Microbiology TODAY

46:1 February 2019

Oceans

Impact of conservation on ocean animal microbiomes
Pathogenic bacteria in our oceans' shellfish
Are sea sponges part of the solution to antimicrobial resistance?
Ocean robots uncover microbial secrets
Viruses – the invisible majority of the oceans

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Editorial

Happy New Year! We are already in the second month of 2019 and I would like to welcome everyone to the first edition of *Microbiology Today* for this year and wish everyone the best of luck with their endeavours in 2019. We're starting off the year by considering the effect microbes have on the world's oceans. The oceans have fascinated people for centuries, and have been utilised for travel, food and for pleasure. Increasingly, we now also see that the oceans are a wonderful source of microbial diversity.

Whole Picture

As research advances, so does our understanding of how oceanic microbes can impact on the world. In this issue, our authors demonstrate the variety of roles microbes can hold, ranging from conservation through to novel antimicrobial agents.

First in this edition is Amy Apprill, whose research investigates the role of microbiota in marine conservation. Questioning how changes in environmental niches have impacted on the resident microbial flora within those niches, Amy discusses how improving understanding of the baseline microbiome of marine populations could aid our efforts to protect and conserve ocean species in the future.

Moving from conservation to self-preservation, Aoife Boyd walks us through the potential dangers of consuming the bacteria associated with shellfish. A much-loved tasty treat enjoyed by many can lead to food poisoning if it harbours certain pathogens. Aoife provides details on how research into *Vibrio* has shown how multiple virulence factors, including toxins, can cause a series of opportunistic diseases in those unlucky enough to ingest these bacteria. Aoife also provides us with information how shellfish diseases caused by the same pathogens can affect shellfish aquaculture on a global scale.

Providing a glimpse into another area of research, which could have direct implications for human health, Mat Upton, Matthew Koch and Kerry Howell discuss the potential for sea sponges in medicine. Could these ancient life forms be the source of novel antimicrobial compounds needed to combat antimicrobial resistance? Research using the latest sampling technology has allowed the hunt for these deep sea sponges, their associated microflora and bioactive compounds to go to previously unexplored depths.

The process of obtaining samples from deep or remote locations at sea has traditionally been limited by ship-based logistics. To better understand how ocean microbes impact on biogeochemical cycles, Susan Evans, Jim Birch, John Breier, Michael Jakuba, Mak Saito and Julie Robidart have been using autonomous samplers unconstrained by those limitations. Giving an overview of three novel autonomous samplers, they describe how molecular ecology research can be enhanced through technology. They provide examples of where this new technology has already led to the discovery of microbial activity previously undetected at sea.

In our last themed piece, Elina Laanto reminds us of the diversity and number of marine viruses and how these have substantial influence on both food webs and biogeochemical cycling in the oceans. Discussing how the interactions between viruses and hosts can control microbial population and influence the nutrients available in surface waters, Elina also reminds us that climate change could alter these interactions. However, as viruses are often omitted from modelling, the impact on and from marine viruses in response to change in the marine environment is largely undefined.

For our Comment piece, Aditee Mitra addresses the role of mixotrophs in the oceans, providing details of how mixotrophs impact in perhaps unexpected ways. Involved in a diverse range of activities, these microbes can impact on our atmosphere, as well as producing components which are utilised in the production of everyday consumables. Traditionally underrepresented in research, Aditee demonstrates to us how mixotrophs actually dominate in the oceans and how they achieve their success.

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False-colour composite satellite image of what appears to be a large bloom of cyanobacteria (blue-green algae) swirling in the Baltic Sea. NASA/Science Photo Library

MICROBIOLOGY SOCIETY

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From the President

I will not deny that taking on the role of President is daunting. I do not believe in changing things for the sake of change and making a mark. Over the past few years the Microbiology Society has, through the hard work and vision of past Presidents, the Council and Committees, backed up by an exceptionally dynamic Chief Executive and officers, transformed into a really vibrant Society that is making a difference to both the research environment of our members, and the understanding of microbiology in the wider community. Rather than change the things that are already working very successfully, I will try to develop a few new avenues that might make UK microbiology even stronger.

This year I will be working with the member engagement team on a series of roadshow to be held across the UK and Ireland. We want to listen to the broad community of microbiologists, members and non-members, and discover what we can do to help bring microbiologists together in your area, strengthening communities and links between neighbouring institutions. We hope each roadshow event will bring together both 'card-carrying' microbiologists and researchers that are using microbes, but who might not identify as microbiologists. Through discussion, we hope to identify mechanisms by which we might help you develop a local, active community of microbiologists and facilitate exciting new collaborations. I hope to see many of you there.

I am really looking forward to attending the Society's Annual Conference 2019 (**#Microbio19**) in Belfast in April. It will be fantastic to talk to members and hear from the Prize Lecture winners, Hot Topic speakers and presenters in the sessions, and view the submitted posters that will be on display across the venue. The Teaching Microbiology in Higher Education Symposium will be taking place the day before Conference too, for those of you who have teaching responsibilities and wish to attend. The Early Career Microbiologists' Forum Summer Conference will also be hosted in Ireland, at Trinity College Dublin in June. Later in the year, the 2019 Focused Meeting series will run between June and October, with events taking place in Cardiff, Dublin, Glasgow, Newcastle and Oxford.

