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Supplementary information

Changing scientific meetings for the better

In the format provided by the authors and unedited

Supplementary Information

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Supplementary Methods

An Online Database of in-person conferences in various scientific disciplines

Data extraction: Generating the database of in-person conferences. The majority of academic conferences do not report any form of raw or aggregate meeting statistics before or after the event. To compile a large list of national and international in-person conferences, we leveraged Google and lists available online (Supplementary Table 2) and searched for conferences in a wide selection of fields and looked for conferences that scientists would be commonly attending. We also used a number of conference lists compiled by journals and learned societies available online. All the academic meetings in our database were held between January 2018 and December 2019 and spanned a wide range of disciplines spanning engineering, natural sciences, life and biomedical sciences, medicine and a number of humanities disciplines (Supplementary Table 3). The data collected represented conferences organized by over 150 scientific societies and other organizations. We also selected conferences organized by funding agencies such as the United States National Institutes of Health (NIH), United Kingdom Wellcome Trust and United States National Science Foundation (NSF), conferences organized by publishing industry journals such as Nature and Elsevier as well as conferences organized by diagnostic and therapeutic biological companies such as pharmaceutical corporations. We recorded the name and geographic location of the conferences in our manually collated database available online on (https://elifeambassadors.github.io/improving-conferences/). Google searches were performed for each conference to identify the learned society/organization/entity/university/corporation in charge of organizing the meeting and the number of years the meeting has been held and the frequency of the meeting (i.e. held annually, biennially, more or less frequent). Further searches were performed to find the exact or estimated number of members each scientific society (if applicable to a specific conference) had registered. A separate search was performed for each conference, on the meeting website to identify the number of meeting attendees (exhibitors included). If the number of attendees was not provided on the meeting website, full program or program report (in the cases where the conference was already held), a Google search was performed instead. If after all search avenues were exhausted, the exact attendee number was not available online, an estimated number of attendees or society members was used instead (by comparison to members and attendees counts of societies in related fields). The number of attendees was collected to calculate/estimate the total meeting air travel and other (ground transportation, food and accommodation) attendee footprint. We quantified various features of the conferences from the information we had collected manually using the corresponding conference website. When quantifying the number of men and women speakers, chairs, organizing and scientific committee members, in cases where a name appeared ambiguous, we searched for the first and last name of the researcher with their university affiliation and field of

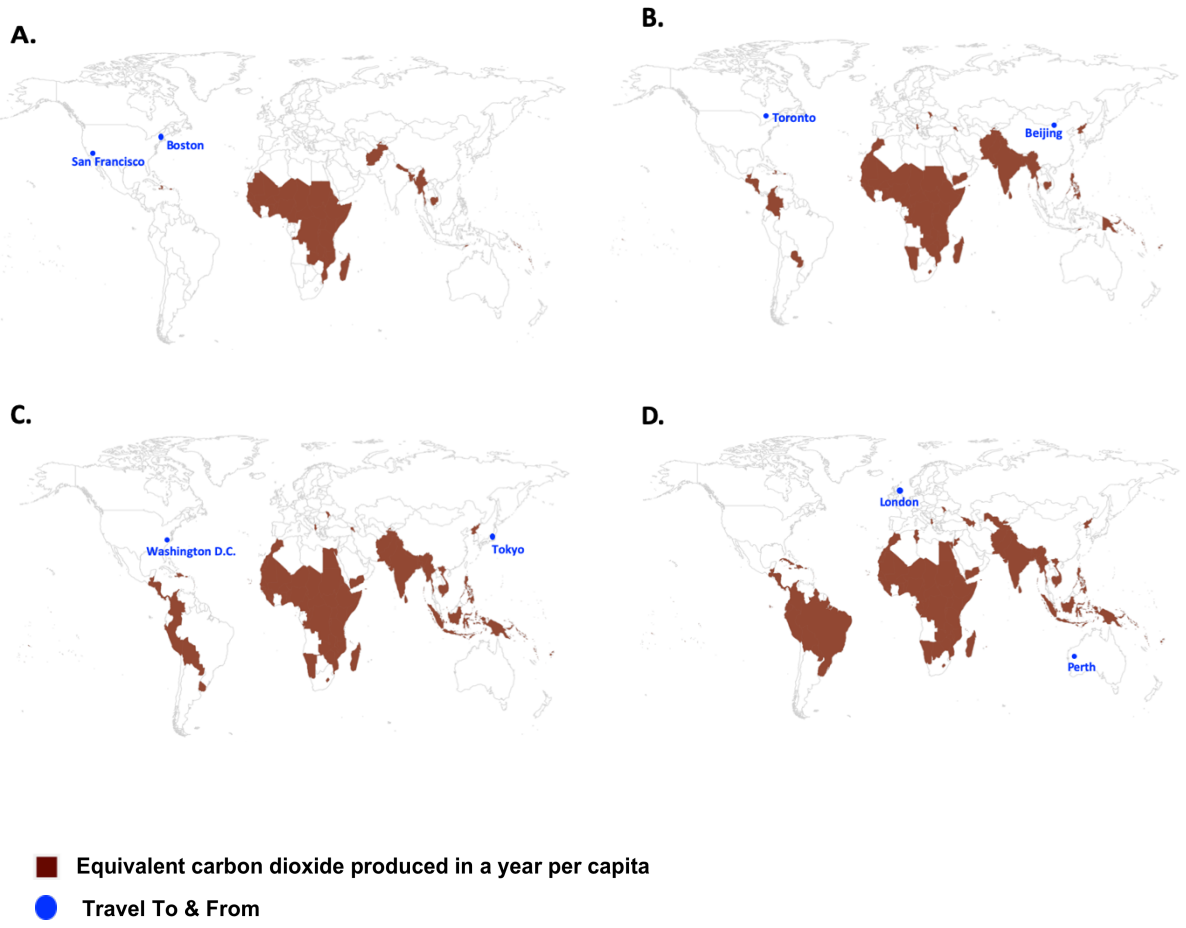
expertise/research/conference topics to locate a photo. Aggregate summaries of the database is presented as Figures 1-2 and supplementary tables 2-11. On each conference website, the name of the conference, geographic location of the meeting, hosts/funders/sponsors, the year that the meeting was held, number of attendees, registration costs for different types of attendees, digital or virtual conferences with live streaming of talks and digital poster options (meaning online posters, excluding digital or ePosters on physical stands on site), availability of recorded talks and ePosters/iPosters (digital libraries), digital libraries/archives of talks, posters and slides after the meeting was held, total conference cost for each attendee (converted to US dollars), minimum and maximum meeting registration cost for each attendee availability of full (both oral and poster sessions detailed) conference program as electronic/virtual meeting scientific program, (keywords "program", "agenda", "schedule" book, "meeting planner", "meeting App" for the scientific program book file or App (talks and abstracts), estimate air travel and other carbon footprint for total attendees of each meeting, on-site or off-site, free or at a cost childcare facilities, lactation or nursing rooms or personal consideration rooms, caregiver grants, types of career development workshops offered, types of Early career Researcher (ECR) promotion events (poster or oral/platform presentation awards, ECR symposia), networking events (mixers, meet and greet, ice-breaker or meet the experts events for trainees), availability of code of conduct, code of ethics (or research integrity), local safety instructions or Apps or facilities (e.g. a body system for watching out for fellow attendees, free bus/train), gender equity statement, diversity statement, invited speakers (those hand-picked by conference organizers, rather than scientists who put themselves forward to give talks or present posters) such as keynote speaker/opening/closing speakers names, plenary speaker names, conference chair names, organizing or steering committee names, session chair/organizer/moderator/convenor/discussion leader names and invited or featured speaker names, environmental sustainability events, public outreach events (such as free public lectures or engagement with local schools and libraries) and green policies were indicated and recorded in our database for this study. To explore early career promotion and appreciation events on conference websites, we looked with terms such as "award", "scholarship", "fellowship", "funding" and "prize". To search for session heads, we searched with keywords such as "session chair", "session moderator", "session organizer" and "session convenor". To find the conference organizing committee, searches were performed with words such as "program committee" or "scientific committee". Searches were also performed to count men and women members of the "organizing committee" or "planning committee" or "steering committee". A separate Google search provided the corresponding academic discipline, the scientific organization associated or supporting the meeting and the most recent number of society members. To find information about sponsoring organizations, institutions or corporations which provided financial, intellectual or media support/partners, searches were performed using keywords "sponsors", "supporters" and "partners" on each meeting website. To source information on code of ethics, we searched the conference and associated learned society webpage with the keywords "code of ethics", "statement of ethics", "professional code of conduct" and "statement/code of research integrity". To explore the available information on the statement of gender equity, we searched the conference and corresponding society website with the keywords, "gender balance statement", "gender equity statement", "diversity statement", "inclusion statement". We also examined the conference webpages for their "sustainability initiatives" or "green policies strategies or considerations" incorporated into the organization of these conferences. We also included the meeting URL address and other important announcements, features or notices available for attendees (such as epidemics or phishing scams for flights and accommodations that could impact attendees).

Data Visualization

Data visualized in Supplementary Figure 1 were sourced from the Carbon Footprint Calculator: https://calculator.carbonfootprint.com/calculator.aspx?tab=3. Data visualized in Supplementary Figure 2 on the annual fossil CO_2 emission per capita for the year 2017 were sourced from https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions and

