Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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conducting a GPS tracking project of the migration behaviour of these vultures and the dangers they face.

The longest migration recorded in the Red Sea project spanned 12,000 kilometres, and the vultures typically travel 360 kilometres in a day. A better understanding of how large birds can achieve this kind of long-haul travel comes from South America.

Soaring successfully
Flight powered by flapping wings becomes increasingly uneconomical with increasing body weight, which is why larger birds make use of thermals and even of the drag created by conspecifics flying in formation (Curr. Biol. (2019) 29, R1055–R1058). In an effort to explore the physical limits of soaring, Emily Shepard from Swansea University, UK, and Sergio Lambertucci at the National University of Comahue at Bariloche, Argentina, and colleagues attached custom-built flight loggers to eight juvenile Andean condors to observe their flight behaviour (Proc. Natl. Acad. Sci. USA (2020) 117, 17884–17890).

With the devices capable of logging every single flapping of the animals’ wings, the researchers established that even the young, inexperienced condors made optimal use of thermals, essentially limiting the use of muscle-powered flight to take-offs. The data show that wing flapping occurred for only 1.3% of the recorded flight time. One condor flew 170 kilometres in five hours without flapping its wings once.

The authors note that high mountains of the Andes generally produce more upwinds than other terrain, possibly explaining the eastern range limits of the condor. They also discuss the implications of their findings for the flight physics of even larger, now extinct bird species. Comparisons with marine species such as the equally large albatross may be more difficult, however, as these face different atmospheric conditions and may use different flight mechanisms.

Studying the condor’s soaring lifestyle also casts an interesting light on the energy balance of vultures more generally. Soaring and gliding is basically free, with energy expenditure only slightly higher than at rest. Take-offs, by contrast are expensive, and spending time on the flat ground (as opposed to the inaccessible rock perches where they tend to nest) also exposes the birds to the risk of attacks by mammalian predators.

Therefore, a condor has to choose wisely where it lands. Studies using experimental placements of carcasses have shown that the birds will disregard food opportunities in certain locations. Majestically staying aloft and on the lookout may be the trait that has earned the condor its great popularity. As we depend on their ecosystem services, it would be wise if we could extend our affection for the soaring condor to other vultures, too.

Michael Gross is a science writer based at Oxford. He can be contacted via his web page at www.michaelgross.co.uk

Q & A
Geoffrey Michael Gadd

Geoff Gadd obtained a BSc and PhD in Microbiology at University College Cardiff, Wales, and subsequently was employed as a Lecturer in Microbiology (1979) at the University of Dundee, Scotland, where he has remained, enjoying an ongoing 40-plus-year research career. He was appointed to a full Professorship in Microbiology in 1995 and from 2010 has held the Boyd Baxter Chair of Biology in the School of Life Sciences. He is a former Head of the Department of Biological Sciences, and the Division of Environmental and Applied Biology, and founded the Division of Molecular Microbiology. He now leads his own independent Geomicrobiology Group and is interested in the cellular, physiological and physico-chemical mechanisms underlying microbial–metal–mineral transformations, with a primary focus on fungi and their environmental as well as biotechnological significance in biogeochemical cycles, bioremediation, biodeterioration and element biorecovery. Several national and international awards and Fellowships have been received in recognition of his contributions to microbiology and mycology.

What turned you on to biology in the first place? I am a country boy and from an early age roamed the fields, hills, woods and lanes around my home, fascinated by all manner of life. I collected everything: rocks, fossils, butterflies and moths, beetles, skulls and bones, birds’ eggs, feathers, owl pellets, caddis worm cases and, if we went to the seaside, shells, seaweed, barnacles and so on. I had a collection of skins, bird wings and feathers. I collected the PG Tips tea cards that depicted animals, birds and so forth and the Corn Flakes tokens so that I could send off for David Attenborough’s early Zoo Quest books. My parents and grandad Bert in particular taught me a lot about the countryside; it was entirely natural for me to focus on biology. This was helped by the Biology teacher at high school being an extremely nice man. I remember an early lesson where he asked “What is biology?” and then answered that it was

Fast food: An Egyptian vulture (Neophron percnopterus, endangered) carrying food to its nest. (Photo: Artemy Voikhansky/Wikimedia Commons (CC BY-SA 4.0).)
"The study of life". I think that this was the crystallisation point for me. It was also the only profound lesson that Mr Pryce ever delivered.