To celebrate our 75th anniversary in 2020, we are launching a wide-ranging programme of events and activities to showcase why microbiology matters and to demonstrate the impact of microbiologists past, present and future.

We launched the programme in November with Why Microbiology Matters, a call to the community to nominate a discovery, event or activity that best highlights how microbiology answers big questions by giving us knowledge of very small things. If you have not already done so, please join in and make your nomination via our website. After making your nomination, you can also share your idea on Twitter using the hashtags **#MicrobioSoc75th** and **#WhyMicroMatters**.

Other events and activities which will form part of our anniversary year, will include a project on microbiology and the UN Sustainable Development Goals, which you can read about on pages 38 and 39, celebrations of microbiology in art and literature and a showcase of our Fleming Prize winners. We will release more information about the programme and how you can get involved over the coming months.

Collaborating in science is key and we want to support the microbiology community, to help build connections and support the range of careers of the membership. Do log in to the member area of the website, Mi Society, where you can find member-only information and resources. Add your details to the Members' Directory and search for others in your field or related fields to find fellow microbiologists. Take advantage of the networking opportunities at Annual Conference too. If you need some advice about how to network, read the article on page 35 compiled by the professional development team. Follow the Microbiology Society on Twitter to keep up to date, and you can find out about my activities as President via my Twitter account too **@Armitage_Judy**. (And can I encourage those microbiologists who do not think Twitter is for them to give it a go. I did and the world of microbiology I was missing is a revelation!)

Judith Armitage
President
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From the Chief Executive

One of my favourite parts of working for the Microbiology Society is attending Focused Meetings, where communities of members come together to discuss, advance and develop the latest science in particular subjects. With the topics selected from members' ideas, the programmes constructed by passionate experts, the venues chosen to be accessible and conducive to welcoming and friendly interaction, and the delegates made up of everyone from students to professors, Focused Meetings exemplify what the Society is here to do.

Focused Meetings allow members to expand and strengthen their networks within their specialist fields. They allow more established members to raise their profile by taking the scientific lead in organising scientific meetings, without any of the administrative burden, all of which is handled by the team of dedicated and professional staff.

During the 2018 programme of Focused Meetings, the speakers alone came from 22 countries in five continents. The poster presenters and other delegates added many more countries to the list and gave the meetings a genuine claim to be global in their outlook. The speakers described amoebae, yeasts and other fungi, bacteria, archaea, phages, DNA and RNA viruses, and cyanobacteria. And I learned that their micro-organisms are associated with poultry, cattle and sheep in agricultural settings, moss, angiosperm plants of every description, ornamental caged birds, household pets, invertebrates and, of course, people.

The talks took me to wonderful field sites in the Hudson Bay, the high Andes, the tundra of Iceland, Kenyan livestock farms, impenetrable South American rainforest, shallow lakes in Europe and deep ones in America, and even a Russian bog where the land is several metres deep but is floating on a huge and almost fathomless invisible lake. I experienced every possible scale of study, from the submolecular to the truly global, through technologies from electron microscopy to satellite imaging.

These meetings proved the truth of the first sentence in the Microbiology Society's strategy: Microbes are everywhere and affect almost all aspects of our lives. They also verified the statement that 'our members have a unique depth and breadth of knowledge about the discipline'.

If anyone has ever doubted that microbiology matters, they should just read the tweets about the Society's Focused Meetings – microbiologists are helping us to understand everything from human health and disease, through food security to global climate change. Not only that, but microbiology is helping in the search for solutions to the challenges these global issues bring.

Focused Meetings are chosen from proposals submitted by members, and the Scientific Conferences Committee is always on the look out for good ideas. One of the first steps is to contact the Chair of the relevant Division (Prokaryotic, Eukaryotic, Virology and the Irish Division) or discuss your application with the Conferences Team by emailing **conferences@microbiologysociety.org**, as we are always keen to discuss outline proposals at an early stage. You can find out more information online (**microbiologysociety.org/focusedmeetingproposals**), including the proposal form and criteria for the events.

While Focused Meetings each concentrate on one area or discipline, the Annual Conference brings the whole field together in a great festival of microbiology. For this year's event in Belfast, we received even more abstracts than we did last year. We can look forward to some inspiring Prize Lectures that will showcase high profile results, great workshops and forums where new research will be explored, and wonderful professional development sessions that will allow members of all career stages to learn new skills and refresh existing ones, while making new friends and catching up with old ones.

I look forward to seeing you at the Annual Conference in Belfast, at some of the Focused Meetings, which you can read more about on pages 32 and 33, and at other Society events coming up this year, including the ECM Forum Summer Conference in June and FIS 2019 in November.

Peter Cotgreave
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News

Plan S and the Microbiology Society

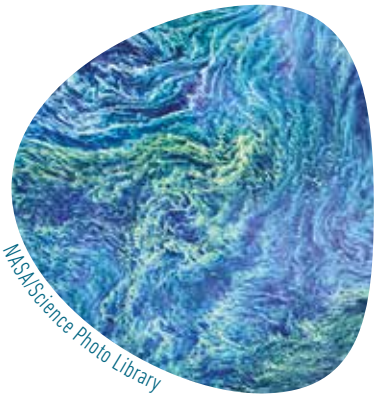
You might have seen reference to something called Plan S, a new initiative from a coalition of European national research funding bodies, including UKRI, the Wellcome Trust and the Gates Foundation. Plan S calls for universal open access (OA) to research funded by the plan's signatories from 1 January 2020. Find out more about the initiative on our blog, Microbe Post (**microb.io/2HxcwWX**).