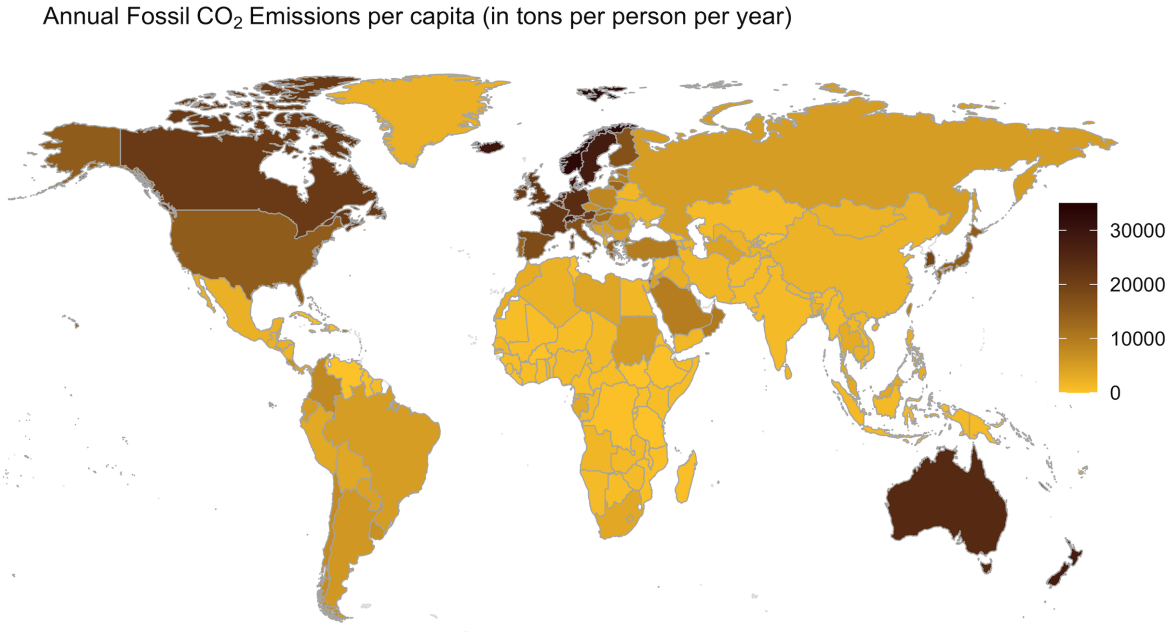
https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. Data visualized in Supplementary Figure 3 on the 2019 gross minimum wage worldwide (full amount an employer pays before taxes and other deductions are withheld) minimum annual (earned for 12 months in US dollars) were sourced from https://data.worldbank.org/indicator/PA.NUS.PRVT.PP. Data visualized in Supplementary Figure 4 were sourced from: https://www.henleyglobal.com/henley-passport-index/. All supplementary figures were made with R and the ggplot2 package (https://books.google.com/books?hl=en&lr=&id=XgFkDAAAQBAJ&oi=fnd&pg=PR8&ots=spY07U8X3P&sig=Vw5aHFonM3Ee56OTEuWCfgUXA-c#v=onepage&q&f=false), with colours from the RcolorBrewer package (https://cran.r-project.org/web/packages/RColorBrewer/index.html). Code and data underlying all figures are available on (http://doi.org/10.5281/zenodo.4067243). All in-person conference data displayed in Figure 1 were manually collated from https://elifeambassadors.github.io/improving-conferences/.

Supplementary Figures

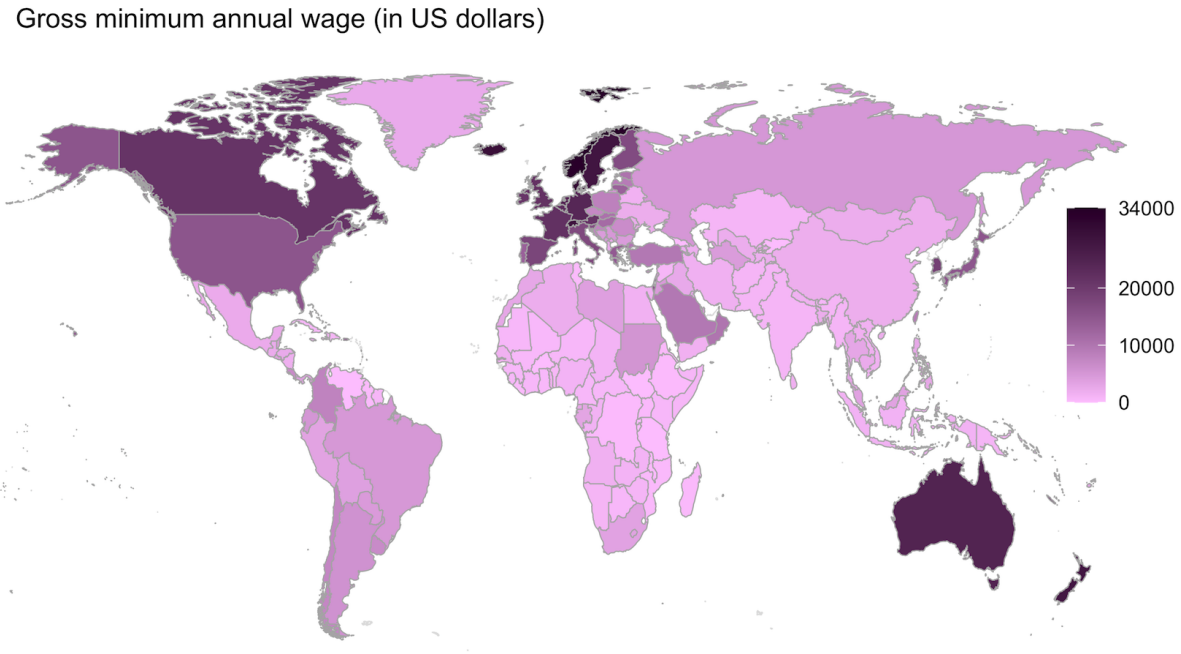


Supplementary Figure 1. In-person conferences leave a large carbon footprint. The air travel of a *single* attendee emits as much CO_2 as many people do in a year. Even short-haul and domestic flights produce large amounts of CO_2. A) Flying from Boston, Massachusetts to San Francisco, California and back for an annual American Biophysical Society (BPS) conference generates about 623 kg (0.69 tons) of CO_2. There are 47 countries where the average person produces less CO_2 in a year (shown in colour here). B) Flying from Beijing, China to Toronto, Canada and back for a Society for Neuroscience (SfN) meeting generates

about 1,621 kg (1.79 tons) of CO_2. There are 84 countries where the average person produces less CO_2 in a year (shown in colour here). C) Flying from Tokyo, Japan to Washington D.C, United States and back to attend an annual American Association for Cancer Research (AACR) conference generates about 2,144 kg (2.36 tons) of CO_2. There are 91 countries where the average person produces less CO_2 in a year (shown in colour here). D) Flying from Perth, Australia to London, United Kingdom and back for the annual Immuno-Oncology summit generates about 3,153 kg (3.47 tons) of CO_2. There are 109 countries where the average person produces less CO_2 in a year (shown in colour here) (Data Source, Carbon Footprint Calculator (Supplementary Table 8)). Comparable to global annual per capita CO_2 emissions in many countries (Supplementary Figure 2).

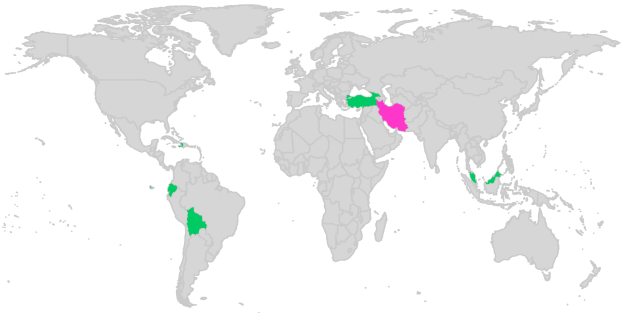


Supplementary Figure 2. The Annual Fossil CO_2 Emission per capita: Qatar at 47.8 tons of CO_2 per capita, United States at 16.4 tons of CO_2 per capita (more than three times the global per capita average), and China at 7.4 tons per capita are amongst the highest emitting countries. Data shown here is for the year 2017 (Data source: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions & https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data).



Supplementary Figure 3. Shown is the gross (full amount an employer pays before taxes and other deductions are withheld) minimum annual (12 months) wages (in US dollars) for the year 2019 (data source https://data.worldbank.org/indicator/PA.NUS.PRVT.PP & https://stats.oecd.org/Index.aspx?DataSetCode=RMW). Early career researcher salaries are at minimum annual wage worldwide (https://www.payscale.com/research/UK/Job=Postdoctoral_Research_Associate/Salary). Attending a single national or international conference typically costs USD $1,000-$4,000 (https://elifeambassadors.github.io/improving-conferences/) hence attending in-person conferences is not feasible for many researchers in particular early researchers worldwide.

A.



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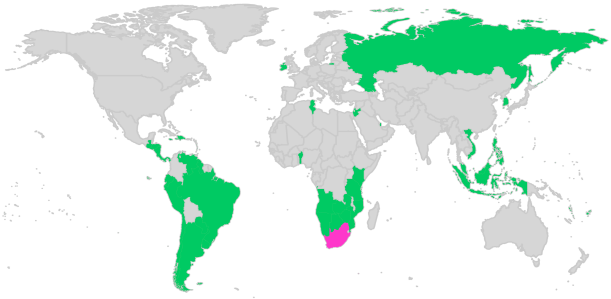

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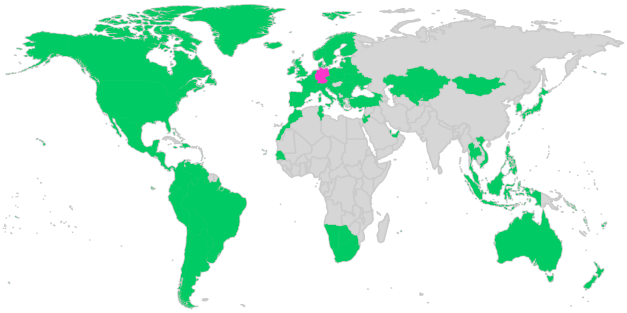

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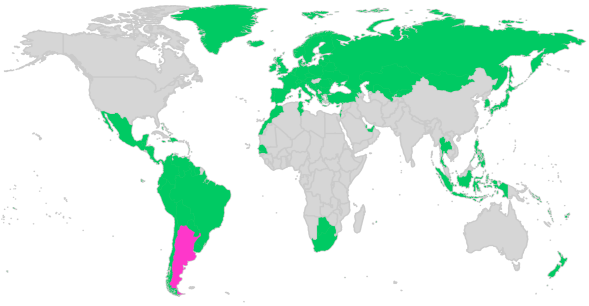

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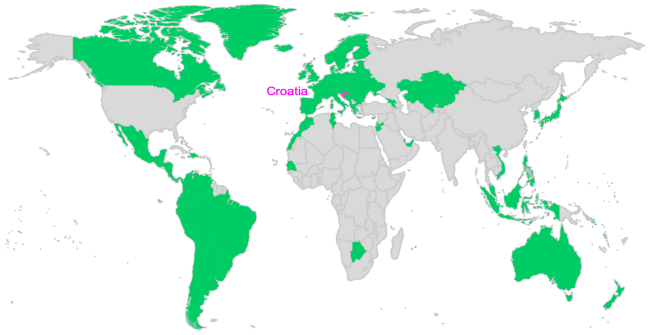

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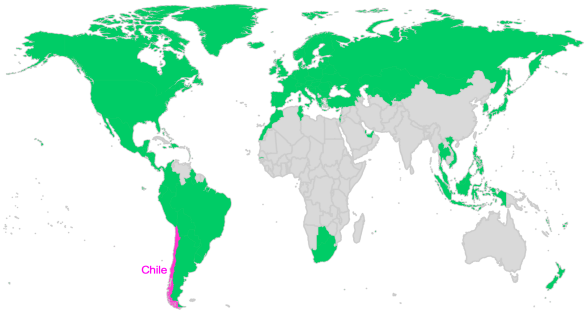

