [51] research programme. Other important information is in Canada's Changing Climate Report [52] and the special reports of the IPCC (Global Warming of 1.5 °C (2018); Ocean and Cryosphere in a Changing Climate (2019) and Climate Change and Land (2019)). The atmospheric averages concentrations of two of the most important greenhouse gases have increased since 1750 to present, for carbon dioxide from 280 ppm to 410 ppm and for methane from 700 ppb to 1800 ppb (over double) (Fig. 1).

Most of the increases have occurred in the past century and most rapid increases in the past few decades as direct affect of growing population, industrialization and transport based on fossil fuels, agriculture for methane and other societal sources. The average global temperature for 2015-2019 was 1.1 °C (± 0.1 °C) above pre-industrial (1850-1900) times and the warmest period on record. The NOAA [53] report on 16 January 2020 states that "*The five warmest years in the 1880–2019 record have all occurred since 2015, while nine of the 10 warmest years have occurred since 2005.*" Sea level has risen, and sea-ice extent and glacier mass have been reduced. Canada's climate has warmed over the last few decades at a rate of about double the magnitude of global warming and the Canadian arctic has warmed about three times the global rate and the warming will continue in the future, driven by human influence. An overview from the Royal Society and the US National Academy of Sciences (2020) [54] on Climate Change: Evidence and Causes: Update 2020, states in its summary: "*Detailed analyses have shown that the warming during this period is mainly a result of the increased concentrations of CO***2** *and other greenhouse gases*". The Intergovernmental Panel on Climate Change is in the process of preparing its Sixth Assessment Report, Climate Change (2021-2).

As the decade of 2020's moves ahead, it is important to recognize how important it is for all humanity to address the Earth's changing climate now and in the future. The World Economic Forum (WEF) [55] is an international organization of high credibility to most government leaders. The WEF Global Risk Reports assess, in terms of impact and likelihood, the global risks which are defined as an uncertain event or condition that, if it occurs, can cause significant negative impact for several countries or industries within the next 10 years. The 2020 Report [56] executive summary states: "*Climate change is striking harder and more rapidly than many expected."* The Report ranks: *Failure of climate change mitigation and adaption* as the number one risk by impact and number two by likelihood over the next 10 years, and *Extreme weather events* (e.g., floods, storms) as the highest in likelihood and 4th highest in terms in impacts. Worldwide economic stress and damage from natural disasters in 2018 totalled US$165 billion, and 50% of that total was uninsured [57]. Climate-related economic damage in the United States could reach 10% of GDP by the end of the century [58]. In the private sector, there is recognition of the costs of climate change with nonaction (nearly US$1 trillion) and the significant benefits of right strategies [59]. The losses will be distributed unequally, with the highest economic costs being felt by large economies, while risks of exposure, death and non-economic costs are higher in smaller, poorer economies [60], raising the issues of international equity and ethics. Extreme weather is impacting Canada with the average annual insurance disaster payments, inflation adjusted, exceeding $B Canadian 2.1 for 2016-18, and there are additional societal costs. The estimated annual direct physical damage costs (Fig. 2) are increasing and the projections for 2030 and beyond are in the $10B to $15B range and higher beyond.

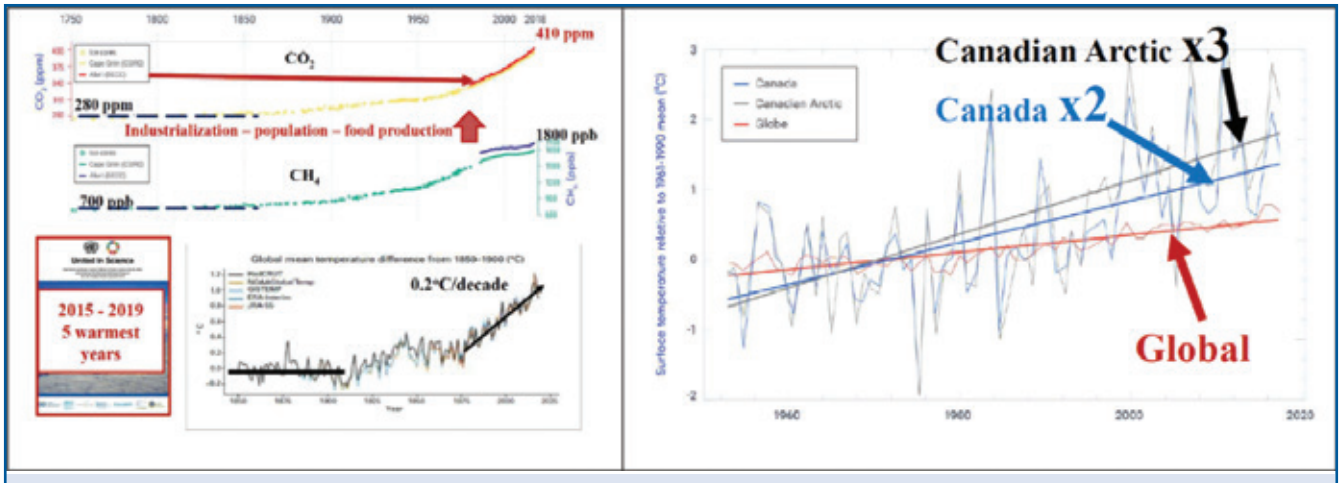

Fig. 1 Left: Global average changes in greenhouse gas concentrations and temperature – from United in Science Report [50]. Right: the observed warming in Canada and Canadian Arctic compared to global warming [52].

To reduce these costs, there is need to both reduce emissions to reduce the longer-term climate change and to adapt through making adjustments in our decisions, activities and thinking because of the changes in climate, in order to moderate harm or take advantage of new opportunities.

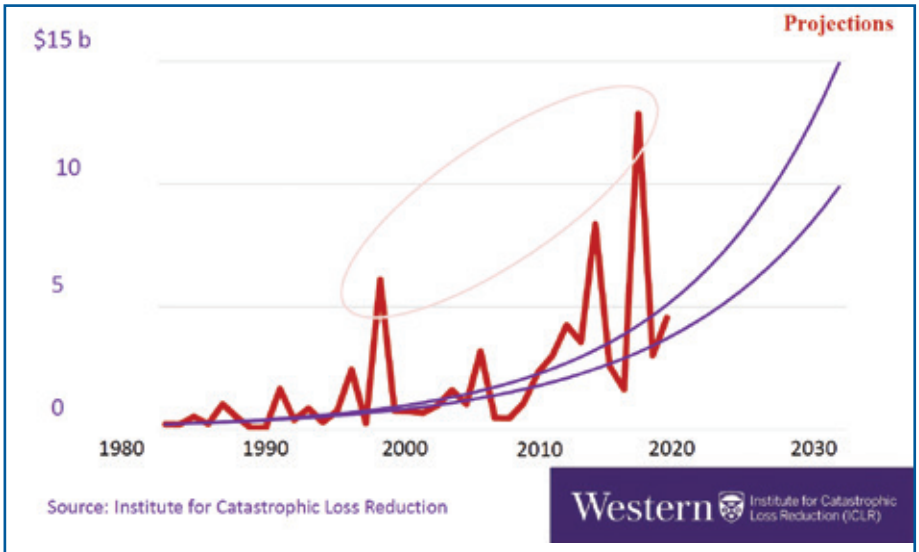

Fig. 2 Estimated annual direct physical damage, $B Canadian, adjusted for inflation (ICLR [61]).

CONCLUDING COMMENTS

In the opinion of this author and almost all climate scientists in Canada and around the world, the climate has warmed, with the past five years being the warmest since humans have been on this planet and the human influence has been the dominant cause of the observed warming since the mid-20th century. The social and economic costs of a changing climate are substantial and much larger than the costs of acting — reducing emissions and adapting to climate change and reducing disaster risk. Polls [62] show that the majority of Canadians agree with action on climate change. Climate change was a dominate factor in Canada's October 2019 election [63]. Former Governor of the Banks of England and Canada Mark Carney has been appointed United Nations Special Envoy for Climate Action and Finance and he says: "*I would say we're in a climate crisis ... action needs to be taken*" [64]. There is need for Canadians and the global community to act on this issue of intergenerational and international equity and ethics.

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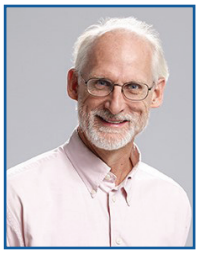
Medal for Excellence in Teaching Undergraduate Physics / *Médaille de l'ACP pour l'excellence en enseignement de la physique au premier cycle*



Kenneth Ragan
McGill University

For his overall accomplishments in teaching, and the promotion of quality teaching at his institution and within the CAP. He has taught many different courses spanning the range from large introductory courses for non-specialists to upper-level courses for final-year honours students and graduate students. His deep physics knowledge, along with his passion for physics and for his students, makes him a perfect candidate for the CAP Medal in Undergraduate Physics Teaching.

Pour ses réalisations globales en enseignement et pour la promotion d'un enseignement de qualité dans son établissement et au sein de l'ACP. Le professeur Ken Ragan a donné de nombreux cours différents allant de longs cours d'introduction pour non-spécialistes à d'autres de niveau supérieur destinés aux étudiants de dernière année et aux étudiants diplômés. Ses connaissances poussées en physique ainsi que sa passion pour cette discipline et pour ses étudiants font de lui un candidat idéal pour la médaille de l'ACP en enseignement de la physique au premier cycle.