Antibiotics Unearthed: leaving a legacy

Antibiotics Unearthed was a public engagement venture inspired by the Small World Initiative™ and ran for four very successful years. It gave members of the public, students and educators throughout the UK and Ireland a unique opportunity to work with scientists as part of a global initiative to discover new antibiotics from soil bacteria. Although the venture has now come to an end, we have compiled a number of resources to ensure we continue to learn and unearth antibiotics. See the website for more information (**microbiologysociety.org/antibioticsunearthed**).

Annual Conference early bird deadline

The early bird registration deadline for Annual Conference 2019 is **4 March 2019**. This year's Conference is taking place at the ICC Belfast, UK on 8–11 April 2019. Annual Conference is designed to cover the breadth of microbiology research, and its comprehensive scientific programme has over 30 sessions taking place over four days in a range of formats. Find out more about what to expect on pages 30–31.



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Oceans

This issue of *Microbiology Today* focuses on 'Oceans'. Find out more about marine microbes at the 'Marine protists as emerging models for functional genomics and cell biology' session, organised by Adam Jones (Gordon and Betty Moore Foundation, USA) and Anastasios Tsaousis (University of Kent, UK), taking place at Annual Conference 2019 in Belfast in April. Visit **microbiologysociety.org/Microbio19** for details.

Wladimir Bulgar/Science Photo Library

Access Microbiology

Access Microbiology is open for submissions. The journal introduces a new service to members of our community, allowing the publication of replication studies, negative or null results, research proposals, data management plans, additions to established methods, and interdisciplinary work.

More information about the journal can be found on our website (**acmi.microbiologyresearch.org**).

Look out for the first few articles that will be published soon.

Gradline to become Career Focus

Gradline, a regular series of guides to help undergraduates and early career microbiologists in their careers, is back, under the new name: 'Career Focus'. As the Annual Conference is mere weeks away, the first article in the revival is about networking: why bother, and how to make something awkward beneficial! See page 35 for more details.

Microbiology Society Roadshow

Next month, President Judith Armitage will embark on the first of a number of roadshows throughout the UK and Ireland. This is an opportunity for members to connect locally with fellow members and find out how to get more involved with Society activities, as well as showcasing future plans for the Society, including our 75th Anniversary next year. Visit Mi Society (**microbiologysociety.org/login**) for more information on how to get involved.

Grant deadlines

Date	Grant
31 March 2019	ECM Forum Event Fund: host your own local event for fellow ECMs with up to £500.
1 April 2019	Education and Outreach Grants: up to £1000 for your microbiology education or outreach activities.
	International Development Fund: up to £5000 to support microbiology development initiatives in low-income economy countries.
	Research Visit Grants: up to £3000 to support early career members to visit collaborators.

For more information please visit the website (**microbiologysociety.org/grants**).

UN Sustainable Development Goals

As part of the programme of events and activities surrounding the Society's 75th anniversary in 2020, we are embarking on a project that will celebrate and champion the role of microbiology in addressing the world's biggest challenges, within the global framework of the United Nations Sustainable Development Goals (UN SDGs). Find out more on pages 38–39.

75th anniversary: Why Microbiology Matters

To celebrate our 75th anniversary in 2020, we are inviting members to nominate the discovery or event that best showcases why microbiology matters and helps us demonstrate the impact of microbiologists past, present and future. Submit your nomination using the form on our website (**microbiologysociety.org/WhyMicroMatters**).

ECM Forum Summer Conference 2019: open for abstracts

Following the success of the inaugural event in 2018, the Early Career Microbiologists' Forum (ECM) Summer Conference will again be taking place in 2019, 20–21 June at the Moyne Institute, Trinity College Dublin, Ireland.

Abstract submissions are now open. You can submit your abstract and register for the event on our website (**microbiologysociety.org/ecmconf19**).

Deaths

Professor Willie Russell died peacefully on 31 October, aged 88. He was Head of the Division of Virology (NIMR, London) and Chair of the Department of Biochemistry (University of St Andrews). Willie was an active member of the Society and an elected fellow of the Royal Society of Edinburgh. Read Willie Russell's obituary on the blog (**microb.io/2TT1Bcj**).

Professor Basil Jarvis, a member of the Society since 1970, died peacefully on 18 December 2018 at the age of 82.

Contributions and feedback

The Society welcomes contributions and feedback from members. Please contact **mtoday@microbiologysociety.org** with your ideas.

Get the latest updates, search for the Microbiology Society on:

@MicrobioSoc

Dr David Clarke

Chair of the Irish Division

The Society has four Divisions (Eukaryotic, Prokaryotic, Virology and Irish) made up of members who support the direction and remit of the organisation and who plan sessions and symposia for the Society's annual events. The Chair and Chair-Elect of each Division also sit on the Scientific Conferences Committee, with the responsibility for making decisions on policy and meetings content, and the Chair reports into the Society's governing body, Council. David Clarke is the Chair of the Irish Division. In this article, David tells us about his background, why he became a microbiologist and his role within the Society.