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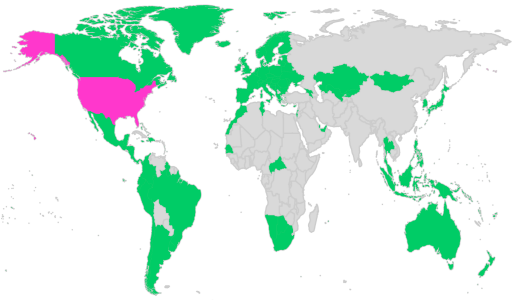
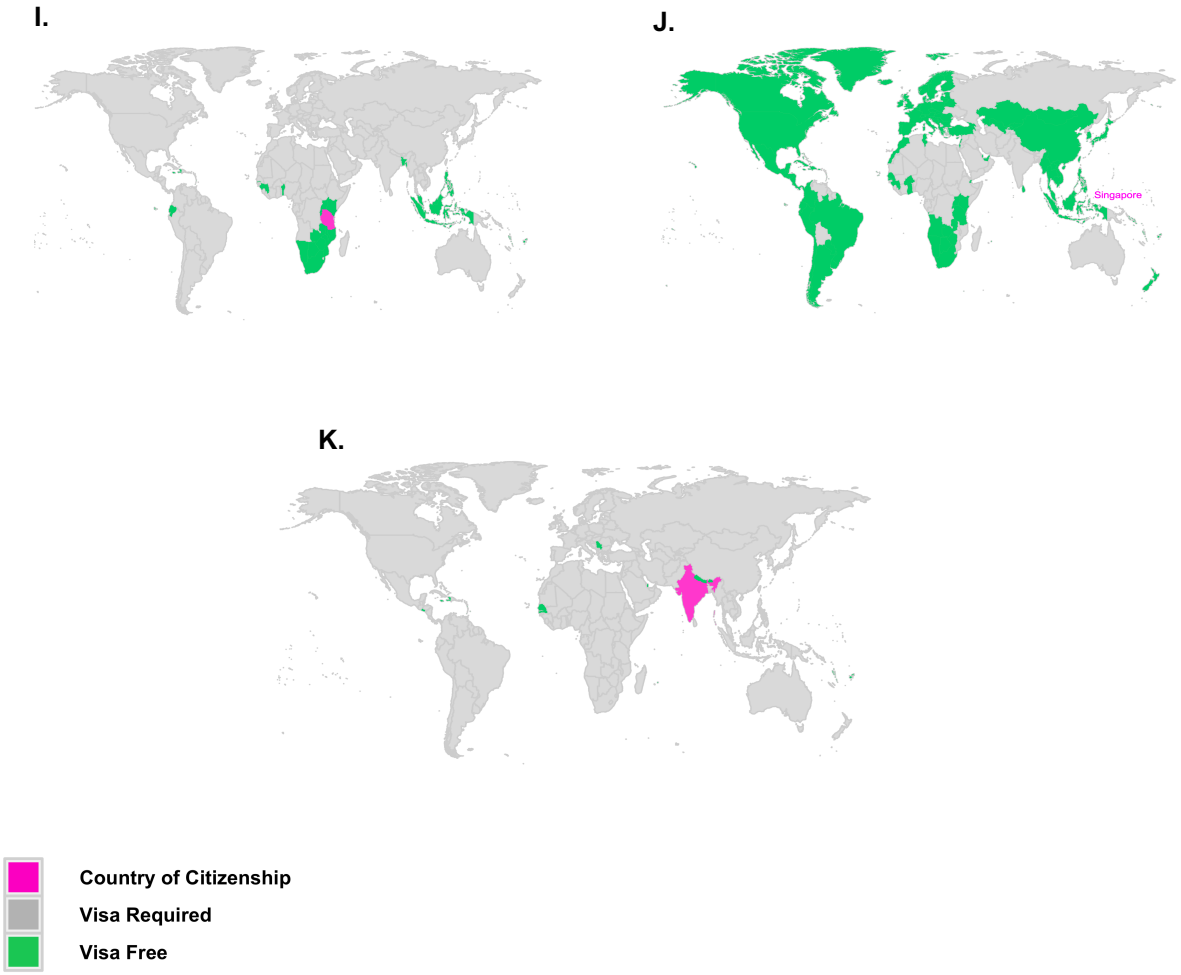
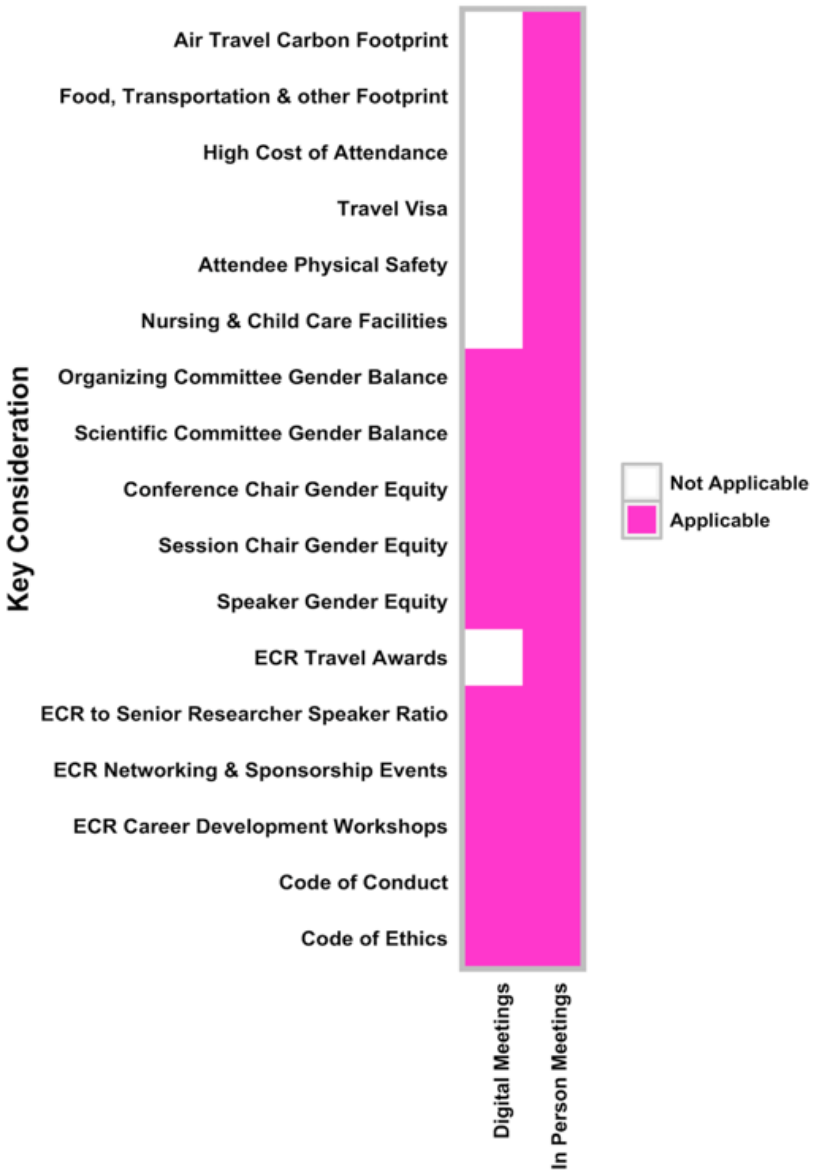




Supplementary Figure 4. Visa restrictions and lack of digital conferencing limit scientific career development. Short-term visitor visa requirements for researchers who are citizens of A) Iran B) South Africa C) Germany and D) Argentina, E) Croatia, F) Chile, G) Pakistan, H) United States I) Tanzania, J) Singapore and K) India. Researchers who are citizens of these countries (in pink) can only travel (short-term for a conference) to select countries (in green) without applying for a visa. Colour pink indicates country of citizenship, colour green indicates countries researchers can visit without applying for a visa, grey regions indicate that visa required to travel (Data source: The Henley & Partners Passport Index: https://www.henleyglobal.com/henley-passport-index/)



Supplementary Figure 5. Digital scientific meetings present many advantages for the diverse scientific community. A visa (travel permit), travel carbon footprint, early career researcher (ECR) travel awards, in-person attendance costs such as flying, accommodation, transportation and meals, childcare and infant nursing facilities and attendee physical safety are not applicable considerations to digital (online) conferences. Virtual conferences do not require catering, venue rental, or on-the-ground logistics coordination, thus are substantially less expensive to organize than fly-in conferences.

Supplementary Tables

Supplementary Table 1. American Chemical Society Fall & Spring in-person Annual Meeting Attendee Statistics						
Year	**Location**	**Attendees**	**Students**	**Expo-Only**	**Exhibitors**	**Total**
Spring 2019	Orlando, FL	7,974	6,043	444	858	15,754
Fall 2018	Boston, MA	8,380	3,691	682	1,172	14,463
Spring 2018	New Orleans, LA	9,067	6,472	334	879	16,752
Fall 2017	Washington, DC	8,400	2,999	477	1,068	12,944
Spring 2017	San Francisco, CA	9,830	6,920	967	1,200	18,917
Fall 2016	Philadelphia, PA	7,860	3,257	697	1,175	12,989
Spring 2016	San Diego, CA	8,776	5,989	477	1,068	16,310
Fall 2015	Boston, MA	8,599	3,468	595	1,266	13,928
Spring 2015	Denver, CO	7,612	5,142	357	847	13,958
Fall 2014	San Francisco, CA	10,372	3,724	550	1,128	15,774
Spring 2014	Dallas, TX	7,083	5,172	433	810	13,498
Fall 2013	Indianapolis, IN	6,849	2,664	418	872	10,803
Spring 2013	New Orleans, LA	8,329	5,848	383	913	15,473
Fall 2012	Philadelphia, PA	8,130	3,184	690	1,224	13,228
Spring 2012	San Diego, CA	9,266	5,749	716	1027	16,758
Fall 2011	Denver, CO	6,712	2,387	356	998	10,453
Spring 2011	Anaheim, CA	7,641	4,688	596	1,097	14,022
Fall 2010	Boston, MA	8,554	3,240	770	1,508	14,072
Spring 2010	San Francisco, CA	10,200	5,717	927	1,223	18,067
Fall 2009	Washington, DC	8,914	3,159	671	1,449	14,193
Spring 2009	Salt Lake City, UT	5,963	3,443	420	780	10,606
Fall 2008	Philadelphia, PA	8,699	2,972	838	1,488	13,997
Spring 2008	New Orleans, LA	7,581	4,671	385	1,158	13,795
All years Combined	Total Attendees	190,791	100,599	13,183	25,208	330,754
Total Carbon Footprint	Average CO_2 produced: Average Arctic ice melted:	~190,791metric tons 572,373 m^2	~100,599 metric tons 301,797 m^2	~13,183 metric tons 39,414 m^2	~25,208 metric tons 75,624 m^2	~300,754 metric tons 902,262 m^2 ~ Over 4 times the area of NY Grand

						Central Station

Supplementary Table 1. Over a decade of American Chemical Society (ACS) annual meeting attendance has left a large carbon footprint. These are statistics for fall and spring annual meetings only and do not include the many in-person regional meetings of this society at various states across the United States (Data source (American Chemical Society National Meeting and Expo-Attendee Demographics (2019): https://www.acs.org/content/acs/en/meetings/national-meeting/exhibitors/attendee-demographics.htm). A round-trip flight from New York to San Francisco emits about 1 metric tons of carbon dioxide per person. Every metric ton of CO_2 emitted leads to 3 square meters of Arctic sea ice loss. If every attendee trip, food and accommodation produced about 1 metric tons of CO_2 on average, total ACS annual meeting attendance resulted in loss of over 900,000 m^2 of arctic ice. The Grand Central Station in New York, NY, the largest train station in the world by platform count, measures 200,000 square meters (m^2) in total area.