CAP Medal for Lifetime Achievement in Physics / *Médaille de l'ACP pour contributions exceptionnelles à la physique*

Eric Hessels
York University

For his world leadership in advancing the state of the art for high precision atomic physics measurements, and their significance as tests of fundamental physics.

Pour son leadership mondial dans l'avancement des mesures de haute précision ultramodernes en physique atomique, et leur importance en tant que tests de la physique fondamentale.

CAP-TRIUMF Vogt Medal for Contributions to Subatomic Physics / *Médaille Vogt de l'ACP-TRIUMF pour contributions à la physique des particules subatomiques*

Gordon C. Ball
TRIUMF

For seminal contributions to low-energy tests of the Standard Model through ultra-high precision measurements of superallowed Fermi beta decays and for his leadership in the development of the ISAC science program at TRIUMF.

Pour ses apports fondamentaux aux tests à faible consommation d'énergie du modèle standard, grâce à des mesures de précision ultra-élevées de désintégrations béta Fermi suralignées, et pour son leadership dans l'élaboration du programme scientifique de l'ISAC à TRIUMF.

2020 CAP Medal

CAP Herzberg Medal / *Médaille Herzberg*

Ebrahim Karimi
University of Ottawa / Université d'Ottawa

For his innovative leadership in developing structured quantum waves for applications to quantum communication and computation, microscopy and materials science.

Pour son leadership novateur dans le développement d'ondes quantiques structurées pour des applications à la communication quantique, au calcul quantique, à la microscopie et à la science des matériaux.

Brockhouse Medal / *Médaille Brockhouse*

Alexandre Blais
Université de Sherbrooke

For his pioneering contributions to, and continued leadership in, the field of quantum information science. His theoretical research has greatly influenced the forefront experiments in this field.

Pour son travail précurseur et son leadership dans le domaine de la science de l'information quantique. Ses recherches théoriques ont grandement influencé les expériences de pointe dans ce domaine.

2020 HS Awards

High School / CEGEP Physics Teaching Awards / *Prix ACP en enseignement de la physique au secondaire et au collégial*

2020 Winners / *Récipiendaires 2020*

British Columbia and Yukon / *Colombie-Britannique et Yukon*

Joseph Muise
St. Thomas More Collegiate

Joe Muise has been teaching physics at St. Thomas More Collegiate since 2004 and in that time enrolment in Physics 12 has nearly doubled, with a significant increase in the number of female students. Joe strives to make physics interesting and accessible to his students through varied instruction and real-world examples. He manages to push his students to strive for excellence, while keep the classroom tone light and relaxed.

Joe seeks out professional development opportunities to improve his teaching and works to share these opportunities with others. He has attended LIGO's International Physics and Astronomy Workshop, CERN's International Teacher Weeks and The European Space Agency's Robotics & Automation workshop and presented those experiences to fellow teachers at conferences run by the BC Association of Physics Teachers, the NSTA, and the BC Science Teachers Association.

Joe also goes to great lengths to provide opportunities for his students to participate in applied physics activities outside of the classroom. He and a group of his students travelled to Bologna, Italy and became the first Canadians to compete in the European Space Agency's CanSat competition. He has led two student groups (with a third in currently in preparation) through the Students on the Beamlines program at the Canadian Light Source, where they conducted original research at Canada's national synchrotron. He has brought many groups to the UBC Physics Olympics, and the Kwantlen Science Challenge. His love of astronomy lead to the formation of a school astronomy club that regularly sees many students out on the school track looking at the night sky.

Earlier this year, Joe was recognized by the National Science Teaching Association as the recipient of the

Robert E Yager Exemplary Teaching Award for Canada. He recently joined STEP UP as an ambassador, working to encourage other Canadian teachers to join the program that strives to inspire young women to pursue physics.

Joe Muise enseigne la physique à St. Thomas More Collegiate depuis 2004 et, durant cette période, les inscriptions en physique 12 ont presque doublé, le nombre d'étudiantes augmentant sensiblement. Joe s'efforce de rendre la physique intéressante et accessible à ses étudiants par des exemples d'enseignement divers, tirés du monde réel. Il réussit à pousser ses étudiants à viser l'excellence, tout en conservant une atmosphère légère et détendue en classe.

Joe cherche des possibilités de perfectionnement professionnel pour améliorer son enseignement et il s'emploie à les partager avec les autres. Il a participé à l'Atelier international de physique et d'astronomie de LIGO, aux Semaines internationales des enseignants de la CERN et à l'atelier de robotique et d'automatisation de l'Agence spatiale européenne. Il a en outre exposé ces expériences à d'autres enseignants lors de conférences de la BC Association of Physics Teachers, de la NSTA et de la BC Science Teachers Association.

Joe s'efforce fort d'offrir à ses étudiants des occasions de participer à des activités de physique appliquée hors de la salle de classe. Lui et un groupe de ses étudiants se sont rendus à Bologne, en Italie, et sont devenus les premiers Canadiens à participer au concours CanSat de l'Agence spatiale européenne. Il a dirigé deux groupes d'étudiants (et se prépare à en diriger un troisième) dans le cadre du programme Students on the Beamlines au Centre canadien de rayonnement synchrotron, où ils ont mené des recherches originales. Il a amené divers groupes aux olympiques de physique de l'UBC et au Kwantlen Science Challenge. Son amour de l'astronomie l'a amené à former un club d'astronomie scolaire qui incite régulièrement de nombreux étudiants à parcourir la piste de l'école tout en scrutant la nuit étoilée.

Plus tôt cette année, la National Science Teaching Association a choisi Joe comme récipiendaire du Prix Robert E Yager d'enseignement exemplaire pour le Canada. Il a adhéré récemment à STEP UP à titre d'ambassadeur, s'employant à encourager d'autres enseignantes et enseignants canadiens à prendre part au programme qui vise à inciter les jeunes femmes à poursuivre leur éducation en physique.

Prairies and Northwest Territoires / *Prairies et Territoires du Nord-ouest*

Ryan Beck
Chinooks Edgle School Division

Ryan is deserving of recognition for his tireless efforts in promoting physics education and science education in general at Sundre High School. In addition, he has made a tremendous impact on the character of the school by developing numerous non-science and extra-curricular programs at the school and in the community.

Remarkable intelligence and knowledge, along with 18 years of science teaching experience, equip him to engage and motivate students to academic success in physics. His expertise is underlined by the fact that Ryan was requested as a member of committees for Alberta Education for Diploma exam item-writing, PD development, and curriculum design. He has also been hired by the Perimeter Institute to help develop teacher resources for Alberta.

Beyond thoroughly understanding the material and presenting it in an understandable manner to students, Ryan has worked hard to his student's engagement in learning physics. He acquired 5 grants totalling $50,000 to purchase materials and equipment that have greatly augment students hands-on understanding. He led students on several field trips to West Edmonton Mall to experience live physics, and most recently coordinated and mentored a group of 12 grade 10-12 students in developing a winning proposal to gain beam time on at the CLS Synchrotron at the University of Saskatchewan. This project has been over a year in duration, and has generated interest and excitement from students, parents, teachers, media, and members of the wider community.

Ryan is also very committed to ongoing professional development. He recently attended the Perimeter Institute Einstein Plus conference, participated in Schrodinger's class at the Institute for Quantum Computing, and was a presenter at the Southwestern Alberta Teachers Convention on "Black Holes and the Event Horizon Telescope".

His contribution to education in Sundre doesn't end with Science. Ryan founded and facilitates a Leo club, a student service club that has received international recognition for their work in Sundre on gender and equality issues.

Ryan mérite d'être reconnu pour ses efforts inlassables à promouvoir la formation générale en physique et en science à l'école secondaire Sundre. De plus, il a eu une profonde influence sur le caractère de l'école en la dotant, ainsi que la collectivité, de nombreux programmes non scientifiques et parascolaires.

L'intelligence et les connaissances remarquables de Ryan et ses 18 années d'enseignement des sciences l'ont rendu apte à engager et à motiver les étudiants à la réussite scolaire en physique. Son expertise est soulignée par le fait qu'il a été invité à faire partie de comités d'éducation en Alberta et à rédiger des points pour l'examen au diplôme d'enseignant ainsi qu'à élaborer et à concevoir le programme d'études. L'Institut Perimeter l'a également embauché afin d'aider à développer des ressources pour l'enseignement en l'Alberta.

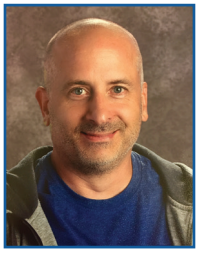
Outre qu'il comprend à fond le matériel et le présente d'une manière compréhensible aux étudiants, Ryan s'est

employé à engager ses étudiants à l'apprentissage de la physique. Il s'est mérité 5 bourses totalisant 50 000 $ pour l'achat de matériel et d'équipement qui ont grandement enrichi la compréhension pratique des étudiants. Il les a dirigés lors de plusieurs excursions au West Edmonton Mall afin d'expérimenter la physique en direct et, tout dernièrement, il a coordonné et encadré un groupe de 12 étudiants de la 10e à la 12e année à élaborer une proposition leur permettant de obtenir du temps de rayonnement au CLS Synchrotron de l'Université de la Saskatchewan. Ce projet a duré plus d'un an et suscité l'intérêt et l'enthousiasme des étudiants, des parents, des enseignants, des médias et des membres de la communauté en général.