David Clarke

My name is David Clarke and I am a Lecturer in the School of Microbiology at University College Cork (UCC), Ireland. I am also a Funded Investigator in APC Microbiome Ireland, an Irish government-funded research institute focused on the role of the microbiome during health and disease and based at UCC. For many years my group has been interested in understanding the molecular mechanisms that underpin microbe–host interactions. At the moment my group has active projects involving *Escherichia coli*, *Bacteroides* and *Photorhabdus* (a bacterium that is a pathogen of insects while also maintaining a mutualistic association with nematodes).

When did you first decide you wanted to do science (and why)?

During school we had a great biology teacher, Mrs Lynch, and she got me interested in the subject. However, we didn't do very much microbiology in school and it was my father, who spent some time working in the microbiology laboratories in Guinness (both in Ireland and abroad), who probably sparked my interest in microbiology with the initial idea that I might be a brewer! I did a BSc in Biotechnology at Dublin City University, and it was here that my head was turned towards bacteria and genetics. There is something incredibly satisfying about successfully understanding a complex phenotype in terms of the interactions between some genes and their environment.

When did you join the Society and why did you join?

I don't remember exactly when I joined the Society but it was a long time ago! I think that I initially joined to participate in the 123rd Ordinary Meeting of the Microbiology Society (Society of General Microbiology as it was then) in Trinity College Dublin in September 1992.

Please describe your role on the Division

I am currently Chair of the Irish Division. The Irish Division seeks to promote all aspects of microbiology in the Republic of Ireland and Northern Ireland. Every year the Irish Division organises meetings on diverse microbiology topics and everyone is welcome to participate in these meetings.

What motivated you to be part of the Division?

I have been on some sort of committee or another with the Society since 2003 when I was first elected to be a member of the Physiology, Biochemistry and Molecular Genetics Group (now part of the Prokaryotic Division). At the time I was a new member of faculty at the University of Bath and I was very interested in the networking opportunities that working on this committee would provide. It was also very rewarding to be involved in organising conferences and symposia, and I have thoroughly enjoyed working with the Microbiology Society over the years.

Are you a member and would you like to join one of the Divisions? Find out more about the Divisions and what they do on our website (**microbiologysociety.org/divisions**). There is also a Council and Committees shadowing scheme which is a fantastic opportunity to gain an insight into the work of the Society and to gain a wealth of knowledge by experiencing first-hand our Council and Committee activities. Find out more: **microbiologysociety.org/shadowingscheme**.

Impact of conservation on ocean animal microbiomes

Amy Apprill

My elder coral reef colleagues frequently reminisce about the past state of Caribbean coral reefs. Their observations of coral reefs during the 1960s and 1970s include descriptions of abundant elkhorn corals, massive mounding star corals, and plentiful grouper and large-sized parrotfish. All of these features are now rare on most Caribbean reefs, which have been impacted by disease, overfishing and habitat destruction. Abundant and fast-growing macroalgae, smaller corals and fish of reduced size and numbers have replaced the prior keystone species.

As a microbial ecologist listening to descriptions of these past Caribbean reefscapes, I am intrigued by this change. I wonder if and how micro-organisms and their functional processes have altered during this period of dramatic transformation. Did the environmental microbes, including those in the reef waters and sediment, alter in composition? Have the microbiota of the animals altered in response to the pressures of this new environment? Finally, how do these microbial changes feed back into larger ecosystem and animal health changes?

Marine life conservation and microbiomes

It is these scenarios of ecosystem and species decline that have led to conservation efforts for many marine animals, including 10% of the coral species found only in the Caribbean. Conservation is the act of protecting and preserving resources, and it is important because it maintains biodiversity and balanced ecosystems, thus promoting their functioning and overall health. In the ocean, conservation protections are frequently placed on vulnerable marine life to prevent further exploitation and promote recovery of species. These protections are most commonly

Recent photographs of Caribbean reefscapes provide a pictorial contrast of remote and protected reefs in the Gardens of the Queen, Cuba (above) and less protected and more impacted nearshore coral reefs in the Florida Keys, USA (below). Amy Apprill

placed on life due to threats from overexploitation (for example, fishing and harvesting) and habitat degradation that is enhanced by coastal development. Currently, the International Union for Conservation of Nature (IUCN) lists 12,929 marine species on their Red List with 1,679 assigned a threatened or near-threatened status.

There is very little known about how conservation efforts impact the microbiota of marine animals because the microbiomes of most ocean animals are unstudied. Detailed studies do exist for some taxa, but they are generally not done in a manner that allows for direct comparison before and during/after a species is impacted by the aforementioned threats. While it is difficult to 'go back in time' for some marine animals, there are predicted to be around two million marine animal species in the oceans, and most of these are not thought to be in decline. Understanding the microbiomes of these healthy animals at the present time could enhance future conservation and management efforts.

Need for baseline microbiomes

The microbiomes of healthy, non-threatened marine animals can provide an understanding of their baseline or normal microbiomes. This is most cost-effectively examined using high-throughput sequencing of small subunit ribosomal RNA genes or other taxonomic marker genes, which provide data about the taxonomic composition of the associated micro-organisms. At a greater cost, metagenomic sequencing of all the DNA in an environment provides additional insight into functional genes of the micro-organisms, as well as cells that may not be accounted for by the primers applied to the marker gene studies.