Supplementary Table 2. Online sources with compiled lists of conferences		
Type	**Name**	**Website**
Conference List	Nature Ecology and Evolution	www.nature.com/natecolevol/about/conferences
Conference List	the National Invasive Species Information Centre	www.invasivespeciesinfo.gov/conferences-and-events
Journal List	List of ecology, evolution, and conservation journals	https://docs.google.com/spreadsheets/u/1/d/1uG2Dg0LogysCSAsK51Rh9lD_dxRRFOeo2jq92_TwqF0/htmlview
Broad Search platform	Google	www.Google.com

Supplementary Table 2. Lists and resources used to compile our conference database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/.

Supplementary Table 3. Conference Disciplines	
Physics, Astronomy, Space Research, Astronautics, Condensed Matter Physics	(3/270)
Chemistry, Chemical Engineering, Mass Spectrometry, Glycobiology	(7/270)
Molecular Biology, Molecular Life Sciences, Biochemistry	(4/270)
Microbiology, Microbial Communication, Microbial Population Biology, Veterinary Microbiology	(12/270)
Cell Biology, Single Cell Biology, Developmental Cell Biology, Mechanobiology	(10/270)
Developmental Biology, Zebrafish Biology, Evolutionary Developmental Biology	(3/270)

Behavioural Biology, Behavioural Ecology	(2/270)
Fish & Wildlife science, Forest insect science, Forest conservation	(3/270)
Coral Reef Biology, Island Biology	(2/270)
Land Ecology, Ecosystem Restoration, Lake Ecology, Soil & Water Conservation	(6/270)
Agriculture, Agricultural Engineering, Enology	(2/270)
Integrative & Comparative Biology	(1/270)
Veterinary Microbiology, Veterinary parasitology	(2/270)
Evolution, Human Evolution, Ecology, Archaea Ecology, Molecular Ecology, Microbial Ecology, Mathematics of Ecology, Ecology & Cancer	(44/270)
Zoology, Ornithology, Primatology, Mammalogy, Herpetology	(8/270)
Insectology, Entomology, Myrmecology, Pesticide Resistance, Beekeeping	(7/270)
Palaeontology, Palaeoanthropology, Vertebrate Palaeontology	(4/270)
Oceanography, Marine Biology, Ocean Science, Marine Mammalogy	(4/270)
Climate Science	(2/270)
Human Genetics, Fungal Genetics	(7/270)
Vertebrate Pest Science	(1/270)
Invertebrate Pathology	(1/270)
Epigenetics	(2/270)
Pathology, Molecular Pathology	(2/270)
Pharmacology & Drug Development, Neuropsychopharmacology, Pharmaceutical Sciences, Peptide Science, Redox Chemistry & Medicine	(5/270)
Mathematics, Mathematical & Theoretical Biology	(2/270)
Immunology, Virology, Infectious Disease, Clinical Microbiology, HIV, Vaccines, Allergy, Leukocyte Biology, Lymphology	(19/270)
Biophysics, X-ray Diffraction Crystallography & Scattering, Chromatin Biophysics	(5/270)
Neuroscience, Neurological Disorders	(3/270)
Cognitive Sciences	(3/270)
Plant Science (Plant-microbe interactions, bacterial wilt, aquatic plant science)/Synthetic Biology, Phytobiome research	(14/270)
Biomedical Engineering, Medical Physics, Biomedical Electronic Devices	(3/270)
Imaging, Microscopy	(5/270)
Biomolecular Research Facilities	(1/270)

Materials Science & Engineering, Computational Modelling of Materials, Mining Engineering	(5/270)
Mechanotronic & Robotics	(1/270)
Environmental & Energy Engineering	(1/270)
Systems Biology, Computational Biology, Molecular Dynamics	(11/270)
Bioinformatics, Data science, Machine Learning	(2/270)
Computer Science (Software & Hardware Applications)	(3/270)
Conservation Biology	(5/270)
Cancer Research	(1/270)
Epidemiology, Molecular Epidemiology	(2/270)
Bone & Skeletal Disorders, Autism, Osteoporosis, Osteoarthritis, Musculoskeletal Disease	(4/270)
Psychology, Psychonomics	(2/270)
Clinical Laboratory Science, Clinical Research	(2/270)
Nutrition	(1/270)
Toxicology	(1/270)
Ophthalmology	(1/270)
Geology & Earth Science, Biogeography (invasive species), Geography	(6/270)
Health care/Human health, Medicine, Anaesthesiology	(3/270)
Cardiovascular Disease, Diabetes, Vascular Biology	(3/270)
Alzheimer's	(1/270)
Endocrinology	(1/270)
Maternal Medicine, Infant studies (Development of infants), Reproductive Biology, Study of birth defects, Paediatric Research	(5/270)
Rare Disease	(1/270)
Gerontology, Biology of Aging	(1/270)
Sports Medicine	(1/270)
Behavioural Medicine	(1/270)
Linguistics	(1/270)
History, Philosophy & Social Sciences of Biology, Ethnobiology, History of Medicine	(4/270)
Biosafety & Biosecurity	(1/270)

Education, Gender, Diversity (Research Culture)	(2/270)

Supplementary Table 3. The research disciplines for the 270 conferences analysed. Conference names and year the meeting was held are available in the database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/.

Supplementary Table 4. Frequency of in-person National & International Conferences Worldwide	
Annual	73.7% (199/270)
Biennial	20% (54/270)
Triennial	1.5% (4/270)
Quadrennial	3.7% (10/270)
Other: meetings held multiple times a year	1.1% (3/270)

Supplementary Table 4. The frequency of occurrence of the 270 conferences examined in this study (From a database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/).

Supplementary Table 5. Years Conferences held	
Minimum	1 Year
Average	29 Years
Maximum	187 Years

Supplementary Table 5. The number of years the 270 academic conferences examined were held (From a database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/.)

Supplementary Table 6. Number of Conference Attendees (Researchers & Exhibitors)	
Minimum	70 researchers
Average	2,500 researchers
Maximum	31,000 researchers
Estimate total Attendees	~859,114 researchers
Estimate total Learned Society Members, representing over 150 learned societies	~1,658,602 researchers

Supplementary Table 6. The number of attendees varied widely for the 270 conferences in our database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/.

Supplementary Table 7. Cost of Conference Registration for Attendees	
Minimum	Free of charge
Average	Over US$200
Maximum	US$2,296
Average Total Funds spent for all attendees (~859,114 researchers, each on average spent US$1500)	US$1.288 billion

Supplementary Table 7. The registration cost for the 270 conferences we examined. Minimum and maximum registration costs were recorded for each conference, available online (From a database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/.)

Supplementary Table 8. Travel & other Carbon Footprint of Conferences	
Minimum per attendee	Traveling 1 mile by train to the convention centre produces 0.5 kg CO_2
Maximum per attendee	Flying from Perth, Australia to London, United Kingdom and back for Virology & Infectious Diseases (ICVID) 2019 generated about 3,153 kg (3.47 tons) of CO_2
Total **Air Travel** carbon footprint generated from 270 conferences (~859,114 attendees combined, average air travel CO_2 of 2 tons per attendee)	1,718,228 tons of CO_2
Total **Other** carbon footprint generated from 270 conferences (~859,114 attendees combined, average all other CO_2 production of 0.5 tons per attendee)	429,557 tons of CO_2
Aggregate attendee travel carbon footprint for a trip to the American Association of Geographers annual meeting	Air travel by 6,741 attendees to and from a single meeting of the American Association of Geographers in Seattle produced ~16,000 metric tons of CO_2, equivalent to the amount that 53,500 people living in Haiti generated during 2014: https://www.tandfonline.com/doi/full/10.1080/00330124.2013.784954

Further examples & resources on air travel and researcher carbon footprint	The aviation industry is responsible for over 860 million metric tons of CO_2 emissions every year, with every metric ton of CO_2 emitted leading to 3 square meters of Arctic sea ice loss. With an upward of 2,500 flights a day over the north Atlantic, transatlantic flights are the third largest contributors to annual global CO_2 emissions (Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission: https://science.sciencemag.org/content/354/6313/747). A single researcher's flight from the United States to Europe and back to attend a conference will generate over 1,000 kg of CO_2. There are 57 countries where the average person produces less CO_2 in a year (**Supplementary Figures 1,2**). In addition, each night spent in a hotel creates over 70 lbs of CO_2 from fossil fuel derived electricity. The average three-day, 1,000-person national conference generates over 580 tons of planet-warming CO_2 emissions every year. The total carbon footprint from a single annual meeting of the Society for Neuroscience, hosting 31,000 attendees, is equivalent to the annual carbon footprint of 1,000 medium-sized laboratories (https://elifesciences.org/articles/15928). Multiplying these amounts of CO_2 generated by the hundreds and thousands attending a single conference (Supplementary Table 1,8). Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission: https://science.sciencemag.org/content/354/6313/747 American Physical Society meeting statistics: https://www.aps.org/publications/apsnews/201204/lrgestmarchmeet.cfm atomsfair-Climate-friendly air travel: https://www.atmosfair.de/en/offset/flight/ Carbon Footprint Calculator: https://calculator.carbonfootprint.com/calculator.aspx?tab=3 CO_2 emissions (metric tons per capita)-The World Bank: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways. New York, NY: The Intergovernmental Panel of United Nations on Climate Change (2018): https://www.ipcc.ch/sr15/ Reducing emissions from aviation. European Union: European Commission Climate Action (2019): https://ec.europa.eu/clima/policies/transport/aviation_en The climate mitigation gap: education and government recommendations miss the most effective individual actions (2017): https://iopscience.iop.org/article/10.1088/1748-9326/aa7541

	Carbon footprint of science: More than flying (2013): https://www.sciencedirect.com/science/article/pii/S1470160X13002306 How your flight emits as much CO_2 as many people do in a year (2019): https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year Early Human Health Effects of Climate Change-WHO Office for Europe (1998): http://www.euro.who.int/__data/assets/pdf_file/0006/119184/E64599.pdf Transformative change requires resisting a new normal (2020): https://www.nature.com/articles/s41558-020-0712-5 Report Of The Secretary-General On The 2019 Climate Action Summit-The Way Forward In 2020: https://www.un.org/en/climatechange/assets/pdf/cas_report_11_dec.pdf Code of Conduct to support a low-carbon research culture: Tyndall Travel Strategy - towards a culture of low carbon research for the 21st Century (2019): https://tyndall.ac.uk/travel-strategy Addressing Greenhouse Gas Emissions from Business-Related Air Travel at Public Institutions: A Case Study of the University of British Columbia. Department of Geography, University of British Columbia (2018): https://pics.uvic.ca/sites/default/files/AirTravelWP_FINAL.pdf Printing program books of 200 pages each for 15,000 conference attendees at a meeting uses 3 million pages of paper (~150-300 trees).