Ryan est également très engagé envers le perfectionnement professionnel continu. Il a récemment assisté à la conférence Einstein Plus de l'Institut Perimeter, participé à la classe de Schrodinger de l'Institut d'informatique quantique et il a fait un exposé sur les « trous noirs et le télescope Event Horizon » au congrès des enseignants du Sud-Ouest de l'Alberta.

Son apport à l'éducation à Sundre déborde la science. Ryan a fondé et dirige un club Lions, un club de services étudiants qui a été reconnu sur le plan international pour son travail à Sundre relativement aux questions de genre et d'égalité.

Ontario



Shawn Brooks
University of Toronto Schools (UTS)

Shawn Brooks is a high school teacher at UTS in Toronto. His blend of humour, compassion and his ability to connect physics concepts to the real world make Shawn an outstanding physics teacher. Shawn supports his students both in and outside the classroom. This might involve running physics "parties" (extra help sessions after school), supervising the physics club or supporting his students when they send experiments to the International Space Station. Shawn supports his innovative colleagues in the UTS science department. His colleagues describe him as the "tech savvy" department member. This enables him to incorporate the latest technology in the classroom. It also allowed him to transform the OAPT grade eleven physics contest from a paper version to an online contest that is free to write for senior high school physics students across the country.

"I hope that the projects and activities that I have been involved in provide evidence to my personal interest (and commitment) to always supporting students, teachers, and volunteer organizations such as the Ontario Association of Physics Teachers. My vision of education values technology, innovation, and supporting those who like trying new things."

Shawn Brooks est enseignant au secondaire à l'UTS de Toronto. Son mélange d'humour et de compassion et sa capacité à relier les concepts de la physique au monde réel font de Shawn un professeur de physique exceptionnel. Shawn appuie ses étudiants en salle de classe comme à l'extérieur. Cela peut l'amener à tenir des « parties » de physique (séances d'aide supplémentaires après l'école), à superviser le club de physique ou à appuyer ses étudiants lorsqu'ils soumettent des expériences à la Station spatiale internationale. Shawn soutient ses collègues innovateurs du département des sciences de l'UTS. Ceux-ci le décrivent comme le membre « futé » du Département, ce qui lui a permis d'intégrer les dernières technologies en classe. Cela l'a aussi amené à transformer le concours de physique de première année OAPT d'une version papier à un concours en ligne auquel peuvent s'inscrire les étudiants de physique du secondaire de tout le pays.

« J'espère que les activités et projets auxquels j'ai participé témoignent de mon intérêt (et engagement) personnel à toujours soutenir les étudiants, les enseignants et les organismes bénévoles comme l'Ontario Association of Physics Teachers. Ma vision de l'éducation valorise la technologie et l'innovation et appuie ceux qui aiment essayer de nouvelles choses. »

Quebec and Nunavut / *Québec et Nunavut*

Patrick Mayard
English Montreal School Board

Patrick Mayard is both a passionate physics teacher and motivator. The symbiosis of these qualities has imparted a lasting, positive impact on his students. From an educational perspective, Patrick used innovative and pragmatic teaching methods rooted in applied physics; he linked each physics concept to an everyday life example as well as implemented a year-end robotics project. He also introduced his students to Microsoft Excel to strengthen their understanding of graphing and shared motivational principles on a weekly basis. This approach resulted in high student achievement. For example, his physics or science students won the First Prize at the Rosemount High School Science Fair for three consecutive years; another student, who enrolled in the McGill Honours Physics program, graduated at the top of his class, and another student, who became a two-time champion of the Canadian Robotics Competition, pursued an engineering career.

Patrick's contributions transcended the classroom. He established an advanced robotics mentorship program

with Rosemount Technology Center to deepen students' understanding of complex robots. He also partnered with McGill and Concordia universities to give engineering presentations at Rosemount High School to inspire the next generation of physicists and engineers. From a provincial perspective, he co-organized a seminar in Montreal for the professional development of new physics teachers and was a jury member of an engineering committee for the Canadian Robotics Competition. Patrick served, for two years, as an advisory councillor in the Canadian Association of Physicists. He was also selected by the Quebec Science Association to present his problem-solving method to physics and science teachers at their annual Congress; hence, in 2019, he won the Raymond-Gervais Provincial Award for Excellence in teaching science in Quebec. Patrick Mayard is also an author of seven educational works, which made him a nationally recognized speaker.

Patrick Mayard est à la fois un professeur de physique passionné et un motivateur. La symbiose de ces qualités a eu un effet durable et positif sur ses étudiants. Sous un angle éducatif, Patrick a utilisé des méthodes d'enseignement innovantes et pratiques enracinées dans la physique appliquée; il a lié chaque concept de physique à un exemple de la vie courante ainsi qu'à la mise en œuvre d'un projet de robotique de fin d'année. Il a aussi initié ses étudiants à Microsoft Excel pour renforcer leur compréhension de la graphique et des principes de motivation partagés sur une base hebdomadaire. Cette approche a permis au rendement des étudiants d'atteindre un haut niveau. Ainsi, ses étudiants en physique ou en sciences ont remporté le premier prix à l'Expo-sciences de l'école secondaire Rosemount trois années de suite; un autre étudiant, inscrit au programme spécialisé en physique de McGill, a obtenu son diplôme à titre de premier de classe et un autre étudiant, deux fois champion du Concours canadien de robotique, a poursuivi une carrière en génie.

Les apports de Patrick débordent la salle de classe. Il a mis sur pied un programme avancé de mentorat en robotique au Rosemount Technology Center afin d'approfondir la compréhension des robots complexes par les étudiants. Il s'est également associé aux universités McGill et Concordia pour faire, à l'école secondaire Rosemount, des exposés en génie visant à inspirer la prochaine génération de physiciens et d'ingénieurs. Sur le plan provincial, il était co-organisateur à Montréal d'un séminaire de perfectionnement professionnel des nouveaux professeurs de physique et il a siégé au jury d'un comité d'ingénierie au Concours canadien de robotique. Pendant deux ans, Patrick a été conseiller consultatif à l'Association canadienne des physiciens et physiciennes. Il a également été choisi par l'Association des sciences du Québec pour présenter sa méthode de résolution de problèmes aux professeurs de physique et de sciences lors de leur congrès annuel; ainsi, en 2019, il a remporté le Prix provincial Raymond-Gervais d'excellence en enseignement des sciences au Québec. Patrick Mayard est également l'auteur de sept ouvrages éducatifs, ce qui a fait de lui un conférencier reconnu à l'échelle nationale.

PhD Physics Degrees Awarded in Canadian Universities*
Doctorats en physique décernés par les universités canadiennes*

December 2018 to December 2019 / Décembre 2018 à Décembre 2019

Brock University

OBIED, L., "Infrared Spectroscopy of Ge:Mn Thick Films Prepared by Ion Implantation and Post-annealing", (D. Crandles), June 2019, now a part-time instructor in the Physics Department at Brock University, ON, Canada.

Dalhousie University

BALDWIN, S., "Structural variation and Enzymatic Susceptibility of Collagen Fibrils Extracted from Native and Overload Tail Tendons", (L. Kreplak/M. Lee), October 2019, now pursuing a Postdoctoral Fellowship, Dalhousie University, Halifax, NS, Canada.

HAMMER, M., "Inferring Atmospheric Aerosol Properties from Satellite Observations and a Global chemical transport model.", (R. Martin), October 2019, now pursuing a Postdoctoral Research Associate, Washington University in St. Louis, McKelvey School of Engineering, St. Louis, MO, USA.

MARCH, S, A., "Four-wave mixing Experiments on solution-processed methylammonium lead Iodide (CH3NH3PBI3) perovskite thin films", (K. Hall), May 2019, now pursuing a Postdoctoral Fellowship, Dalhousie University, Halifax, NS, Canada.

McMaster University

ARMSTRONG, N., "The Electrodynamics of Quantum Materials: Quasicrystals, Semimetals, and Poor Metals", (T. Timusk), November 2019, now a Faculty Member at St. Paul American School Systems, Shanghai, China.

CAI, Y., "Frustrated Magnetism Studies in NaCaNi2F7, Er3Ga5O12 and ErMgGaO4", (G. Luke), November 2019, now pursuing a Postdoctoral Research Scientist at TRIUMF/UBC, Vancouver, BC, Canada.

PLESTID, R., "Quantum Effects in the Hamiltonian Mean Field Model", (D. O'Dell), November 2019, now a Postdoctoral Fellow at the University of Kentucky, Department of Physics and Astronomy, Lexington, KY 40506, USA.

SCHLIEF, A., "The Antiferromagnetic Quantum Critical Metal: A Nonperturbative Approach", (S. Lee), November 2019, now pursuing a Postdoctoral Fellow at Max Planck Institute for Physics of Complex Systems, 01187 Dresden, Germany.

Polytechnique Montréal

BELLEMARE, J., "Fragilisation par hydrogène de l'acier 4340 électroplaqué : test non destructifs électromagnétiques et analyses avancées de mesures de spectroscopie à désorption thermique", (F. Sirois / D.Ménard), December 2019, now searching for employment.

DI MAURO, E., "The Biopigment Eumelanin in the Sustainability Challenge: Interfaces with Metal Electrodes, UV-Absorption Enhancement of Plastics and its Biodegradability", (C.Santato / F.Cicoira), May 2019.

GUERBOUKA, H., "Enabling Real-Time Terahertz Imaging with Advanced Optics and Computational Imaging", (M. Skorobogatiy), December 2019, now pursuing a Postdoctoral Fellowship at Brown University, Rhode Island, USA.