**And what drew you to your specific field of research?** As mentioned, I was interested in everything, but again I have to thank my parents and my Biology teacher. I possessed plastic pond viewers and hand lenses for looking at pond life, flowers, insects and so on, so my parents bought me a little microscope for Christmas that opened up the microscopic world for me. As I was now allowed to study Biology at Advanced Level at school, I was reacquainted with Mr Pryce, the nice Biology teacher. He never formally taught us (two people in the class) and over the two years mostly sat in a back room smoking, reading the paper and ruminating. However, he gave us the syllabus one day and told us to get on with it. So for two years we carried out every practical experiment that we could, and the preparation of microscope slides of plant and tissue sections and small invertebrates was routine. We also dissected worms, frogs, rats and dogfish as well as any dead birds and animals that we found in the countryside. I had a fine collection of pickled specimens and dried dogfish eye lenses. One day we came to the microbiology part of the syllabus and made an amoeba farm, examined pond mud and water and set up yeast fermentations. The teacher was persuaded to buy us some agar and we made agar plates and inoculated them with all manner of things. I remember seeing multitudes of bacteria and yeasts in our contaminated fermentations. It therefore seemed natural to apply for microbiology courses, and I finally went to Cardiff University, where my aforementioned Biology teacher had previously secured a third-class degree in Zoology and thrown all his books into the River Taff on the day of the results, as he seemed rather proud of telling us at regular intervals. I remain shocked to this day.

**If you had to choose a different field of biology, what would it be?** All biological fields are fascinating to me. At school, I had an early phase of wanting to be an ‘ecologist’, saving habitats and stopping animals becoming extinct. Once, when the brutal Deputy Head grabbed me in the playground for some misdemeanour, he berated me and asked disparagingly “What are you going to be when you grow up?” I replied: “An ecologist”. He paused, looked puzzled, clearly not knowing what that was, and then said “Not much call for that” and stalked off, thankfully not delivering the usual clip around the ear. While I am very happy with my choice of microbiology, and ultimately settling in the geomicrobiology sphere, I would also feel at home within plant sciences, perhaps cacti and succulents, insectivorous plants or tropical plant biology, or entomology, perhaps butterflies, moths and beetles. Lichenology would also have strongly appealed. If not biology, then chemistry or Earth sciences.

You have worked on a variety of microbial groups, but your main research organisms are fungi. **How did you end up focusing on fungal systems?** I was always interested in fungi as fascinating countryside inhabitants, but the research focus was rather accidental. My PhD was initially concerned with the rhizosphere of metal-tolerant grasses and, after almost two years of unremitting failure, I made some shake-flask soil-enrichment cultures overloaded with extremely high concentrations of toxic metals, such as copper, zinc and cadmium. This was to see if I could find some interesting organisms with which I could work, as I was desperate for results. I was jealous of fellow researchers who worked with pure cultures, churning out reams of results. After examining the semi-forgotten flasks some weeks later, it was a surprise to see significant growth and essentially pure cultures of a strange yeast-like organism that made yeast cells but also mycelium and black-pigmented cells of various morphologies. No one in the mycologist-lacking department knew what this was, so I naturally thought that I had discovered a fantastic new organism. It produces a lot of extracellular melanin granules in liquid culture and I spent weeks wasting time trying to ‘purify’ the culture, thinking that they were contaminating bacteria. Disappointingly, the organism turned out to be *Aureobasidium pullulans*, one of the most common fungi in terrestrial habitats and on phylloplanes, industrially important as a serious biodeteriogen and an industrial producer of the polysaccharide pullulan. This enabled me to write a clear introduction and rationale in my thesis justifying research on this organism, despite only finding out what it was near the end of my experimental work! This organism provided a foundation for subsequent work with fungi on metals as well as minerals and underpinned my interests in fungal ecology, growth, physiology and differentiation. It still appears in our work at irregular intervals.

**Who were your key early influences?** My parents and grandad Bert. My Physics, Chemistry and Biology teachers. All who taught and inspired me at the Department of Microbiology at University College Cardiff.