Supplementary Table 8. Examples of individual CO_2 production and aggregate amount for 270 conferences held between January 2018 and December 2019. Details of CO_2 production for each meeting is detailed in the online database of 2018-2019 in-person conferences: https://elifeambassadors.github.io/improving-conferences/.

Supplementary Table 9. Summary statistics on features of 270 in-person scientific conferences (Visualized as Figure 1 in the main article text)			
Key Considerations		**Yes**	**No**
Equity, Intersectionality & Inclusivity Considerations	Live streaming or Recordings of **some or all** talks is available at the time of in-person meeting	3.7% (10/270)	96.3% (260/270)
	Live streaming or Recordings of **ALL** talks is available at the time of in-person meeting	3.3% (9/270)	96.7% (261/270)

	Virtual Reality or Digital Posters (e-Posters/ i-Posters/Twitter Posters)	1.4% (4/270)	98.6% (266/270)
	Archives of all or most recorded talks or e-Posters available from conference or scientific society website from previous meeting years	11% (30/270)	89% (240/270)
	Code of Conduct (COC)	41% (111/270)	59% (159/270)
	Code of Research Ethics & Integrity	22% (59/270)	78% (211/270)
	On-site Facilities for Mothers such as Lactation/Nursing Room also called a Personal Considerations Room	15% (41/270)	85% (229/270)
	Caregiver Grants	12.2% (34/270)	87.8% (236/270)
	Some form of Childcare (free or at cost) available on-site	19% (51/270)	81% (219/270)
	Free on-site Childcare	11% (30/270)	89% (240/270)
	On-site Childcare at a cost ($$)	8% (21/270)	92% (249/270)
	ECR Training Workshops for Career Development	35% (94/270)	65% (176/270)
	ECR promotion Events (special symposia, talks, poster sessions for postdoctoral researchers on the job market, ECR awards)	38.5% (104/270)	61.5% (166/270)
	ECR Networking Events (such as mixer/ice-breaker events with fellow ECRs and senior researchers)	20% (54/270)	80% (216/270)
	ECR travel Award (Limited in number: 5-20 awarded during each conference)	55% (149/270)	45% (121/270)
	Local Safety Apps or Instructions for attendee physical safety in town/city	4% (12/270)	96% (258/270)
	Diversity statement Reported on the conference website online	22% (59/270)	78% (211/270)
	Gender equity/balance statement Reported on the conference website online	8% (22/270)	92% (248/270)
	Conferences chair gender balance 39.3% (106/270) of conferences reported this information on the meeting website	46.2% (49/106)	53.8% (57/106)
	Keynote speaker gender balance 41% (111/270) reported this information on the meeting website	40.5% (45/111)	59.5% (66/111)

	Plenary speaker gender balance 47.4% (128/270) of conferences reported this information on the meeting website	38.3% (49/128)	61.7% (79/128)
	Invited/Featured speaker gender balance 52.2% (141/270) of conferences reported this information on the meeting website	19.1% (27/141)	80.9% (114/141)
	Session Chair gender balance 52.6% (142/270) of conferences reported this information on the meeting website	36% (51/142)	64% (91/142)
	Organizing/Steering Committee gender balance 46.3% (125/270) of conferences reported this information on the reported website	36.8% (46/125)	63.2% (79/125)
	Program/Scientific Committee gender balance 30% (81/270) of conferences reported this information on the reported website	27.2% (22/81)	72.8% (59/81)
	Local public outreach events (e.g. public talks)	6% (15/270)	94% (255/270)
Environmental Sustainability Considerations	Sustainability Policy or Green Strategy (e.g. buying carbon off-sets, going paperless, reducing plastic bottles, sourcing local vegetarian food options for catering)	5.6% (15/270)	94.4% (255/270)
	Electronic Apps or online program books (complete schedule of talks and posters/abstract book) (in the form of interactive schedule or a .pdf file or mobile phone App)	91% (247/270)	9% (23/270)
	Nature (e.g. Forest, Beach) clean-up walks/ events	0% (0/270)	100% (270/270)

Supplementary Table 9. Summary Statistics from a database of 270 in-person conferences held between January 2018 and December 2019: https://elifeambassadors.github.io/improving-conferences/. Not every conference reported or designated scientists in certain roles. For instance, a number of conferences did not assign session chairs during their meeting. Plenary, keynote and invited/featured speaker roles were not also all consistently assigned in all meetings. Majority in-person conferences lack a code of conduct. Lack of infant and child-care support and the complexities of arranging care can make travelling for conferences extra expensive and stressful for early career researchers (ECR) parents who must choose to either miss out on the career opportunities of travel, or incur costs and significant personal stress to them and their family. Only 19% of all conferences offered some form of on-site childcare (free or at a cost). 92% of conferences did not provide a gender equity statement on members of committees and speakers and did not disclose these gender statistics on their website. 40% of conferences with information (such as first and last name of speakers and affiliations) available online had keynote speaker gender balance, 38% of conferences with information on plenary speakers and 19% of conferences with information on invited/featured speakers achieved a 50% or higher participation of women. 37% of conferences that reported information on their website achieved organizing committee gender parity and 27% achieved scientific committee gender balance. 46% of conferences reporting conference chair names and 36% of conferences reporting session chair names achieved gender parity. Only 41% and 22% of conferences examined included a code of conduct and code of research ethics or research integrity on their website respectively. The quality of these

codes varied considerably among conferences. The code of conduct examined here includes both code of conduct for organizers and attendees. Only 35% of the conferences examined included some form of a career development workshop for ECRs and 38% included promotion events such as (either) special symposiums or podium talks or poster or oral presentation awards for ECRs. Only 20% of the 270 conferences offered networking events in the form of ice-breakers, mixers and "meeting with experts" sessions for ECRs. Accessibility of conferences for researchers with disabilities needs to be examined in future studies, and should be kept in mind even when switching to virtual conference formats. These scientific societies combined have ~1,658,602 researchers registered members attracting a combined ~859,114 attendees to their meetings. 1% of these meetings were held multiple times a year, 74% were held annually, 20% were held biennially and only 1% and 4% were held triennially and quadrennially respectively. Only 6% of conferences included any form of green policy. Number of attendees reached up to over 30,000 for a single event. The features offered by conferences were evaluated using data available online from meeting websites, all collated at https://elifeambassadors.github.io/improving-conferences/.

Supplementary Table 10. Types of Educational/Career Development Workshops/Events offered at the 270 in-person conferences analysed

Type of Workshop	Number of Conferences which offered the workshop	Notes/Details
Events/Workshops for Undergraduate/Graduate/Postdoctoral Trainees		
Mentoring & Leadership Training	23	Overcoming bias through mentorship, mentoring connections, one-on-one Mentoring, Career Mentoring
Improving academic environments & culture	1	Research culture
Managing Yourself as a researcher	1	Leadership
Tools for Negotiations	4	Advocating for yourself and your brand/goals/ Advocating for your research publications
Professionalism: Building Success in Science	1	
Early career Researcher Networking & Conversations	14	Supporting ECRs/ Early career days/ ECR Challenges/ Community & Connections
Creating Early Career Researcher (ECR) committees	1	Engagement in scientific community
Effective Management of shared facilities	1	Management skills
Effective Teaching in Classrooms	7	Through practice/

		Inclusive pedagogy/ Creating a comfortable and welcoming learning community: from a strategic syllabus to realized student engagement/ effective use of online resources for your class/ Developing a concept inventory to evaluate Student learning In undergraduate courses
Career Advice: Navigating the Job market	11	Career Transition/Hiring & Promotion/job skills/career planning for success/Diverse career paths in specific fields/First year on the jobs tips/career planning, getting hired, Searching, Applying, Interviewing, and Negotiating for Your First Job
Career Fair/Career Panel/Career Consultation	10	Building a good CV/ Recruitment event
Graduate & Postdoctoral researcher career development session	12	Networking: How to Create Your Dream Career, Networking, Informational Interviews for ECRs, navigating the path to professional success, preparing trainees for modern careers, IDPs: Individual Career Development plans
Developing a value statement	4	Elevator pitch, Three-minute thesis competition, Student & Early career pop talks (5-minute TED style talks)
Graduate & Postdoctoral Career Development	8	Developing graduate skills / The Strategic Postdoc: How to find & leverage your postdoc experience, creating an individual development plan/postdoctoral challenges/non-traditional postdocs, ECR discussions on various PhD projects with senior researchers, tips for successful graduate school applications, Career Speed-Networking Luncheon
Networking in research	2	
Engaging more Graduate & Postdoctoral trainees in scientific societies and their organizing committees	3	
Academic Career Track	12	Preparing your Written Application Materials: CV, Cover Letter, Research Statement, the job talk, Understanding the search process from the perspective of search committees and Decoding Job