HAFEZIAN, S., "Growth Control and Study of Ultrathin Silver Film for Energy-Saving Coatings", (L.Martinu / S.Kéna-Cohen), May 2019.

KILICASLAN, A., "Dépôt de revêtements durs et résistants à l'érosion sur la surface interne de cathodes creuses pour des applications en aérospatiale", (L.Martinu / J.-E.Sapieha), May 2019.

LABERGE, M., "Modeling the tribomechanical properties of multifunctional thin film coatings", (L.Martinu / J.-E.Sapieha), August 2019.

LEBLANC-HOTTE, A., "On-Chip Fabry-Pérot Microcavity for Refractive Index Cytometry and Deformability Characterization of Single Cells", (Y.-A.Peter / J.-S.Delisle), April 2019, now searching a Postdoctoral Fellowship.

MUSONGELA, M., "Implantation d'un modèle de fuites B1 hétérogène avec la méthode des caractéristiques (MoC)", (G. Marleau), December 2019, now searching for employment.

Queen's University

BAUER, J., "Nature or Nurture? Collisionless Evolution of Galactic Disc-Halo Systems", (L.M. Widrow), November 2019, now a Data Scientist/Deep Learning Researcher at Strivework, Austin, Texas, USA.

KESZTHELYI, Z., "The Role of Surface Fossil Magnetic Fields on Massive Star Evolution", (G.A. Wade), November 2019, now pursuing a postdoctoral fellowship at the Anton Pannekoek Institute for Astronomy at the University of Amsterdam, NL, Amsterdam.

LEWIS, C., "Modelling Low-Resolution Galaxies to Predict Next-Generation Telescope Survey Statistics", (K. Spekkens), November 2019, now a Data Scientist at TELUS Digital, Whitby, ON, Canada.

MUZAR, E., "Photonics Crystal Surface Structures on Gallium Arsenide", (J.A.H. Stotz), November 2019, now in IT, Private Sector, Toronto, ON, Canada.

NAVAEIPOUR, P., "Nonlinear Response of Monolayer Graphene to THz Frequency Radiation", (M.M. Dignam), November 2019, now a Computational Physicist at Distributed Compute Labs, Kingston, ON, Canada.

SEIFOORY, H., "The Dynamics of Quantum States of Light in Lossy Coupled-Cavity Systems", (M.M. Dignam), November 2019, now pursuing a postdoctoral fellowship at the University of Toronto, Toronto, ON, Canada.

SHAHALIZAD, A., "Suppression of the Efficiency Roll-off Characteristics in Solution-processed Lanthanide-base Organic Light-emitting Diodes (OLEDs)", (J.-M. Nunzi), May 2019, now a Director at Genoptic LED Inc., Calgary, AB, Canada.

SIKORA, J., "On an Emerging Paradigm of Tepid Stars: Assessing the Magnetic Origin of Surprisingly Common Star Spots", (G.A. Wade), November 2019, pursuing a postdoctoral fellowship at Bishop's University, Sherbrooke, QC, Canada.

Ryerson University

BLAHUT, K., "Hepatitis C Virus Modelling In Vitro And In Vivo", (C. Beauchemin), June 2019, now a Data Engineer at Torstar Corporation, Toronto, ON, Canada.

MOORE, M., "Ultra-High Frequency Photoacoustic Microscopy: From Organelles To Organisms", (M. Kolios), June 2019, now a Medical Physics

Resident at Grand River Hospital, Kitchener, ON, Canada.

NOSRATI, R., "Development Of An MRI-Based Workflow For Post-Implant Dosimetry Of Prostate Low-Dose-Rate (LDR) Brachytherapy", (G. Stanisz / A. Pejovic-Milic), October 2019, now a Medical Physics Resident at Harvard Medical School, Boston, MA, USA.

NUSRAT, H., "Quantifying Radiobiological Variation In Cancer Radiotherapy Using Monte Carlo Simulation And Doped Plastic Scintillators", (A. Sarfehnia / C. Kumaradas), October 2019, now a Medical Physics Resident at Sunnybrook Hospital/University of Toronto Dept. of Radiation Oncology, Toronto, ON, Canada.

PANDYA, A., "Fiber optic SERS probes for remote sensing", (A. Douplik / C. Kumaradas), June 2019, now a Postdoctoral Research Fellow at Tornado Spectral Systems, Toronto, ON, Canada.

SHASWARY, E., "Frequency-Domain Synthetic Aperture Focusing Techniques for Imaging with Single-Element Focused Transducers", (J. Tavakkoli / C. Kumaradas), October 2019, now a Postdoctoral Research Fellow at Tornado Spectral Systems, Toronto, ON, Canada.

Simon Fraser University

ABRAHAM, R., "Investigations of the deep double donor magnesium in silicon", (M. Thewalt), June 2019.

FITZPATRICK, M., "Out-of-equilibrium dynamics of the Bose-Hubbard model in the strong coupling regime", (M. Kennett), October 2019.

GALVEZ, T., "Cosmological and astrophysical observables from field theory in curved backgrounds", (A. Frolov), October 2019.

NIROOMAND, D., "Spin Transport in an Ultra-cold Trapped Non-condensed 87Rb Gas", (J. McGuirk), June 2019.

SIAVASHI, R., "Ceramide and Cholesterol Interactions in Phospholipid Membranes: A 2H NMR Study", (J. Thewalt), June 2019.

ZUCCA, A., "Cosmological Tests of Fundamental Physics", (L. Pogosian), October 2019.

Trent University

KALLIKRAGAS, D., "Superficial Water Chemistry: Molecular Dynamics Simulations and Flow Reactor Studies", (I. Svishchev), January 2019, now a Research Assistant at Trent University, Peterborough, ON, Canada.

PORQUEZ, J., "Advanced broadband CARS microscopy based on a supercontinuum-generating photonic crystal fiber", (A. Slepkov), September 2019, now a Photonics Engineer at Hyperion Sensors Inc, Markham, ON, Canada.

RASLAN, A., "The Role of Dielectric Screening in SrTiO3-Based Interfaces", (B. Atkinson), January 2019, now a Sessional Instructor, UOIT, Oshaway, ON, Canada & a Teaching Assistant at Trent University, Peterborough, ON, Canada & a Research Assistant at Trent University, Peterborough, ON, Canada.

University of Alberta

BLANCO BENAVIDES, J., "Internal Alfven waves as a possible driver for auroral kilometer radiation", (R. Rankin), June 2019.

DINH, H., "Integrated 4D analysis of an underground blowout", (M. van der Baan), June 2019

DOOLIN, CALLUM, "Integrated optical and mechanical resonators for evanescent field sensing", (J. Davis), Dec 2019.

GENTILE, F., "Computer-Aided Drug Design of DNA Repair Inhibitors Targeting the ERCC1-XPF Endonuclease", (J. Tuszynski), June 2019.

GHARAEE, H., "Physical Models of the Lunar Wake and Data-Model Comparisons", (R. Marchand), Dec 2019.

HUTCHINSON, J., "Transport and superconductivity in spin-orbit coupled electron systems", (J. Maciejko), Dec 2019.

JELIC, V., "Imaging Ultrafast Dynamics on the Atomic Scale with a Terahertz Scanning Tunneling Microscope", (F. Hegmann), June 2019.

KIM, P., "Passive and active cooling of cavity optomechanical torque sensors for magnetometry applications", (J. Davis), Dec 2019.

MOHAMMED, T., "Electrical Properties of Rocks", (D. Schmitt), Dec 2019.

NARRETO, M., "Ultrafast Photoluminescence and Photoconductivity Dynamics of Semiconductors", (F. Hegmann), Dec 2019.

OSUGA, K., "Quantum Gravity: From Black Holes to Matrix Models", (D. Page), June 2019.

RESENDIZ LIRA, P., "Particle Sensors in Ionospheric Plasma", (R. Marchand), Dec 2019.

WANG, E., "Multidimensional magnetotelluric studies of the Precambrian Alberta basement", (M. Unsworth), Dec 2019.

University of Guelph

ARTHUR, Z., "In Situ Synchrotron Radiation Investigation of Charge Compensation and Phase Evolution Mechanisms In Li2fesio4 Electrodes", (D. Jiang), June 2019, now an Associate Scientist, Canadian Light Source, Saskatoon, SK, Canada.

DUNLOP, R., "β and β-delayed neutron decays of the N = 82 isotopes $^{128-130}$Cd and ^{131}In studied with GRIFFIN", (C. Svensson), October 2019, now an Analytics Analyst II - Claims Analytics, The Co-operators, Guelph, ON, Canada.

JIGMEDDORJ, B., "Nuclear Structure of 122Xe Studied via High-Statistics β+/EC Decay of 122Cs", (P. Garrett), June 2019, now a Postdoctoral Researcher, Canadian Nuclear Laboratories,Chalk River, ON, Canada.

University of Manitoba

ANDALIB, T., "Magnetic Fields and Ultracold Neutron Production: Studies Towards the Neutron Electric Dipole Moment Experiment at TRIUMF", (J. Martin), May 2019.

HYDE, P., "Magnetic Fields and Ultracold Neutron Production: Studies Towards the Neutron Electric Dipole Moment Experiment at TRIUMF" New Methods for Controlling Coupling Effects in Cavity Magnon - Polariton Systems", (C-M Hu), October 2019.

REBENITSCH, L., "Detecting High Rates of Ultracold Neutrons and Thermal Neutron Production", (B. Jamieson), February 2019.

SHAKER, F., "Measurement of the Electron Anti - Neutrino Cross - Section on Carbon at the T2K Near Detector", (B. Jamieson), February 2019.