A remotely operated hexacopter or drone approaches a humpback whale in the waters surrounding Patagonia, Chile. The drone holds a petri dish, which is used to collect exhaled breath or blow samples from large whales. These blow samples are being analysed to understand the composition of the associated microbiome. This technique is being explored as a means to non-invasively assess the respiratory health of whales. Courtesy of Daniel Casado (MERI) and taken under permit MERI 1197-Feb-2017

These types of sequencing-based data are valuable and can provide a window into the micro-organisms associated with healthy or normal functioning animals. Studies of human microbiomes, and especially gut microbiomes, show clear connections between the diversity and composition of the microbiota and individual diet and health states. These microbiome baselines can be most informative when disease symptoms are present. As such, the healthy microbiome can be used to document changes, including noting the presence of potential pathogens or loss of beneficial micro-organisms. Gathering knowledge of the associated animal microbiome prior to, and following, animal health or habitat declines is a major challenge in this comparison. Indeed, under the current rate of climate-associated change impacting the ocean, it is difficult to attain true baselines on the microbiomes of non-impacted animals.

It is impossible to apply today's deep-sequencing methods to the Caribbean reefs of the past, yet studies are taking creative approaches towards building an understanding of how conservation efforts can impact the microbiomes of marine animals. A recent three-year field experiment examined how overfishing and nutrient pollution, as well as natural temperature fluctuations, impacted the surface mucus microbiomes of coral. This elegant experiment demonstrated shifts in microbial community composition within the surface mucus layer of corals, following the stressors. Further, putative pathogens and observations of coral disease symptoms coincided with the ecosystem disturbances. This work provides a link between overfishing and nutrient pollution impacting coral microbiomes, and suggests that ecosystem conservation could also conserve the coral microbiome and decrease the susceptibility of corals to disease. My laboratory group, together with colleagues, is further examining this relationship through comparative studies of coral microbiomes sampled inside and outside of marine protected areas.

Ocean warming and pathogens

Ocean warming is directly related to animal microbiome composition in the ocean, including animals under conservation protection. This relationship has been observed in corals, sponges, oysters and even in microbiomes on the surfaces of whales. The specific mechanisms behind why community alterations occur have not been directly examined. There are at least two possible hypotheses driving this relationship. The first is that temperature is a major and controlling factor of microbial growth. Thus, enhanced temperature may select for the growth of certain micro-organisms. The second hypothesis is that enhanced temperatures, especially for prolonged periods, could impact immune and biochemical changes within the host, thus influencing the chemical growth or communication environment that is optimal for the microbes. Overall, ocean warming and altered microbiomes could impact the health and major functioning of ocean animals, especially if the microbes are endosymbionts or involved in an obligate relationship.

Another major concern for ocean animal microbiomes is that warmer sea conditions could promote the growth of pathogens and/or promote virulence of normally benign species. A 40-year ocean time-series recently demonstrated that warming oceans promote the growth and persistence of *Vibrio*, including pathogenic strains. Indeed, marine diseases have increased in prevalence over the past few decades. Some of these new outbreaks are not caused by new and emerging micro-organisms, but rather known pathogens infecting previously untargeted hosts. For example, many Caribbean sea fans are infected by the pathogen *Aspergillus sydowii*, which is a fungus inhabiting soils and known to infect terrestrial life.

Health diagnostics, probiotics and future prospects

A benefit of understanding the microbiome of an animal is that a framework is developed for health diagnostics. This health diagnostic approach could play a role in conservation efforts or management decisions. Towards this idea, my laboratory, along with colleagues, is examining the microbiota within skin, as well as within the exhaled breath or 'blow' from large whales. As large whale populations continue to face pressures from human use of the oceans, microbiome metrics could provide a means to document animal health alterations.

Intervention by probiotics is an emerging and controversial idea, which certainly benefits from extensive knowledge of ocean animal microbiomes. The idea behind probiotics is that supplements of beneficial micro-organisms are given to an animal, which will then enhance its health and/or recovery from disturbance. Human probiotics is a more than $40 billion industry, yet the scientific data demonstrating their benefits is still largely lacking. In conservation biology, especially for terrestrial animals, probiotics are viewed as potentially beneficial for captive-raised animals. In the ocean, research groups are examining the benefits of probiotics for aquaculture, as well as to improve coral resistance to disease following ocean warming-related and widespread bleaching events.

In animal conservation studies, surveys are commonly conducted to understand the number and distribution of species. Similar information is needed for the microbiomes of ocean animals. This knowledge could have powerful benefits for animal conservation in the oceans, and is especially pressing to obtain under the current and planned climate-related impacts facing the ocean.

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Amy Apprill leads the Microbial Ecology for Ocean Conservation research laboratory at the Woods Hole Oceanographic Institution. Her laboratory conducts research which examines the contribution of micro-organisms to the health and ecology of sensitive animals and ecosystems of the ocean. She also partners with communication professionals to convey this science to public audiences.

What is the most rewarding part of your job?

The most rewarding part of my job is the time I spend in the field. I enjoy the beauty and tranquility that ocean ecosystems offer, the challenge of conducting research in remote locations and working together with a team of scientists.

What advice would you give to someone starting out in this field?

Don't be afraid to ask for help or advice when you are stuck. Most of us have been in that same place many times and have counted on others for help identifying solutions.