		Announcements
Non-Academic Career Tracks	17	The industry interview, government & NGO jobs, Resume review session, progressive lunch with Industry
Writing Diversity Statements	1	
Scientific Communication	23	Increasing the impact of your research through social media, communicating for Impact: Workshop on engaging meaningfully with your neighbours, your elected officials, funders and the broader public about science/ turn your science into news/ effective communication of your data, How to design and give dynamic Powerpoint talks and TED talks, scientific storytelling, Developing Strategies for Effective and Trustworthy Communication
Scientific Writing for Public	5	Uncomfortable conversations: Engaging Diverse Communities
Scientific writing in Academia	10	For trainees & New Principal Investigators, writing your paper, increasing the impact of your research, Writing from Qualitative Data
Public Policy for Scientists	6	How to transition your research to public policy, Advocating for Biomedical Research: we have done it so can you
Public outreach, Advocacy	4	Increasing your success and social capital in conservation
Citizen science workshops	3	Working with data collected by citizen scientists – challenges & opportunities, empowering citizen science leaders with tools for robust community engagement
Reproducibility in Research	6	Experimental or Computational research, Tools for open science: reproducible data analysis and paper writing in R, Resources for Reproducible Research: https://www.repro4everyone.org/
Data/Statistical Analysis Techniques	2	
Data Management	8	Data collection/ Database/ Repository Building Techniques/ Digital Tool development/How to

		use Github, Integrating Advanced Technologies to Improve Data Quality and Reduce Bias in Population Research and Management, Data Analytics, Data mining, Data Cleaning
Teaching computing tools to researchers	3	
Building Digital Data Collection Apps	2	Software Carpentry/ building Apps
Visualization or illustration Techniques	6	Graphic recording/ how to make a video of your research/artwork for your research publication, Data visualization
Grant proposal Writing	17	Optimizing Grant Applications/ Funding Opportunities, Training & Fellowship grants
Grant information session with specific funding agencies, Funding & budgeting the research	9	e.g. NSF, NIH, FDA, European Council Funding Agency/ Early career grant writing opportunities, Communicating with Program Officers, study section review, progress reports, Science, Dollars, and Outcomes: The Critical Pieces of Budgeting You Can't Work Without, NIH Support for Typical and Non-typical Career Trajectories: getting to where you want to be
Forming Successful Collaborations, Networking	7	Core competencies for partnering)/ Navigating Team science/ strategies to generate data/ joining consortium projects/ Collaborative Science with diverse stakeholders/ Industry collaborations & technology development/new technologies & expanded opportunities for collaboration, promoting yourself by making connections that count, finding your voice
Succeeding in Interdisciplinary Research, Effective Team-building and Communication workshop	3	
Multidisciplinary Research Needs	1	
International Opportunities in Science	1	Working as a scientist outside of the U.S. requires curiosity, adaptability, and open-mindedness, which are valuable qualities important for success in any career

Getting your foot at the door for leadership positions	1	Getting hired
Media Engagement/Communication	3	Media training
Public Involvement	4	Pitch your science to non-scientists/Public Engagement/ Citizen Science Data
Tips for STEM Educational Engagement outside Colleges & Universities	1	Engaging with schools, youth groups and home educators
Science & Arts	2	Researcher Film Festivals/Science & Poetry
Promoting Diversity, Equity & Inclusivity	17	In classrooms & In research environments/Promoting Women/LQBTQI researchers/cultural diversity, Diversity and Inclusion: Leveraging Actions Through Collaboration
Immigration Challenges	1	On Obtaining Visas
Mental Health & Well-Being	1	
Work-Life Balance	4	Avoiding burn out during your career
Responding to Bullying	2	
Gender inequalities in research environments	3	(e.g. in field work), Navigating power dynamics in academia
Implicit Bias, Bias Awareness in Academia	3	
Disability in Academia	1	
Imposter Syndrome	1	
Tips for successful publishing in a Journal	11	Publishing Q & A: Managing the Expectations of Peer Reviewers
Open Access (OA) publishing: Preprints/Peer Community In	1	(https://peercommunityin.org/)
Peer-reviewing Training	8	Reviewing training for reviewing manuscripts & grant applications, best practices, mock review sessions
Publication/Research Ethics/Teaching Integrity	6	Ethics in research environments, Professional Ethics & Advocacy, Irresponsible & wrong conduct of research
Fostering/Unlocking Early Career Potentials	3	Youth Capacity Building workshop

Career Development Events/Workshops for Faculty		
Faculty Career Development Workshops (PUI faculty)	2	
Early to Mid-Career PI challenges	4	New Faculty Forum/Striving for Success/Network, learn and find support, Tips for New and Early Stage Investigators: Planning for Success: Navigating Your First Faculty Position/How to get Tenure
PUI faculty training	1	Strategies for successful faculty/undergraduate student collaborative research at PUIs
Enabling Work–Life Balance in Your Research Group	1	
Meet the Editors	9	What editors expect in your publication/how to be a good associate editor
Lab Management Course for Principal Investigators (PIs)	2	including budget management, hiring staff, mentoring trainees
Grant Information Session for faculty and other professionals (Presented by Representatives of the funding agencies)	2	United States National Science Foundation information session

Supplementary Table 10. Details of the early to mid-career trainee and PI development workshops offered only by 91 of the 270 conferences in our database of in-person conferences held between January 2018 and December 2019: https://elifeambassadors.github.io/improving-conferences/. A number of conferences offered more than one career development workshop, workshops are categorized by topic.

Supplementary Table 11. Types of Early Career Researcher (ECR) promotion events held at the 270 in-person conferences analysed		
Type of Event	**Number of Conferences which offered the event**	**Notes**
Promotion for Undergraduate/Graduate/Postdoctoral Trainees		
Graduate & Postdoctoral Trainee Reception/Mixer	4	Student Networking Events
Early Career trainee Research/Young Investigator Career Awards/Distinguished student Award/Merit Awards	54	For outstanding science, for ECRs with disabilities, for best talk, best poster, for women, minorities, best in their specific field (Graduate &

		Postdoctoral researchers), Infancy Early Career Researcher Award, Medical student achievement award
Trainee Career Development Award	2	
Technologists Award	1	Lab Technicians/non-doctoral research staff
Best talk/presentation/platform award	22	
Early career trainee symposium	13	Typically, mini conference last 1-2 days
Networking (meet & greet/ice breaker/Mixer) events for ECRs	12	Meeting senior researchers at conference breakfast, lunch or dinner events/student-faculty networking lunch, for under-represented minorities, LGBTQI trainees, for women, meet the women leaders, Student-Industry Mixer
Social reception following the Early Professionals Mini-Talk Symposium	1	Provides a chance to meet with the participants and other early career and mid/senior
First time delegate mentoring by other delegates	1	
Young Investigator Forum	1	
Outstanding Abstract Award	1	
Poster competition award	24	Meet the faculty candidate poster session/(best poster) or special viewing sessions
ECR job application networking event	2	Recruitment event
Fellow in training award	3	Basic research fellows, clinical research fellows, trainee award for innovation in medical education
Best paper published award	4	
Outstanding Dissertation/Thesis Award	3	
Participants favourite talk or poster	1	
Diversity & Inclusion Awards	3	
Mobility Awards	1	

Science Communication Scholar Award	1	
Outreach initiative awards	1	
Ethics in research Essay and Video competition	1	
Best Essay Competition	1	
Student Engineering Design competition	1	
Undergraduate trainee platform presentations	1	
Undergraduate trainee research awards	6	
Promotion efforts for ECR Faculty		
Early Career Research Awards for Principal Investigators (PIs)	24	Prizes for independent investigators/Faculty Development Award/ECR professionals for best research, R1 and PUI (Primarily Undergraduate Institutions) faculty, US-based or International are all eligible, Emerging leader award, Public policy award, Distinguished Early Career Contribution Award, ECR investigator Lectureship, basic researchers, Physician-scientists
Early Career Development Awards for Principal Investigators (PIs)	1	
Excellence in Research, Teaching & Service Award	1	
Mid-Career Research Awards	1	
Mid-Career Development Awards	1	
Emerging Leaders Mentorship Award	2	Mentoring Excellence Award

Supplementary Table 11. Details of the Early Career Researcher (ECR) promotion and networking events offered by a number of conferences in our database of in-person conferences held between January 2018 and December 2019: https://elifeambassadors.github.io/improving-conferences/.

Supplementary Table 12. Additional supporting information & resources for the readers	
Theme	**Additional Reading**

Attendee reflections on in-person conferences	A recent survey carried out with participants of conferences in an entire research sector, revealed that only 2% of its 2,326 respondents found these meetings to be useful and cost-effective. 44% mentioned that these conferences had "no perceptible impacts" on their research projects, programmes or policies, while 26% found conferences to be impactful, but not cost-effective (Impacts of Megaconferences on the Water Sector: https://www.springer.com/la/book/9783540372233). Profiling conference delegates using attendance motivations: https://www.tandfonline.com/doi/abs/10.1080/15470148.2010.502032
High economic costs of in-person conferences	Scientific conferences generate multi-billion dollar expenditures, feeding business ecosystems that prey on national and international research and development budgets but beyond personal value to some participants, the overall value of in-person conferences for the scientific community is seldom measurable: https://www.srhe.ac.uk/conference2017/abstracts/0068.pdf The Economic Cost of Attending Educational Conferences:https://www.ijonses.net/index.php/ijonses/article/view/3 Rethinking academic conference funding: https://www.universityaffairs.ca/opinion/speculative-diction/its-time-to-re-think-academic-conference-funding/) The cost of a recent academic conference of 20,000 attendees in Mexico reached over US$190 million: https://www.springer.com/la/book/9783540372233). The costs of attending international conferences are well in excess of national and regional meetings (~US$2,000-$4,000). A plane ticket constitutes a substantial cost for international conferences and obtaining a travel visa is expensive (~US$100-$1,000). Trainees often have to cover the expenses upfront and on their own as travel awards are scarce and typically, only a limited number are offered by the meeting organizers, universities and non-profit organizations. In addition, these awards often barely cover the bulk of conference attendance costs, which include travel, food, visa and accommodation expenses (Supplementary Table 9). Attendance expenses may not appear burdensome to wealthy participants from select academic labs in developed nations but are unaffordable for many academic research labs worldwide. Even tenured academics can struggle to afford conference participation. The less wealthy subsidize the expenses of the speakers, who usually attend scientific meetings free of charge and benefit from these events to further build their scientific status (The Matthew effect in science funding: https://www.pnas.org/content/115/19/4887). Bursaries or reduced rates for some participants do not provide a convincing justification for why speakers, who often comprise the most well-off academics, should have their expenses paid for by other conference participants. Even if all ECRs attended free of charge, other non-keynote academic participants then may have to pay their way for the sessions. Attaining travel funds is more difficult during early career stages, and this is aggravated by funding structures and researchers' lack of financial stability. In nations of low to middle income economies, researchers are often unable to attend national or international meetings (**Supplementary Figure 3**) unless they are invited or manage to acquire travel grants. Furthermore, the research budget for many laboratories can be limited so that even in the rare