TEIMOORISICHANI, M., "Geometry Optimization and Evaluation of PET - Inserts of Simultaneous PET / MR Neuroimaging", (A. Goertzen), October 2019.

ZHOU, L., "Models for Firewall Creation in Massless Scalar Field Theory", (G. Kunstatter / M Carrington), February 2019.

Université de Montréal

BARON, F., "Recherche de compagnons de type Jupiter à très grandes séparations autour d'étoiles jeunes dans le voisinage solaire", (D. Lafrenière), November 2019, Médiatrice scientifique à l'Observatoire du Mont-Mégantic, Université de Montréal, Montréal, QC, Canada.

BLOUIN, S., "Modélisation des effets de haute densité à la photosphère des naines blanches froides", (P. Dufour), November 2019, now a Director's Postdoc Fellow at Los Alamos National Laboratory, Los Alamos, New Mexico, USA.

FAVRON, A., "Photo-oxydation et spectroscopie Raman de couches minces de phosphore noir", (R. Leonelli & R. Martel), May 2019, now currently unemployed.

GENDRON-MARSOLAIS, M.-L., "Observations multi-longueur d'onde d'amas et de groupes de galaxies proches", (J. Hlavacek-Larrondo), April 2019, now pursuing a Postdoctoral Fellowship at ESO/ALMA at European Southern Observatory Santiago, Chile.

GENEST-BEAULIEU, C., "Analyse et modélisation d'étoiles naines blanches de type DB dans le Sloan Digital Sky Survey et le relevé Gaia", (P. Bergeron), November 2019, maintenant un Professeur en physique, CEGEP Gérard-Godin, Montréal, QC, Canada.

LALONDE, A., "Etude Monte Carlo de l'impact de la tomodensitométrie multiénergie sur la précision du calcul de dose en protonthérapie", (H. Bouchard), July 2019, now Postdoctoral Research Fellow at Harvard Medical School, Boston, MA, USA.

MAHMOUD, S., "Étude numérique de la diffusion des défauts ponctuels dans les alliages de nickel", (N. Mousseau), July 2019, now a Postdoctorant, Université de Lille, Lille, France.

PLANTE, A., "Searching for Dark Matter with Superheated Liquid Detectors", (V. Zacek), November 2019, now pursuing a Postdoctoral Fellowship at Polytechnique Montréal, Montréal, QC, Canada.

ROJO, M., "Formation et transport de poussières en plasma magnétisé basse pression", (J. Margot / R. Clergereaux), April 2019.

ROLLAND, B., "Étude de l'évolution spectrale des étoiles naines blanches riches en hélium et le problème de l'origine de l'hydrogène dans les hybrides de type DBA", (P. Bergeron / G. Fontaine), November 2019, now a Junior Data Scientist at CANN Forecast, Montreal, QC, Canada.

ROY-GAROFANO, V., "Diagnostiques spectroscopiques de plasmas RF en régime de pulvérisation physique et en présence de générations successives de poussières dans les chimies organosiliciées", (L. Stafford), April 2019, maintenant un Professeur en physique, CEGEP ST-Laurent, Montréal, QC, Canada.

Université d'Ottawa / University of Ottawa

ALMALKI, S., "Nano-engineering of High Harmonic Generation in Solid State Systems", (T.Brabec), October 2019, now an Assistant Professor of Physics, Najran University, Saudi Arabia.

BEAMISH, E., "Biomarker Assay Development and Sensing with Solid-State Nanopores", (M. Godin), October 2019, now Patent Agent Trainee at MERIZZI RAMSBOTTOM & FORSTER.

BOUCHARD, F., "Quantum cryptography beyond qubits", (E. Karimi), October 2019, now a Research Associate, National Research Council Canada, Ottawa, ON, Canada.

BRIGGS, K., "Solid-State Nanopores: Fabrication, Application, and Analysis", (V. Tabard-Cossa), March 2019, now a CEO and co-founder at Northern Nanopore Instruments.

DING, X., "Increasingly complex systems in intense laser fields", (P.Corkum), December 2018, now a Postdoctoral fellow at the University of Michigan, Ann Arbor, MI, USA.

GAO, S., "Fabrication of tapered dual-core As2Se3-PMMA fiber and its applications", (X. Bao), March 2019, now a Lecturer, Shandpong Normal University, Jinan, Shandong province, China.

GUAY, J-M., "Metal colorization using picosecond laser pulses", (A.Weck / P. Berini), May 2019, now a Research And Development Scientist at Iridian Spectral Technologies.

KONG, F., "High-order harmonic generation with structured beams", (P. Corkum), October 2019, now a System Design Engineer, Ciena Canada, Ottawa, ON, Canada.

KUCHAR, J., "How water, ice, and sediment deform the Earth: Novel developments and applications of models of glacial isostatic adjustment", (G.Milne), December 2018, now working at Statistics Canada, Ottawa, ON, Canada.

MELANSON, A., "Effective stochastic models of neuroscientific data with application to weakly electric fish", (A. Longtin), May 2019, now a Lecturer in Physics, Université de Moncton, Moncton, NB, Canada.

NESRALLAH, M., "Kerr Nonlinear Instability: Classical and Quantum Optical Theories", (T.Brabec), October 2019, now a Postdoctoral fellow at University of Ottawa, Ottawa, ON, Canada.

OULD HAMOU, C.A., "Decomposition Mechanism of Lignin Models on Pt(111): Combining Single Crystal Experiments and First-Principles Calculations", (J.Giorgi), May 2019, now a Senior Scientific project Coordinator at Health Canada, Ottawa, ON, Canada.

SAFARI, A., "Resonant Light-Matter Interaction for Enhanced Control of Exotic Propagation of Light", (R.Boyd), May 2019, now a Postdoctoral fellow at University of Ottawa, Ottawa, ON, Canada.

SAXENA, B., "Electrostriction in As2Se3-PMMA Microtapers", (X. Bao), December 2019, now a Postdoctoral Fellow at the University of Waterloo, Waterloo, ON, Canada.

University of Regina

BEATTIE, T., "Measurement of the Beam Asymmetry for the eta and eta-prime mesons with the GlueX Experiment", (Z. Papandreou), June 2019, now a Postdoctoral Fellow at University of Regina, Regina, SK, Canada.

KOLACEKE, A., "Applications of Synchrotron Radiation Techniques to the Study of Taphonomic Alterations and Preservation in Fossils", (M. Barbi), March 2019, now a Quantitative Analyst at Bank BNP Paribas, Lisbon, Portugal.

University of Saskatchewan

DUNLEA, C., "Magnetic Compression of Compact Tori Experiment and Simulation", (C. Xiao), Fall 2019, now pursuing a Postdoctoral Fellowship, at Tokamak Energy, United Kingdom.

HUYGHEBAERT, D., "The Ionospheric Continuous-Wave E-Region Bistatic Experimental Auroral Radar (ICEBEAR)", (G. Hussey), Fall 2019, now pursuing a Postdoctoral Fellowship, Living Planet Fellow, at University of Saskatchewan, Saskatoon, SK, Canada.

RIEGER, L., "Improvements to the Limb Scattering Stratsopheric Aerosol Record", (A.Bourassa / D. Degenstein), Spring 2019, now a Guest Scientist, at Environment and Climate Change Canada, Victoria, BC, Canada.

ROMADANOV, I., "Theoretical and Experimental Studies of Large Scale Modes in Hall Thrusters and Methods of Their Control", (A. Smolyakov), Spring 2019, now a Postdoctoral Fellowship, at Nova Scotia Health Authority, Halifax, NS, Canada.

SAGE, F., "Aspects of Scalar Field Theory and the Dark Matter Problem", (R. Dick), Spring 2019, now a Software Developer, at Vendasta Technologies, Saskatoon, SK, Canada.

TAYLOR, B., "A Positive Ion Beamline for Space Qualification of Birefringent Materials", (A. Bourassa / M.Bradley), Fall 2019, now a Research Engineer, at Honeywell Aerospace, Kanata, ON, Canada.

Université de Sherbrooke

ACHECHE, S., "Effets des corrélations électroniques et du champ magnétique dans les semi-métaux de Weyl", (A.-M. Tremblay), Janvier 2019, now a Data Scientist orienté recherche at Thales, Paris, France.

BOUTIN, S., "Ingénierie optimale et signatures micro-ondes de modes de Majorana en physique mésoscopique", (I. Garate), Juin 2019, now a Postdoctoral Researcher at Microsoft at Santa Barbara, CA, USA.

CAMIRAN-LEMYRE, J., "Ingénierie de systèmes quantiques pour une mise à l'échelle

compatible aux plateformes industrielles de microélectronique", (M. Pioro-Ladrière), Décembre 2019, now Président of Nord Quantique, Sherbrooke, QC, Canada.

LEGROS, A., "Étude en transport de la phase pseudogap des cuprates supraconducteurs : point critique, limite Planckienne et transformation de la surface de Fermi", (L. Taillefer / D. Colson), Janvier 2019, now a Postdoctoral Research Scholar at Johns Hopkins University, Baltimore, MD, USA.

RINKEL, P., "Dynamique du réseau dans les semimétaux de Weyl sous champ magnétique", (I. Garate), Janvier 2019, now a Machine Learning Researcher at Uncharted Technologies, Paris, France.

ROYER, B., "Photons micro-ondes, mesure et informatique quantique", (A. Blais), Juin 2019, now a Postdoctoral Researcher at Yale, New Haven, CT, USA.