**And do you have a scientific hero?** I was always inspired and impressed by many of the early scientists who featured in the antiquated text books that our school possessed. For some inane reason, you could not study Biology for the O-Level qualifications unless you dropped Physics and Chemistry, so most of my familiarity was with early pioneers, physicists, chemists and engineers, such as Galileo, Copernicus, Lavoisier, Boyle, Newton, Faraday, Brunel and so on. Text books were old and recycled through successive generations, and it was hard to find portraits that had not been defaced with extra glasses, moustaches, Spitfires and other additions. I still have clean copies of the text books, retrieved after searching through a bin full of discarded text books in a rare renewal of resources. My own favourite scientific
heroes are Antonie van Leeuwenhoek, Isaac Newton, Louis Pasteur and Charles Darwin because they changed everything in my fields of interest and remain an inspiration to countless generations to this day.

**Do you have a favourite science book?**

I have many favourites, but one that always holds fond memories is *Garden of Microbial Delights* (1988) by Dorion Sagan and Lynn Margulis — engagingly written, precise as well as philosophical and beautifully illustrated. It is still a great *Practical Guide to the Subvisible World* and perfect for both a general and an expert audience. I bought it in the early 1990s in a hippy second-hand shop in the Haight-Ashbury district, San Francisco. Where else?

**What is the best advice that you've given?**

Some gems from some of my mentors, supervisors and lecturers include "In microbiology, cleanliness is next to godliness", "If something is worth saying then it's worth repeating ad nauseam", "Time is papers", "Don't spray full stops and commas around your page like machine gun fire" and, pre-interview, "Wear a tie and get a b****y haircut".

**If you had not made it as a scientist, what would you have become?**

As a schoolboy I worked on a milk round and also worked on a farm for several years, the latter also during undergraduate holidays. My fellow school milk-mate and I were offered the chance to take over the milk round should we screw up our exams and fail to leave town for university. I loved work on the farm and would have also been happy doing that. Both jobs were great and a massive part of my formative years.

**What has been your biggest mistake?**

Too many to list. Maybe pipetting a mouthful of 1M hydrochloric acid to test if it were water. Well, it looked like water...

**What is your least favourite conference?**

Those held on sterile university campuses, miles from the nearest habitation, with small worn-out student rooms complete with short sagging bed, one bent wire clothes hanger, a primitive fungal-ridden shower with a few microns ranging between scaling hot and freezing cold and the capacity to hear all your neighbours snoring.

**What is your greatest research ambition?**

To keep learning and being involved in research until the end.

**Do you feel a push towards more applied science?**

My work has always had relevance to applied contexts, such as pollutant bioremediation, soil management, biodeterioration and element recovery, so that is no problem. I have been lucky in that I was always able to carry out what I wanted to do in research and, of the several industrial contracts or applied grants that I had, they were always to carry out fundamental research on microbial processes, with freedom to publish. I am happy that the relevance and application of my work are easily understood by the general public and it always generates much interest.

**Do you believe that there is a need for more crosstalk between biological disciplines?**

I don't know whether there is a widespread problem. Perhaps it depends on the discipline. I am sure that most imaginative and innovative scientists collaborate widely and appreciate the broader picture. In my own field there are definite demarcations between prokaryotic and eukaryotic microbiologists, as well as people who work with organic or inorganic substances, and there is frequent ignoring of microbial roles and involvement by plant biologists, but I hope that this is declining with time as the interconnections between almost everything become clearer. What is more significant is crosstalk across scientific disciplines, inter- and multidisciplinary, as evidenced by the growth of geomicrobiology, which transcends microbial and Earth science boundaries. Chemistry goes hand in hand with biology. In my own work, we collaborate with all kinds of microbiologists, pro- and eukaryotic, mineralogists, geologists, geochemists, organic and inorganic chemists, soil scientists, mathematical modellers and civil engineers, nationally and internationally.

**Any strong views on social media and science?**

I do not bother much with social media apart from WhatsApp and WeChat to keep in touch with friends and colleagues around the world, the latter indispensable for China. I am on Twitter, which I find useful for seeing stuff on subjects close or some distance away from my core topic, for example, geology, birds, lichens, plants, butterflies and moths. Nothing much comes through of core importance that I would otherwise have missed. I am not interested in blogs. Social media gives a voice to everyone whether intelligent, qualified or not, and unsubstantiated opinions can be widely circulated and readily swallowed as facts by the gullible. Witness the vaccination and climate change deniers and 5G COVID-19 conspiracy theorists. This is not helped by certain world leaders. It also gives a voice to the self-important who think that their mundane opinions are so supremely insightful that they deserve a worldwide audience. What I find poor are the constant twitterising at scientific conferences and resulting streams of posts consisting of a distant image of someone in front of a screen on a stage giving “an excellent talk”. I have never seen one that mentions a poor talk, incoherently delivered and beset with IT problems, which would be more interesting.