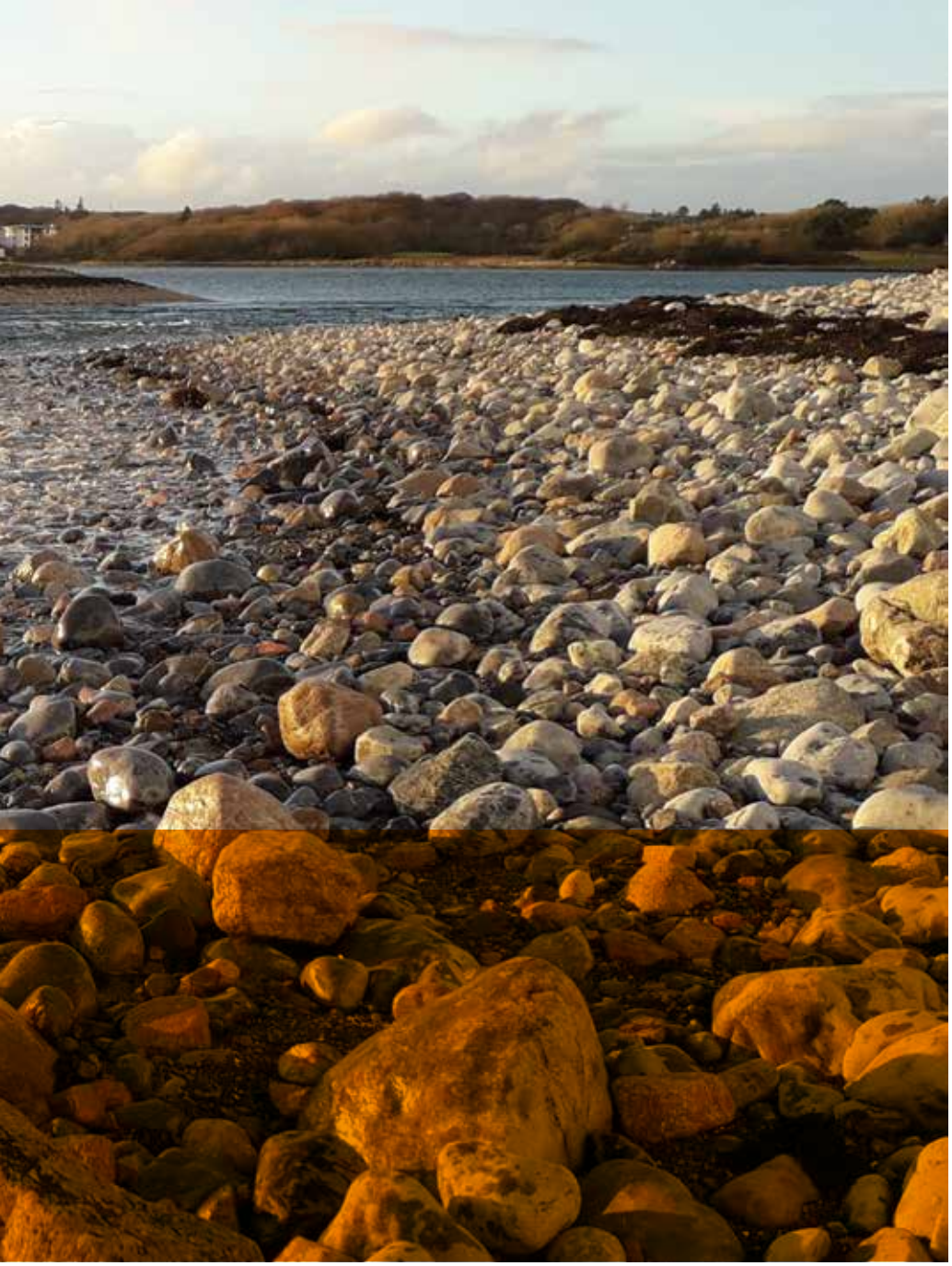
Pathogenic bacteria in our oceans' shellfish

Aoife Boyd

Mussels, oysters, clams – some of the most appetising culinary dishes, such as moules-frites, feature shellfish. These foods are considered healthy as they are fresh from the ocean, but looks can be deceiving.

Location of mussel beds below the waves in Galway Bay, Ireland. Aoife Boyd

Improperly prepared or incorrectly stored shellfish can harbour bacterial, viral and algal pathogens and toxins that can cause extremely unpleasant food poisoning, with symptoms of gastroenteritis, diarrhoea and nausea lasting for several days. Antibiotic treatment and drinking plenty of water to prevent dehydration helps most sufferers. However, for people with underlying health conditions, or whose everyday living conditions and state of health are poor, the consequences can be life-changing, potentially leading to



systemic disease, organ failure and, in extreme cases, even death.