University of Toronto

BADALI, M., "Extinction, Fixation and Invasion in an Ecological Niche", (A. Zilman), September 2019, now a High School Science Teacher.

BERGER, P. J., "End-to-end Pipeline Methods for Full-sky 21 cm Cosmology: Application to the CHIME Pathfinder Array", (J.R. Bond / U.L. Pen), June 2019, now pursuing a Postdoctoral Fellowship at Jet Propulsion Laboratories, Pasadena, CA, USA.

CATUNEANU, A., "Magnetic and topological aspects of spin liquid candidates with strong spin-orbit coupling", (H.Y. Kee), June 2019, now a R&D Scientist at Dana Incorporated.

CRESSWELL, J. C., "Quantum Information Approaches to Quantum Gravity", (A.W. Peet), September 2019, now a Machine Learning Scientist at Layer6 AI, Toronto, ON, Canada.

DEMARCO, D., "Searching for the Higgs Boson Produced in Association with a Pair of Top Quarks in Multilepton Final States Using the ATLAS Detector at the LHC", (R.S. Orr), June 2019, now a Special Projects Officer at Trinity College, University of Toronto, Toronto, ON, Canada.

GALLOWAY, M. N., "Stratospheric Ballooning with SPIDER and BIT", (C.B. Netterfield), June 2019, now pursuing a Postdoctoral Fellowship at the Institute of Theoretical Astrophysics, University of Oslo, Norway.

GOMES, G., "An Integrative Modelling Approach for Disordered Proteins Using Single-Molecule Fluorescence Spectroscopy", (C.C. Gradinaru), September 2019, now pursuing a Postdoctoral Fellowship at the University of Toronto, Mississauga, ON, Canada.

GU, C. M., "Course-grained Theory and Simulation of Assemblies of Intrinsically-Disordered Nucleoporins", (A. Zilman), June 2019, now a Data Scientist at Unity Technologies, Montreal, QC, Canada.

KOLONJARI, F., "An Investigation of the Distribution of Ozone Depleting Substances in the Upper Troposphere and Lower Stratosphere", (K. A. Walker), June 2019, now a Senior Program Advisor, Environment and Climate Change Canada, BC, Canada.

LAKHLANI, G., "The Structure and Dynamics of the Interstellar Medium in the FIRE Simulations", (N. Murray), June 2019, now a Risk Manager at Scotia Bank, Toronto, ON, Canada.

LIBLONG, A., "Measurement of the Higgs Boson Produced in Association with a Z Boson and Decaying to WW* with a Leptonic Final State in pp Collisions at $\sqrt{s}$ = 13TeV with the ATLAS Detector", (P. Krieger), June 2019, now a Senior Data Scientist at Loblaw Digital, Toronto, ON, Canada.

LIN, C., "Investigating Fine Structures of the Earth's Interior Based on Spectral-Element Seismic Wave Simulations", (Q. Liu), June 2019, now looking for employment.

LIU, L., "Chemistry in Action: Making Molecular Movies with Ultrafast Electron Diffraction and Data Science", (R.J.D. Miller), September 2019, now a Research Scientist at AI and Data, Toronto, ON, Canada.

LUTSCH, E., "The Influence of Biomass Burning on the Arctic Atmosphere", (K. Strong), September 2019, now pursuing a Postdoctoral Fellowship at the University of Toronto, Toronto, ON, Canada.

MANCHEE, K., "Ultrafast Lasers and Amplifiers based on Yb-doped Gain Materials", (R.J.D. Miller), June 2019, now an Electro-Optical Designer at L3 WESCAM, Guelph, ON, Canada.

PASCUZZI, V. R., "Looking for Beyond the Standard Model Physics in Dijet-Plus-Lepton Events Collected with the ATLAS Detector", (P. Krieger), September 2019, now a Postdoctoral research scholar at Berkeley Lab, San Francisco, CA, USA.

RAMOS BENITEZ, J. R., "Tunnelling Time of a Bose-Einstein Condensate", (A.M. Steinberg), September 2019, now pursuing a Postdoctoral Fellowship at ICFO, Barcelona, Spain.

SHALCHIAN TABRIZI, M. E., "A Convergent Continuum Strong Coupling Expansion for Quantum Mechanics & Quantum Field Theory/ String Tensions in Deformed Yang-Mills Theory", (E. Poppitz), September 2019, now looking for employment.

SONG, X., "Seimic Array Imaging of South-Central Alaska Subduction Zone Based on Teleseimic Body Waves: from Finite-Frequency Tomography to Full-Waveform Inversions", (Q. Liu), September 2019, now looking for employment.

TSAI, C. A., "Enhancing GPR Surveys by Utilizing Dispersive properties and Phase Information", (R.R. Ghent), June 2019, now a Data Scientist at Ingram Micro.

VINCENT, T., "Binary Neutron Star Simulations: New Tools and Insights", (H.P. Pfeiffer), September 2019, now a High-Performance Computing Specialist at Xanadu, Toronto, ON, Canada.

VOVK, A. I., "Coarse Grained Modeling of Intrinsically Disordered Protein Structures and Dynamics", (A. Zilman), September 2019, now looking for employment.

WEAVER, D., "Water Vapour Measurements in the Canadian High Arctic", (K. Strong), June 2019, now a Tenure stream Lecturer, University of Toronto, Scarborough, ON, Canada.

ZHANG, X., "Mitigating the Impact of Chemical Transport Model Biases on Top-Down CO ad Nox Emission Estimates Using Multi-Species Chemical Data Assimilation", (D.B.A. Jones), September 2019, now a Sessional Lecturer at the University of Toronto, Toronto, ON, Canada.

University of Victoria

BEAULIEU, A., "The Study and Shielding of Electromagnetic Radiation from SuperKEKB Electron and Positron Beam Interactions", (M. Roney), April 2019, now a Regional Director at LTI Informatique et Génie/Software and Engineering, Montréal, QC, Canada.

BREITKREUTZ, D., "Design and evaluation of a Monte Carlo model of a low-cost kilovoltage x-ray arc therapy system", (M. Bazalova-Carter), June 2019, now a Medical Physics Resident at Stanford Medicine, Stanford, CA, USA.

JOHNSTONE, C., "Microcomputed Tomography Dosimetry and Image Quality in Preclinical Image-Guided Radiation Therapy", (M. Bazalova-Carter), April 2019, now a Medical Physics Resident at Princess Margaret Cancer Centre, Toronto, ON, Canada.

LONGO, S., "First Application of CsI(TI) Pulse Shape Discrimination at an e+e- Collider to Improve Particle Identification at the Belle II Experiment", (M. Roney), October 2019, now starting a DESY Fellowship in Experimental Particle Physics, Hamburg, Germany.

MAYNARD, E., "Applications of x-ray computed tomography polymer gel dosimetry", (A. Jirasek / M. Hilts), December 2018, now a Medical Physics Resident at BC Cancer Agency, Victoria, BC, Canada.

University of Waterloo

BAO, C., "Loop Optimization of Tensor Network Renormalization: Algorithms and Applications", (N. Turok), October 2019.

BOGAN, A., "Few Hole Quantum Dots in a Gated GaAs/AlGaAs Heterostructure", (J. Kycia / S. Studenikin), October 2019.

CHAMBERLAND, C., "New Methods in Quantum Error Correction and Fault-Tolerant Quantum Computing", (R. Laflamme), June 2019.

CORONADO, F., "Constructing Exact Correlators in N = 4 SYM Using Integrability", (P. Vieira / R. Myers), October 2019.

DI MATTEO, O., "Methods for Parallel Quantum Circuit Synthesis, Fault-Tolerant Quantum RAM, and Quantum State Tomography", (M. Mosca), June 2019.

DRAKOS, N., "The Evolution of Dark Matter Haloes in Mergers", (J. Taylor), October 2019.

FLANNERY, J., "Optical Resonators Integrated into a Hollow Core Photonic Crystal Fiber for Enhanced Light-Matter Interactions", (M. Bajcsy), October 2019.

HAAS, H., "Engineering Effective Hamiltonians for Magnetic Resonance", (D. Cory), October 2019.

ISHTIAQUE, N., "On Cohomological Algebras in Supersymmetric Quantum Field Theories", (J. Gomis), October 2019.

KARAMI, M., "Probing the Dark Universe with Gravitational Lensing", (N. Afshordi / A. Broderick), June 2019.

KATIYAR, H., "Control Techniques in Spin Based Quantum Computation", (R. Laflamme), October 2019.

KIEFEROVA, M., "Quantum Algorithmic Techniques for Fault-Tolerant Quantum Computers", (M. Mosca), October 2019.

KULCHYTSKYY, B., "Probing Universality with Entanglement Entropy via Quantum Monte Carlo", (R. Melko), October 2019.

KUMARI, M., "Quantum-Classical Correspondence and Entanglement in Periodically Driven Spin Systems", (S. Ghose / R. Mann), October 2019.

LEE, Y., "Transition Matrix Monte Carlo Methods for Complex Systems", (D. Yevick), June 2019.

MACLEAN, J., "Ultrafast Metrology in the Quantum Domain", (K. Resch), June 2019.

MARROCHIO, H., "Complexity in the AdS/CFT Correspondence", (R. Myers), October 2019.

MBAREK, S., "Explorations of Black Hole Thermodynamics in de Sitter Spacetime", (R. Mann), June 2019.

MCMAHON, C., "Symmetry of the Charge Ordering Phases in Hole-Doped Cuprates Studied by Resonant X-ray Absorption and Scattering", (D. Hawthorn), October 2019.