**Which aspect of science, your field or in general, do you wish the general public knew more about?**

The wonderful world of microbes and their positive aspects on which we depend to counteract their usual highlighting as ‘germs’ and causes of death and misery. As the biosphere’s dominant and oldest life forms, their beneficial activities determine and pervade every aspect of human existence and ecosystem function. From global elemental cycling and biosphere chemistry, soil formation, development and fertility, plant and animal productivity to production of food and drink, chemicals, enzymes, medicines and antibiotics and treatment of our wastes, microbes deserve widespread attention and respect. Microbiology can be considered to be the focal point and foundation for all branches of biology.

**Do you think that there is too much emphasis on ‘big data’-gathering collaborations as opposed to hypothesis-driven research by small groups?**

I don't understand
what is meant by big data. Huge amounts? A colossal amount of funding associated with it? Hypothesis-driven or investigative research by small groups is important but so is collaboration. Multidisciplinary research requires collaboration.

**What do you think are some of the problems faced by science today?**

Funding and recruitment are always issues. Directed funding opportunities in current fads or hot topics that reduce funding for other science areas. Ignorance and short-termism from politicians who only think of science if it fits their policies and does not harm their re-election. Actual antagonism to science and scientists, and disrespect for experts from certain world leaders and politicians. Brexit, Political interference and censorship. Expanding centralisation and administrative bureaucracy within institutions. Lack of public awareness or appreciation of science and scientists. Plagiarists, copiers and cheats. Religious fundamentalists and creationists. ‘New Age’ philosophies, crystal therapy, spiritualism, astrology and anti-science social media posts. Pseudoscience in product advertising. Fake and predatory journals, fake conference and journal invitations and yet more new journals. Probably there are a few more that I have not included.

**What do you think of the post-publication peer review of papers?**

Ridiculous, pointless and illogical for such obvious reasons that I don’t need to state to an educated readership.

**Do you support open-access publication?**

There are pros and cons. Of course we want science to be unrestricted and accessible to all. However, open access is not open at all as there is a cost, not feasible for some, and someone has to pay, usually the tax payer. This contributes even more to the rivers of income for increasingly powerful publishers who rely on a global army of unpaid researchers to write, review and edit the papers, solicit articles and edit the journals. Nice system. I wonder who thought of it?

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**Essay**

**Analogies and lessons from COVID-19 for tackling the extinction and climate crises**

Andrew Balmford\(^1\)*, Brendan Fisher\(^2\), Georgina M. Mace\(^3\), David S. Wilcove\(^4\), and Ben Balmford\(^5\)

As environmental scientists working in countries whose COVID-linked deaths already exceed their military casualties from all campaigns since 1945, we believe there are significant messages from the handling of this horrific disease for efforts addressing the enormous challenges posed by the ongoing extinction and climate emergencies.

Like the climate and the extinction crises, the SARS-CoV-2 pandemic perhaps may at first have seemed like a relatively localised problem, far-removed from most people’s everyday lives. But a disease epidemic is, at its heart, a phenomenon of positive feedbacks, with each new case spawning others. Human impacts on our planet are likewise characterised by positive feedbacks. Unravelling ecological inter-dependencies and interacting threats accelerate the extinction of species. Anthropogenic warming can trigger state shifts in ecosystems, which further increase net emissions. Moreover, there are significant time lags in the dynamics of each problem — such as between infection and presentation of symptoms; between removal of habitat and the protracted extinction of species whose small and disconnected populations are thereby all but doomed to extinction; and between greenhouse gas emissions and the full effects of thermal expansion and ice-sheet melting on sea-level rise. These time lags mean that all three systems are succeeding the longer they are delayed [5,6].

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Geomicrobiology Group, School of Life Sciences, University of Dundee, Dundee DD1 5EH, UK.
E-mail: g.m.gadd@dundee.ac.uk

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