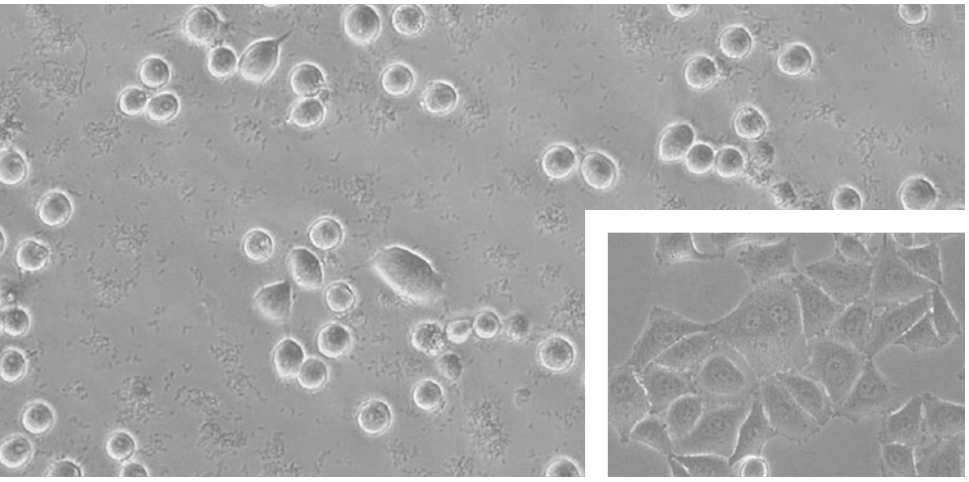
Marine *Vibrio* as seafood pathogens

Some of the most powerful and lethal cases of shellfish food poisoning are due to toxins from dinoflagellate algae. Their disease names alone could discourage the eating of shellfish – paralytic shellfish poisoning, amnesic shellfish poisoning, neurotoxic shellfish poisoning. As symptoms result from ingesting toxins accumulated in the shellfish, adverse effects can be experienced within a few hours of eating the contaminated shellfish and cooking may not inactivate these toxins. More usually though, bacteria or viruses are responsible for shellfish-borne gastroenteritis.

Marine waters teem with abundant *Vibrio* species. A few species are capable of causing human gastroenteritis – in particular *V. parahaemolyticus* and *V. vulnificus*. While *V. cholerae* is more widely known, due to severe outbreaks of cholera, infection occurs through contaminated drinking water and improper sanitation, rather than through shellfish consumption. Startling news headlines about 'flesh-eating bacteria' and graphic images of necrotising fasciitis highlight the severity of disease when *V. vulnificus* invades into the bloodstream, causing extensive tissue damage, low blood pressure, shock and, in 50% of cases, death. Fortunately, these cases are rare and infection normally remains limited to the human gut.

V. parahaemolyticus and *V. vulnificus* cause disease by deploying an armoury of virulence factors, including cell adhesins, haemolysins, toxins, immune modulators, proteases and lipases. Complex multi-unit structures, such as pili, attach the bacteria to host cells. Type III secretion systems (T3SS) inject immune-modulatory effectors and toxins into the cells of eukaryotic hosts. Recently, it has been reported that *Vibrio* species are not only effective at causing disease due to their interaction with, and effects on, host cells, but can also utilise type VI secretion systems (T6SS) to kill the gut microflora, thereby providing the *Vibrio* with a competitive advantage. The discovery of molecules that inhibit virulence may lead to the development of novel treatments for gastroenteric diseases. As these molecules do not directly kill bacteria, there is less selective pressure for the emergence of antimicrobial resistance.

Not all *V. parahaemolyticus* and *V. vulnificus* isolates are capable of infecting humans. Due to extensive genetic diversity in these species, only a proportion of strains harbour the full complement of virulence genes necessary to cause disease. Examples of diversity are the presence, absence, number and type of haemolysin, T3SS and T6SS that each strain possesses, as well as individual amino acid variations



Clusters of *Vibrio parahaemolyticus* attach onto human intestinal epithelial cells. The T3SS causes the disruption of the cell cytoskeleton leading to changes in cell morphology. The inset shows non-infected human cells. Aoife Boyd

within adhesive pilin subunits. Diversity is boosted by the movement of mobile DNA pathogenicity islands containing virulence genes (for example, T3SS and haemolysin genes) between bacteria. The relative contribution of each mechanism and the nucleotide variation within the genes themselves to the pathogenic potential of the bacteria are an active area of research.

As there is no known transmission of *Vibrio* between humans, it is thought that the capability of these bacteria to cause disease is fortuitous – for the bacteria! The virulence factors may have evolved to provide the bacteria with benefits for survival in the marine environment and colonisation of marine organisms.

Pathogens in shellfish disease

Shellfish pathogens have adverse effects not only for human health, but also for shellfish aquaculture. Several pathogens primarily target and infect shellfish, leading to massive kill-offs of thousands of shellfish, which can cripple an industry at a local level. For aquaculture, disease can be particularly devastating in the post-spawning period. At this time, shellfish experience physiological stress due to warm waters and dense crowding. The stress makes the shellfish more susceptible to disease and increased severity of symptoms, while the close proximity of neighbouring shellfish allows easy transmission of disease from one individual to the next.

The control of disease in shellfish is important due to the significant contribution of aquaculture to national and financial interests. The majority (85%) of the world's aquaculture marine molluscs are produced in China, while the country with the next largest production is Japan, with 2%. In 2016, 17 million tonnes of molluscs were harvested from aquaculture and six million tonnes captured from natural environments for commercial, industrial, recreational and subsistence purposes. Oysters account for a quarter of all molluscs harvested, with clams, cockles, ark shells, mussels, scallops and pectens together representing half of all production. Bacterial diseases of larvae and early juveniles are not

The control of disease in shellfish is important due to the significant contribution of aquaculture to national and financial interests.

uncommon in oyster hatcheries. They are most frequently attributed to *Vibrio* species and can lead to mass mortalities. However, disease is not limited to aquaculture and also occurs in natural populations.