MIZERA, S., "Aspects of Scattering Amplitudes and Moduli Space Localization", (B. Dittrich) (F. Cachazo), October 2019.

MOOSAVIAN, S., "Some Applications of Hyperbolic Geometry in String Perturbation Theory", (D. Gaiotto / J. Gomis), October 2019.

MORADI, H., "Topological Order and Universal Properties of Gapped Quantum Systems", (X.G. Wen) (R. Melko), June 2019.

NG, K., "Sensing the Shape of Spacetime: Detector Response and Entanglement Harvesting in Curved Space", (R. Mann), June 2019.

NOURBAKHSH, S., "Biophysical Modelling of Antimicrobial Peptide's Interactions with Phospholipid and Lipopolysaccharide Membranes", (B.Y. Ha), October 2019.

OKOLI, C., "Dark Matter and Neutrinos in the Foggy Universe", (N. Afshordi / J. Taylor), June 2019.

POMARANSKI, D., "Precision Low Temperature Calorimetry and Susceptibility of Magnetic Pyrochlores", (J. Kycia), June 2019.

RAPCAK, M., "The Vertex Algebra Vertex", (D. Gaiotto / J. Gomis), October 2019.

TORLAI, G., "Augmenting Quantum Mechanics with Artificial Intelligence", (R. Melko), June 2019.

VANTYGHEM, A., "An ALMA View of Molecular Gas in Brightest Cluster Galaxies", (B. McNamara), June 2019.

University of Windsor

DECH, J., "Electron Collisions with Atoms and Molecules", (W. McConkey), June 2019, now a Senior R&D Engineer, Charged Particle Optics Systems at Multibeam Corporation, San Francisco Bay Area, CA, USA.

Western University

Pubuditha A., "Calculating the dimensionality of the brain, and other applications of an optimized generalized Ising model in predicting the brain's spontaneous fluctuations", (A. Soddu), June 2019, now pursuing a Postdoctoral Fellowship at Monash University, Melbourne, Australia.

Shayamila M, G., "Development of a 1-dimensional data assimilation to determine temperature and relative humidity combining Raman lidar back-scatter measurements and a re-analysis model", (R J. Sica), October 2019, now pursuing a Postdoctoral Fellowship at Université de Montréal, QC, Canada.

CAP Departmental Members / *Membres départementaux de l'ACP*

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Book Review Policy

Books may be requested from the Book Review Editor, Richard Marchand, by using the online book request form at http://www.cap.ca. You must be a residing in Canada to request a book.

CAP members are given the first opportunity to request books. For non-members, only those residing in Canada may request a book. Requests from non-members will only be considered one month after the distribution date of the issue of *Physics in Canada* in which the book was published as being available.

The Book Review Editor reserves the right to limit the number of books provided to reviewers each year. He also reserves the right to modify any submitted review for style and clarity. When rewording is required, the Book Review Editor will endeavour to preserve the intended meaning and, in so doing, may find it necessary to consult the reviewer. Reviewers submit a 300-500 word review for publication in PiC and posting on the website; however, they can choose to submit a longer review for the website together with the shorter one for PiC.

La Politique Pour la Critique De Livres

Si vous voulez faire l'évaluation critique d'un ouvrage, veuillez entrer en contact avec le responsable de la critique de livres, Richard Marchand, en utilisant le formulaire de demande électronique à http://www.cap.ca.

Les membres de l'ACP auront priorité pour les demandes de livres. Ceux qui ne sont pas membres et qui résident au Canada peuvent faire une demande de livres. Les demandes des non-membres ne seront examinées qu'un mois après la date de distribution du numéro de la Physique au Canada dans lequel le livre aura été déclaré disponible.

Le Directeur de la critique de livres se réserve le droit de limiter le nombre de livres confiés chaque année aux examinateurs. Il se réserve, en outre, le droit de modifier toute critique présentée afin d'en améliorer le style et la clarté. S'il lui faut reformuler une critique, il s'efforcera de conserver le sens voulu par l'auteur de la critique et, à cette fin, il pourra juger nécessaire de le consulter. Les critiques pour publication dans la PaC doivent être de 300 à 500 mots. Ces critiques seront aussi affichées sur le web; s'ils le désirent les examinateurs peuvent soumettre une plus longue version pour le web.

Books Received / *Livres Reçus*

The following titles are a sampling of books that have recently been received for review. Readers are invited to write reviews, in English or French, of books of interest to them. Unless otherwise indicated, all prices are in Canadian dollars.

Lists of all books available for review, books out for review and book reviews published since 2011 are available on-line at www.cap.ca (Publications).

In addition to books listed here, readers are invited to consider writing reviews of recent publications, or comparative reviews on books in topics of interest to the physics community. This could include for example, books used for teaching and learning physics, or technical references aimed at professional researchers.

Les titres suivants sont une sélection des livres reçus récemment aux fins de critique. Nous invitons nos lecteurs à nous soumettre une critique en anglais ou en français, sur les sujets de leur choix. Sauf indication contraire, tous les prix sont en dollars canadiens.

Les listes de tous les livres disponibles pour critique, ceux en voie de révision, ainsi que des critiques publiées depuis 2011 sont disponibles sur : www.cap.ca (Publications).

En plus des titres mentionnés ci-dessous, les lecteurs sont invités à soumettre des revues sur des ouvrages récents, ou des revues thématiques comparées sur des sujets particuliers. Celles-ci pourraient par exemple porter sur des ouvrages de nature pédagogique, ou des textes de référence destinés à des professionnels.

GENERAL / GÉNÉRAL

The Physics of Polarized Targets, Tapio O. Niinikoski, Cambridge University Press, 2020; pp. 530; ISBN: 978-1108475075; Price: 218.95.

Theory of Simple Glasses: Exact Solutions in Infinite Dimensions, Giorgio Parisi, Pierfrancesco Urbani & Francesco Zamponi, Cambridge University Press, 2020; pp. 349; ISBN: 978-1107191075; Price: 91.95.

UNDERGRADUATE LEVEL / NIVEAU DE PREMIER CYCLE

Principles of Optics: 60th Anniversary Edition, Max Born & Emil Wolf, Cambridge University Press, 2019; pp. 992; ISBN: 978-1108477437; Price: 79.95.

The Cosmic Revolutionary's Handbook: (Or: How to Beat the Big Bang), Luke A. Barnes & Geraint F. Lewis, Cambridge University Press, 2020; pp. 286; ISBN: 978-1108486705; Price: 25.95.

Theoretical Concepts in Physics An Alternative View of Theoretical Reasoning in Physics (3d ed.) [v], Malcolm S. Longair, Cambridge University Press, 2020; pp. 636; ISBN: 9781108484534; Price: 68.95.

SENIOR LEVEL / NIVEAU SUPÉRIEUR

Invariant Imbedding T-matrix Method for Light Scattering by Nonspherical and Inhomogeneous Particles, Bingqiang Sun, Lei Bi, Ping Yang, Michael Kahnert and George Kattawar, Elsevier, 2020; pp. 262; ISBN: 978-0-12-818090-7; Price: 158.11.

Mean Field Theory, Vladimir M Kolomietz, Shalom Shlomo [v], World Scientific, 2020; pp. 588; ISBN: 978-981-121-177-5; Price: 252.95.

Pear-Shaped Nuclei, Suresh C Pancholi, World Scientific, 2020; pp. 192; ISBN: 978-981-121-759-3; Price: 121.61.

Statistics, Data Mining, and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data, Updated Edition, Zeljko Ivezić, Andrew J. Connolly, Jacob T. VanderPlas, and Alexander Gray, Princeton University Press, 2019; pp. 560; ISBN: 9780691198309; Price: 103.58.

Book Reviews / *Critiques de livres*

Further Adventures of the Celestial Sleuth, by Olson, Donald W., Springer, 2018, pp. 334, ISBN: 978-3-319-70319-0, price 32.84.

I selected this book because I was intrigued by its premise: using astronomy to solve mysteries regarding the time, date and location of the origins of works of art. As a secondary school physics teacher, I am always interested in finding other ways to teach students about the applications of the knowledge and skills we teach them in school, and this text did not disappoint.

The book reads much like a Sherlock Holmes case file. Donald W. Olson describes how he and his team from Texas State examined paintings, battles, photographs, and literature through an astronomical lens, to locate, re(examine) and challenge their understandings of the works, as well as the conclusions of other researchers. Clues, such as historical documents (e.g., letters, train schedules, tide tables, newspaper clippings) are combined with modern means (e.g., computer planetarium simulations), to build their own portrait, which includes information about the astronomy, as well as the artists themselves.

Broken into four parts — *Astronomy in Art, Astronomy in History, Astronomy in Literature, The Terrestrial Sleuth* — Olson begins each chapter outlining the questions he and his team had set out to solve. In Part One, the challenge was often to deduce the location and date for a painting. Olson works with an underlying assumption that the artist included an accurate representation of what was present in the night sky from their location. From this, he uses stories about the artists and other references to the work, to deduce his answers. Olson also includes in this section an examination of *Times Square Kiss* — and specifically the shadows on the buildings — to add more information to the ongoing discussion on the as-yet unidentified woman and sailor. In Part Two, the team sought to better understand the factors which influenced strategic battle preparations (such as the case for the Battle of Stirling Bridge or the Battle of Normandy), and worked with data to highlight misconceptions. Part Three focuses on literary passages, to determine their accuracy, in terms of celestial movements and season. Olson uses knowledge of each author's astronomical competence to frame the possible legitimacy of the passages, and then move on to determine whether authors had accurately described astronomical events or celestial movements based on the season or location of a scene. In the final part, Olson turns to two final puzzles: a railway and locating the Millais oak tree.