	occasions that ECRs obtain funding, they would privilege its use for research instead of traveling, as few laboratories may be able to afford both.
Human & financial resources devoted to R&D Worldwide	Number of researchers worldwide: Facts and figures: human resources, the UNESCO Science Report, Towards 2030 (2019): https://en.unesco.org/node/252277 Appendix B. Determination of the minimum salary figure. In: The Postdoctoral Experience Revisited: https://www.nap.edu/catalog/18982/the-postdoctoral-experience-revisited Average Postdoctoral Research Associate Salary in the United Kingdom. PayScale (2020): https://www.payscale.com/research/UK/Job=Postdoctoral_Research_Associate/Salary
ECR travel Grants limitations	Travel Grants for Early Career Researchers are limited https://asntech.github.io/postdoc-funding-schemes/travel-grants/ Travel Grants for Latin American Early Career Researchers are limited: https://ecrlarc.github.io/
ECR Visas challenges	Visas for global health events—too many are losing their seat at the table: https://blogs.bmj.com/bmj/2019/07/30/ulrick-sidney-visas-for-global-health-events-too-many-are-losing-their-seat-at-the-table/ Visa denied? Navigating the visa minefield for visiting academics: https://www.theguardian.com/higher-education-network/blog/2012/jan/12/academic-visa-research-south-africa What scientists should know about visa hurdles: https://www.nature.com/articles/d41586-019-01428-8
Gender Imbalance at Conferences	Representation of women among invited speakers at medical specialty conferences: https://www.liebertpub.com/doi/full/10.1089/jwh.2019.7723?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub%3Dpubmed& Representation of women in speaking roles at surgical conferences: https://www.sciencedirect.com/science/article/pii/S0002961019305987 Trends in the Proportion of Female Speakers at Medical Conferences in the United States and in Canada, 2007 to 2017: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2730476 Not “Pulling up the Ladder”: Women Who Organize Conference Symposia Provide Greater Opportunities for Women to Speak at Conservation Conferences: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0160015 Representation of Women Among Invited Speakers at Medical Specialty Conferences: https://www.liebertpub.com/doi/full/10.1089/jwh.2019.7723?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub%3Dpubmed& Data-driven selection of conference speakers based on scientific impact to

	achieve gender parity: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0220481 Historical comparison of gender inequality in scientific careers across countries and disciplines: http://www.pnas.org/lookup/doi/10.1073/pnas.1914221117 Trends in the Proportion of Female Speakers at Medical Conferences in the United States and in Canada, 2007 to 2017: https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2730476 2019 Women, Minorities, and Persons with Disabilities Report. National Science Foundation: https://www.nsf.gov/news/news_summ.jsp?cntn_id=297944&org=NSF&from=news New Answers for Increasing Minorities in Science: https://www.sciencemag.org/news/2010/09/new-answers-increasing-minorities-science
Limited outreach activities at in-person conferences	Outreach evenings at Ecology and Behaviour Conference: https://eb2019.sciencesconf.org/resource/page/id/9

Supplementary Table 13. Benefits of Virtual Conferences for scientific community

Digital conferences return funds to researchers	Eliminating the large in-person national and international conference bubble and their costs will return funds to research labs and enable more trainees and underrepresented groups to attend and exchange their ideas. The global market size for all academic meetings and events is estimated at US$11.5 billion per year, growing annually. A total of ~859,114 attendees of 270 conferences, collectively spent over US$1.288 billion during 2018-2019 to attend these meetings (with a total attendance cost average at US$1,500 per attendee). This is over 3.3% of the NIH total annual budget. In-person conference organizing has become an industry, generating income for commercial or society conference organizers; travel, hotel and catering industries; and local tourist attractions that have little interest in inclusivity or the academic content being discussed. Researchers who attend expect many benefits, such as diverse early career researcher training sessions or finding their next collaborator, but most conferences have never been evaluated for their actual impact on their field. A fraction of research funds used to cover attendance of in-person conferences can be devoted to establishing digital facilities at universities and other research institutions so that scientists globally can attend meetings online. These resources do not require large funds and will be of benefit to the researchers and institutions that invest in them, long after the conferences have ended.
Digital conferences are environmentally sustainable	In-person conference attendance generates multiple million tons of CO_2. Only 5% of the global population enjoy the privilege of flying annually and this includes a subset of academics. A number of scholars routinely fly over 100,000 miles every year. Academic air travel makes up almost half of total university emissions (Supplementary Table 14, example 10). Other damaging aspects of conferences include plastic badges, bottles, paper and other promotional items and unsustainable food catering to masses of attendees.

	Reducing travel to national and international conferences and organizing virtual conferences will have a dramatic impact on the environment. For example, a recent experience with multi-site conferencing showed reductions of 50% - 70% in travel-related greenhouse gas emissions compared to the single-site alternatives despite increased participant numbers (https://www.sciencedirect.com/science/article/pii/S0736585311000773).
Digital conferences are more inclusive	Fly-in conferences may meet the needs of some academics and professionals in wealthy countries but researchers with family commitments, physical or health limitations and vulnerabilities cannot easily attend these conferences. Digital conferences incur lowest costs and can be organized when travel is not possible due to disease outbreaks such as the recent COVID-19 pandemic. Graduate and postdoctoral trainees on average produce about three times less emissions from air travel than fully tenured professors, and female academics also travel less than their male colleagues. Virtual meetings can boost the number of registered participants up to 50% compared to in-person conferences (https://www.sciencedirect.com/science/article/pii/S0736585311000773).In addition to the added socio-economic and ethnic diversity, digital conferencing can increase diversity of the career stages and genders of attendees, which in turn improves the quality of the scientific research and the conferences. Virtual conferences also present an upper hand regarding accessibility issues.

Supplementary Table 14. Examples of best practices & technologies used to improve scientific conferences

Example 1. Tools and platforms used to hold virtual conferences	Multi-Hub conferencing model: The attendees' experience has been positive, showing that the multiple-site format can serve as an alternative to the traditional one-site format of holding national and international conferences: https://www.sciencedirect.com/science/article/pii/S0736585311000773 Scientific electronic panels can be held via platforms such as Virtual Keynote Symposia (VKS), Zoom, business version of Skype, YouTube streaming, Crowdcast, Vimeo livestream (https://livestream.com/), OBS Open Broadcaster Software (https://obsproject.com/). OBS Studio enables organizers to record talks. ON24 platform-Webcasting and virtual event and environment technologies: https://www.on24.com/ Conferencing platform: https://www.sococo.com/ Conference Recording Technology: https://slideslive.com/ Screen recorder & Video editor: https://screencast-o-matic.com Confex used by Ecological Society of America annual virtual meeting 2020: https://confex.com/ Jitsi Meet: https://jitsi.org/jitsi-meet/ has decent functionality and ease of use. The Jitsi Meet Server is also open source https://github.com/jitsi/jitsi-meet. Tencent Conferencing: https://intl.cloud.tencent.com/product/tcc

	Conference software: https://slideslive.com/neurips ShowMe: https://www.showme.com/ Networking App for events and conferences: https://whova.com/ Virtual Whiteboard: https://edu.google.com/products/jamboard/?modal_active=none Discord: https://discord.com/ Discourse: https://www.discourse.org/ Reddit AMA/similar with authors after presentations: https://www.reddit.com/r/IAmA/ Meet by Google, GoToWebinar and GoToMeeting, or a combination of two of these platforms allowing both video conferencing and the opportunity to break into "breakout rooms" accommodating smaller discussion groups and one-on-one interactions (e.g. via Slack, Discord or Discourse). These platforms and others are being utilized for scientific chats on a daily and weekly basis where ideas are exchanged and collaborations are shaped among researchers: 15 Data Science Slack communities to Join-Reach out in Slack to level up in your career: https://towardsdatascience.com/15-data-science-slack-communities-to-join-8fac301bd6ce) IEEE association offers tools such as WebEx (with recording option), Google meet, Google Hangouts (no recording option), Microsoft Teams, INXPO, YouTube for online meetings and recordings and tools such as Camtasia, QuickTime and WebEx Recorder for offline recordings. For anonymous Q&A organizers can use platforms such as Slido: https://www.sli.do/ and Pigeonhole Live https://pigeonholelive.com/ Neuromatch 2020 virtual conference: https://elifesciences.org/articles/57892 & https://neuromatch.io/ Brain Web: a permanent virtual space for online collaborations on projects related to neuroscience (2020): https://brain-web.github.io
Example 2. On holding smaller regional in-person conferences	Traveling 40 miles to a regional conference results in emission of 20 kg of CO_2. Thus, where feasible, public or shared transportation options such as the bus or train should be used instead of a car or plane. American Physical Society (APS) regional meetings & American Chemical Society (ACS) organize multiple regional meetings throughout the year. Carbon footprint calculated for the 14th Congress in Slovenia-Agricultural Economics Society and European Association of Agricultural Economists (EAAE): https://onlinelibrary.wiley.com/doi/pdf/10.1111/1746-692X.12106).

Example 3. Carbon foot print of large in-person national & international conferences	Greenhouse gas emissions caused by business trips can make up 60% of the total university greenhouse gas emissions with air travel responsible for up to 94% of the institutional travel-related emissions. How Can researchers Respond to the Climate Emergency (2020): https://www.sciencedirect.com/science/article/pii/S0896627320301422 Observed Arctic sea-ice loss directly follows anthropogenic CO_2 emission (2016): https://science.sciencemag.org/content/354/6313/747 Reducing emissions from aviation. European Union: European Commission Climate Action (2019): https://ec.europa.eu/clima/policies/transport/aviation_en The climate mitigation gap: education and government recommendations miss the most effective individual actions: https://iopscience.iop.org/article/10.1088/1748-9326/aa7541 Carbon footprint of science: More than flying (2013): https://www.sciencedirect.com/science/article/pii/S1470160X13002306 How your flight emits as much CO_2 as many people do in a year (2019): https://www.theguardian.com/environment/ng-interactive/2019/jul/19/carbon-calculator-how-taking-one-flight-emits-as-much-as-many-people-do-in-a-year Academic Jet-Setting in a Time of Climate Destabilization: Ecological Privilege and Professional Geographic Travel (2013): https://www.tandfonline.com/doi/full/10.1080/00330124.2013.784954m CO_2 emissions (metric tons per capita)-The World Bank: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC Addressing Greenhouse Gas Emissions from Business-Related Air Travel at Public Institutions: A Case Study of the University of British Columbia. Department of Geography, University of British Columbia (2018): https://pics.uvic.ca/sites/default/files/AirTravelWP_FINAL.pdf Early Human Health Effects of Climate Change-WHO Office for Europe (1998): http://www.euro.who.int/__data/assets/pdf_file/0006/119184/E64599.pdf Transformative change requires resisting a new normal (2020): https://www.nature.com/articles/s41558-020-0712-5
Example 4. Sustainability efforts at in-person conferences prior to 2020	The Society for the Study of Evolution meeting sustainability strategies (2020), Cleveland, Ohio: https://www.evolutionmeetings.org/sustainability.html MGAConf2018 conference name badge printed on seed paper-Australian Museums and Galleries Association WA: https://twitter.com/MuseumsAustWA/status/1003609563591933952