This is the second ***Celestial Sleuth*** book, and Olson makes reference to other case files in that volume — although not required to understand what is discussed here. The background knowledge required to understand the text is at the secondary level, and new material and terminology is explained succinctly to allow the reader to follow key ideas of analyses. For me, I felt it did provide some interesting options from which to teach physics at the secondary level, such as Chaucer's description of the moon's path in terms of Kepler's Laws of motion. For the higher education educator, I feel the book gives enough information to provide a roadmap of the kinds of information and tools one would need to endeavor on a similar quest.

Tasha Richardson,
Teacher, Albert Campbell CI, Toronto District School Board

On Gravity—A Brief Tour of a Weighty Subject, by Anthony Zee, Princeton University Press, 2018, ISBN: 9780691174389, price 19.95.

In the preface, Anthony Zee tells his readers that **On Gravity** is supposed to bridge the gap between popular books and textbooks on Einstein gravity. After reading the 142 pages of the main text and the eight-page appendix, I am convinced that he succeeded. The area between popular books and textbooks is somewhat of a no man's land, and especially for individuals with an interest in a particular field (say, gravity, for instance) this can be quite frustrating. What should you read when you already understand the basic idea of gravitation, know the main players in the history of its development, and have perhaps watched a few documentaries on the topic as well?

Well, you should read **On Gravity**.

The book is divided in four parts which consist of a handful of chapters each, and each chapter is again split into digestible sections with fitting and sometimes tongue-in-cheek headlines. Zee is one of the few physics authors who write so fluently and seemingly effortlessly that I didn't even realize I was already halfway through the book. His tone, as usual, is relaxed, conversational, and laid-back, making the seemingly complicated topic of Einstein's General Theory of Relativity a lot more approachable.

In part I, Zee introduces gravity as the weakest of the four fundamental forces in our Universe and explains the nature of electromagnetic (and gravitational) waves. In part II we learn about Einstein's main idea: the principle of relativity. We also learn why we shouldn't call it "principle of relativity." Part III is devoted to a detailed explanation of the action principle in both classical mechanics and gravity theory. Finally, in part IV we learn about black holes, Hawking radiation, gravitons, as well as the concepts of dark matter and dark energy. In the grand finale Zee highlights the importance of gravitational

waves, which, and that's the hope, will provide scientists with new powerful methods of observing and understanding the Universe.

On Gravity takes its time with the reader, and most concepts are explained brilliantly and in quite some detail: the idea of relativity, the action principle, gravitational waves, and even curved spacetime (in the appendix). I wish more professors would read this book and use these explanations in their undergraduate courses! The explanation of Hawking radiation, on the other hand, after a thorough introduction into the quantum uncertainty principle, seems a bit rushed and barely surpasses that given in popular science texts. Moreover, what I would have liked to see (and what is lacking in Zee's treatment) is a deeper discussion of the *limitations* of General Relativity. The Evergreen, a.k.a. the quest for the still elusive theory of quantum gravity, is clearly addressed, but problems at the classical level (say, in the form of gravitational singularities inside of black holes) are not mentioned. I think this is a missed opportunity to make this book more balanced.

Overall, **On Gravity** is a fantastic read. It is supplemented by a whopping 12-page index as well as 13 pages of annotations providing additional anecdotes, insights, and kindhearted encouragements to the reader. Zee's book might be a good choice for undergraduate students who are contemplating to enter the field but don't want to read 800 pages in a standard textbook. And if you work on gravity yourself, and you want to talk to your friends a bit more about your work, give them this book. Seriously. Zee's unique style will surely entice them and present research in gravity from its truly attractive side (pun intended).

Jens Boos,
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Practical Bayesian Influence: A Primer for Physical Scientists, by Coryn A.L. Bailer-Jones, Cambridge University Press, 2017, pp. 295, ISBN: 9781316642214, price 105.95.

Few fields are as fraught with a history of controversy as that of Bayesian inference. Although born in the 18th century in the work of Bayes and Laplace, its "subjective" view of probability fell out of favours in the 20th century after Neyman, Pearson, and others developed statistics based on a frequentist interpretation of probability. In the former, probability measures degrees of rational belief in the truth of a proposition; in the latter, probability is viewed as the limiting frequency in an infinite number of trials.

More recently, there has been a tremendous resurgence of Bayesian methods, which are at the heart of many successful methods in data science and machine learning. With this growth in popularity has come the need to teach the methods to broader scientific audiences. However, perhaps because of its "insurgent" past, many texts have been original and quirky. Think of the books by Harold Jeffreys, Edward Jaynes, D. S. Sivia, and David MacKay for example. Perhaps what makes such books brilliant and inspirational also makes them harder to teach from. Insights that appear deep to the expert may just confuse the student. (The same critique has been made of the Feynman Lectures.)

Coryn A. L. Bailer-Jones' book is an interesting pragmatic alternative. It is straightforward and clear, if not always original — many of its examples and ways of presenting material come from the "quirky" books above. Still, it may be easier to follow than other, deeper treatments. For example, Chapter 9 goes carefully through the procedure for curve fits using Markov-Chain Monte Carlo (MCMC) and also offers a treatment of data outliers using mixture models. The latter example provides a simple way to automatically identify and, in effect, exclude "bad" points from otherwise "good" data. And the introductory discussion to model selection — clarifies many points, such as why use odds ratios, that are often glossed over in other discussions.

An attractive feature of the book is its many numerical illustrations, supported by explicit code available online. Perhaps unfortunately, the chosen language is R, an open-source program from the statistics community that is not widely used by the physics community (at least that part I am familiar with). Matlab, Mathematica, and Python are more common. Of course, these languages share common features, and transcribing a routine into your favourite language can be a good exercise. A similar critique is that the notation, for example E[x] for expectation rather than ⟨x⟩, reflects conventions of statistics more than physics.

In short, Bailer-Jones has written an attractively brief, direct, "practical" introduction to Bayesian Inference. While its presentation and examples are often standard, it is well organized and very clear and should be much appreciated by upper-level undergraduates looking for an introduction to the field, assuming they do not get too hung up on the use of R and statistics notation. For graduate students seeking more depth and derivations, *Bayesian Probability Theory*, by Wolfgang von der Linden, Volker Dose, and Udo von Toussaint, is a comprehensive alternative. And, for inspiration, I still prefer Sivia's *Data Analysis: A Bayesian Tutorial*.

John Bechhoefer, Simon Fraser University

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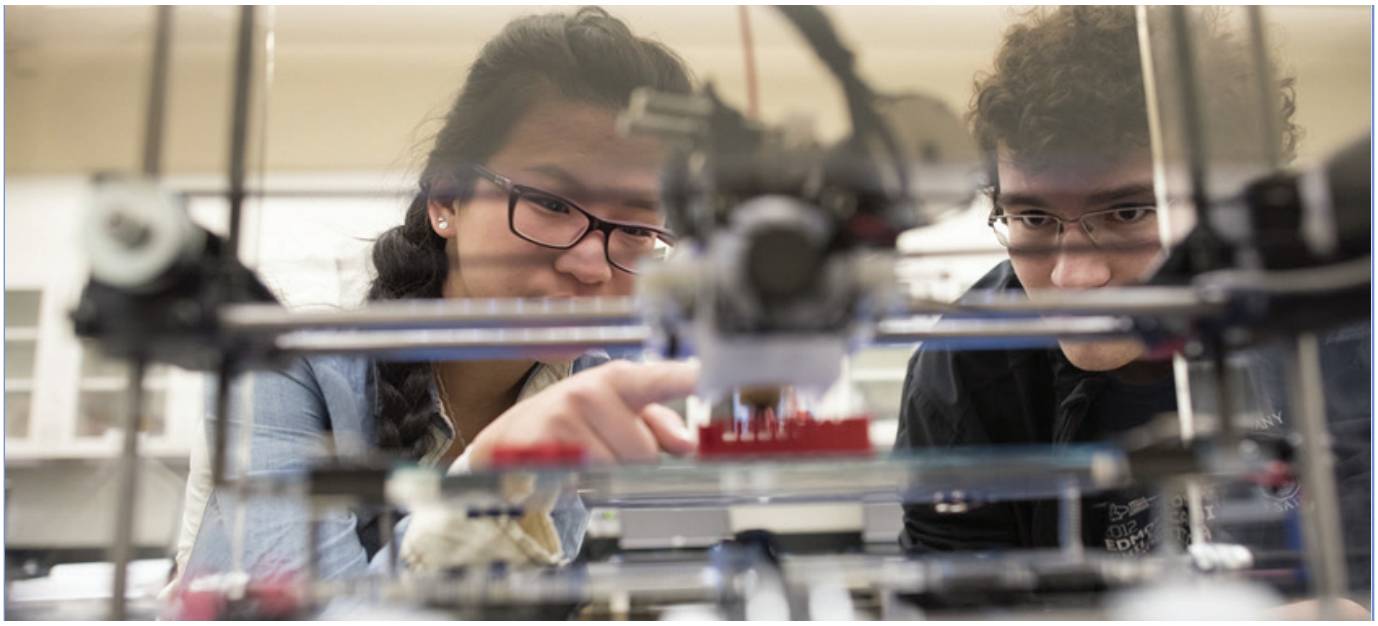

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