Example 5. National Grants to support conference organizers	The UK Wellcome Trust, the US National Institutes of Health (NIH) & National Science Foundation (NSF) support conference organization via designated grants which conference chairs apply for in order to fund the meeting. NIH Support for Scientific Conferences (R13 and U13): https://grants.nih.gov/grants/funding/r13/index.htm NSF supports Research Coordination Networks (RCN): https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=11691
Example 6. Organizations that hold exclusively virtual seminars	iBiology Virtual Talks: a project creating open-access science videos on biology research and science-related topics) has provided virtual talks and lectures for a number of years: https://www.molbiolcell.org/doi/10.1091/mbc.e14-02-0756 The North American Vascular Biology Organization (NAVBO) holds a number of yearlong webinars, online journal clubs and online mini-symposia (2020): https://www.navbo.org/events/online
Example 7. On the value of Preprints for conferences	Preprints & Peer Review complementing conferences: Early dissemination of scientific findings can occur online via preprints. Preprints are written scientific outputs uploaded by researchers to public servers such as *arXiv, bioRxiv* and *OSFramework. BioRxiv* and *medRxiv* currently host in excess of 100,000 manuscripts combined, receiving over 4 and 10 million views per month respectively (bioRxiv: the preprint server for biology: https://www.biorxiv.org/content/10.1101/833400v1). Preprints are already benefiting life scientists at large, but can be used in new ways to aid career development and increase the efficiency of scientific research and communication. Many investigators, especially in countries of low to middle economies, are now able to disseminate and read the most recent updates in their field via preprints months to years prior to reading new results in journals, further reducing the need to travel to discuss already published findings. PREreview: a new platform for the collaborative review of preprints: https://elifesciences.org/labs/57d6b284/prereview-a-new-resource-for-the-collaborative-review-of-preprints
Example 8. Virtual conferences held in 2020 during the COVID-19 pandemic	Low-carbon, virtual science conference in multi-hub virtual mode (2019): https://www.nature.com/articles/d41586-019-03899-1 First Carbon-Reduced Chronobiology Conference-European Biological Rhythms Society (EBRS) (2019): https://srbr.org/join-the-first-carbon-reduced-chronobiology-conference-on-november-18/ The inaugural Photonics Online Meet-up (POM), the first all-online conference for photonics researchers (2020): https://sites.usc.edu/pom/ 2nd Palaeontological Virtual Conference (2020): http://palaeovc.uv.es/ Systems Biology: Global Regulation of Gene Expression: a Virtual Meeting by Cold Spring Harbor Laboratory meetings & courses (2020): https://meetings.cshl.edu/meetings.aspx?meet=SYSTEMS&year=20

	Society for Neuroscience (SfN) Virtual Conferences: https://www.sfn.org/Meetings/Virtual-Conferences Neuronal Circuits: a Virtual Meeting. Cold Spring Harbor Laboratory (2020): https://meetings.cshl.edu/meetings.aspx?meet=CIRCUITS&year=20 CNS2020 Virtual: Cognitive Neuroscience Society Annual Meeting (2020): https://www.cogneurosociety.org/annual-meeting/ R-Ladies Global-a world-wide organization to promote gender diversity in the R community 2020: https://rladies.org/ 5th International Electronic Conference on Medicinal Chemistry Online (2019): https://www.mdpi.com/journal/molecules/events/10089 Molecular Biosystems Conference 2019(#MBIOSYS19)-Eukaryotic Gene Regulation and Functional Genomics, Puerto Varas, Los Lagos, Chile (2019): http://www.molbiosystems.com/ 15th International Conference on Music Perception and Cognition (ICMPC15)-Graz Austria (2018): https://music-psychology-conference2018.uni-graz.at/en/about/ A nearly carbon-neutral conference model- white paper/practical guide (2018): https://hiltner.english.ucsb.edu/index.php/ncnc-guide/#about
Example 9. On Twitter conferences	1st Cyanobacteria Twitter Conference, 24 October 2018 Australian Rivers Institute: https://cyanocost.wordpress.com/2018/08/27/1st-cyanobacteria-twitter-conference-24-october-2018/ Brain Twitter Conference 2019 #brainTC: Neuroscience making an impact: https://brain.tc/ Twitter for scientists: https://www.nature.com/articles/s41568-019-0170-4 The age of the Twitter conferences: https://science.sciencemag.org/content/352/6292/1404.2 Royal Society of Chemistry Twitter Poster Conference (2019): http://www.rsc.org/events/detail/37540/rsc-twitter-poster-conference-2019 How to participate in a Twitter Conference? (2020): https://44c203da-d912-4bb2-9746-daaf050732b4.filesusr.com/ugd/11d9ac_9bae98d91a384fdfb6807233f1e9188f.pdf
Example 10. On air travel mitigation strategies by institutions	Air Travel Mitigation Fund, University of California Los Angeles (2020): https://www.sustain.ucla.edu/wp-content/uploads/Air-Travel-Mitigation-Fund-Program-Guidelines-1.pdf Reducing CO_2 and air travel, ETH Zurich mobility platform (2020): https://ethz.ch/content/dam/ethz/associates/services/organisation/Schulleitung/mobilitaetsplattform/ETH0041_Flugreisen_Factsheet_EN_f03.pdf University College London Travel Emissions (2020): https://www.ucl.ac.uk/sustainable/travel-emissions

Example 11. On carbon offsets	The inconvenient truth of carbon offsets: https://www.nature.com/news/the-inconvenient-truth-of-carbon-offsets-1.10373 How much can forests fight climate change? https://www.nature.com/articles/d41586-019-00122-z
Example 12. Women & other underrepresented minority databases	There are multiple online, open access databases listing women and LGBTQIA ECR trainees and faculty which can be utilized for selection of conference speakers: Inclusive Scientific Meetings-500 Women Scientists: https://500womenscientists.org/inclusive-scientific-meetings 500 Women Scientists-Request a Woman Scientist: https://500womenscientists.org/ 500 Queer Scientists-Request a Scientist: https://www.500queerscientists.com/ Women in BrainStim database: http://womeninbrainstim.com/search/
Example 13. Environmental cost of air travel by a single person	Air travel by an academic in the UK who on average attends only one international conference or meeting per year by plane, will produce CO_2 emissions footprint of about five tons. This is over ten times as much as the average UK person's carbon footprint from leisure flights, and nearly 20% more than the average UK citizen's total annual carbon footprint from travel and home energy combined. Who emits most? Associations between socio-economic factors and UK households' home energy, transport, indirect and total CO_2 emissions: https://www.sciencedirect.com/science/article/pii/S0921800913000980 Why I will be flying less (2019): http://www.russpoldrack.org/2019/06/why-i-will-be-flying-less.html
Example 14. On tenure & promotion requirements in terms of conference participation	Evaluating Computer Scientists and Engineers For Promotion and Tenure-Computing Research Association: https://cra.org/resources/best-practice-memos/evaluating-computer-scientists-and-engineers-for-promotion-and-tenure/ Guidelines on the criteria for promotion and tenure-University of Minnesota College of Science and Engineering: https://cse.umn.edu/college/guidelines-criteria-promotion-and-tenure
Example 15. On facilitating attendee interactions during virtual conferences	Designing a Virtual Neuroscience Conference: Organizers mimic in-person networking using a matching algorithm (2020): https://www.simonsfoundation.org/2020/04/03/designing-a-virtual-neuroscience-conference/ How to moderate a Crowdcast (neuro)science meeting (2020): https://medium.com/@kording/how-to-moderate-a-crowdcast-neuro-science-meeting-858afc8dfa05
Example 16. On providing a statement of gender balance	The European Powder Diffraction Conference (EPDIC17) statement on Gender Balance, Sibenik, Croatia (2020): https://www.epdic17.org/registration Gender Equity and Diversity, Australian Biophysical Society (2020):

	https://www.biophysics.org.au/meetings.html
Example 17. On generating a meeting code of conduct	Your Science Conference Should Have a Code of Conduct (2016): https://www.frontiersin.org/articles/10.3389/fmars.2016.00103/full Code of Conduct to support a low-carbon research culture. Tyndall Travel Strategy - towards a culture of low carbon research for the 21st Century (2019): https://tyndall.ac.uk/travel-strategy Code of Conduct for R Conferences (2020): https://www.r-project.org/coc.html Code of conduct for UNFCCC conferences, meetings and events (2020): https://unfccc.int/about-us/code-of-conduct-for-unfccc-conferences-meetings-and-events Code of Conduct. Evolution 2020 society for the study of evolution annual meeting June 19-23 Cleveland, Ohio: https://www.evolutionmeetings.org/safe-evolution.html
Example 18. On generating a meeting code of ethics	Society of Ethnobiology Code of Ethics (2019): https://ethnobiology.org/about-society-ethnobiology/ethics Principles of Archaeological Ethics-Society for American Archaeology (2020): https://www.saa.org/career-practice/ethics-in-professional-archaeology
Example 19. On providing nursing rooms for mothers at in-person meetings	Best Practices for Lactation Spaces for Event Organizers: https://medium.com/@jackiekazil/best-practices-for-lactations-spaces-for-event-organizers-8b6c77797c45 Add a Lactation Room to Your Checklist: https://ejewishphilanthropy.com/planning-a-conference-add-a-lactation-room-to-your-checklist/ Planning a Conference? Add a Lactation Room to Your Checklist: https://ejewishphilanthropy.com/planning-a-conference-add-a-lactation-room-to-your-checklist/ How to accommodate a breastpumping mom at your event: https://miriamposner.com/blog/how-to-accommodate-a-breastpumping-mom-at-your-event/ Got milk? When packing for a conference requires remembering the breast pump. Science: https://www.sciencemag.org/careers/2018/02/got-milk-when-packing-conference-requires-remembering-breast-pump
Example 20. On providing childcare at in-person meetings	A petition by conference attendees to Improve childcare support at future ISMPMI congresses: https://docs.google.com/document/d/1QAdgecBEig6sgl81aXpk22EIVjdNqWIxevi2r3bzgaM/edit Childcare and Family Resources at The Allied Genetics Conference (TAGC) (2020): https://genetics-gsa.org/tagc-2020/childcare-and-family-resources/ Childcare & Nursing at Evolution 2020 meeting, Cleveland, Ohio, USA (2020): https://www.evolutionmeetings.org/childcare--nursing.html Accessibility at I Scientist meeting Technische Universität Berlin (2019): https://www.iscientist.berlin/accessibility