Safe seafood

So how do we avoid the unwanted symptoms of shellfish poisoning? Cooking will kill the bacteria, but alcohol, lemon or hot sauce will not! Ensure the quality of the producers and the shellfish source. Shellfish producers follow national guidelines and regulations to monitor the occurrence of shellfish pathogens in areas of shellfish production, to ensure their absence in the product and safety and quality of their product. Harvesting may only occur when detection methods have confirmed that human pathogenic microbes are within acceptable safe limits in an area of shellfish culture. Further steps, such as depuration, are carried out to reduce the number of bacteria in shellfish and reduce bacterial growth during storage. Depuration is a process by which shellfish are placed into a clean water environment for a period of time to allow purging of biological contaminants (bacteria and toxins) and physical impurities (such as sand and silt), heavy metals or organic chemicals via the natural filter feeding of the shellfish.

The old adage to only eat seafood in a month with an 'r' – such as February – relates to the increased numbers of bacteria that can be found in warmer waters, and in shellfish, during the summer months. With the proper monitoring, culturing, harvesting and storage, shellfish can be enjoyed in any month.

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Mussels are a tasty shellfish, but may harbour gastroenteric bacteria. Aoife Boyd

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Aoife Boyd is Senior Lecturer in Microbiology at National University of Ireland Galway. Following PhD and postdoctoral research positions in the USA, Belgium and Austria, she returned to Ireland to establish the Pathogenic Mechanisms Research Group. Her research investigates host–microbe interactions of pathogens (especially *Vibrio* species) and of the human gut microbiome.

Why does microbiology matter?

Microbes influence every aspect of our lives and life on Earth. Harnessing knowledge of microbiology brings beneficial impacts to the global environment and to our health and wellbeing.

What is the best career decision you have made?

The best career decision I ever made was to pursue a career in bacterial pathogenesis, host–microbe interactions and molecular biology research. This is actually a decision enacted multiple times at each career move (BSc, PhD, postdoc, biopharmaceutical industry, academia) and throughout the development and progress of each research project. The elegance and sophistication of the powerful systems that microbes create to colonise humans and other organisms continues to fascinate me and drives my research to understand their purpose and molecular intricacies.

Are sea sponges a key part of the complex solution to antimicrobial resistance?

With the impending threat of antimicrobial resistance, now a widely-recognised phenomenon, researchers have begun to look to the deep in search of solutions to one of the greatest threats posed to human health. Boosted by public health initiatives, government endorsement and a concerted effort on the part of researchers worldwide, we are now beginning to work towards potential alternatives to the scenario outlined by Lord O'Neill in 2016 in the Review on Antimicrobial Resistance. But have we begun to turn the tide?

Matthew Koch, Mat Upton and Kerry Howell

Antimicrobial discovery, as part of the much-needed and multi-faceted approach to tackling antimicrobial resistance (AMR), has necessitated that the search for novel compounds be widened to new and unexplored environments. Sponges have emerged in recent decades as the most prolific source of novel biological compounds from the marine environment. Over the last 45 years, sponges have become the most widely sampled marine phyla in the hunt for novel bioactive compounds. Initially, antimicrobial activity in sponge extracts was believed to be derived from the sponge itself, but the rediscovery of compounds across distinct sponge species, as well as the similarity of the compounds to those observed in terrestrial micro-organisms has confirmed that many sponge antimicrobials are in fact of microbial origin. For this reason, focus has shifted towards investigation of the microbial constituents of the sponge microbiota. The use of metagenomics to characterise the microbial inhabitants of specific species, alongside efforts to culture these sponge-associated microbes, is providing sponge researchers with an ever-growing bank of promising drug leads.

Sea sponges and their microenvironment

So what is it about sponges that make them and their resident microbes such an ideal environment for the production of such exciting compounds?

Far left. ***Euplectella*** **sp. sponge prior to sampling (~1,200 metres).** Upper left. ***Pheronema carpenteri in situ*** **on the sea-floor (~1,200 metres).** Dr Kerry Howell courtesy Eurofleets2–funded DeepMap project – University of Plymouth, NUI Galway, Centre for Environment Fisheries and Aquaculture Science (Cefas), Marine Institute.

Our story starts a mere 600 million years ago. The icy desolation of a frozen earth is now a distant memory, multicellular life has transferred from MPhil to PhD and the first 'complex', invertebrate organisms are beginning to emerge. Enter the *Porifera* (sponges). Fast forward 600 million years and you arrive at the existence of an ancient metazoan organism with a unique, complex microbiota and a convergent evolution to be proud of. Sponges can be categorised as either high or low microbial abundance species. With a microbial abundance of 10^{8-10} cells per gram of sponge tissue for 'high microbial abundance' sponges, their complexity exceeds that of the surrounding environment. This, combined with the knowledge that the sponge microbiota is known to play an important role in a range of ecological functions in the marine environment, makes it easier to imagine how the dynamic microenvironment of the sponge holobiont becomes such a reservoir for new and interesting antimicrobials.

The characterisation of the global sponge microbiome has identified a generally conserved or 'core' microbiota across sponge species, albeit with a high degree of interspecies variation. Proteobacteria, predominantly the *Gammaproteobacteria*, dominate the core microbiota, accompanied by members of the *Cyanobacteria*, *Acidobacteria* and *Actinobacteria*. A look at the major producers of antimicrobial compounds thus far from the sponge holobiont reveals that the *Actinobacteria*, specifically *Streptomyces* species, represent the most prolific producers of antimicrobial agents (~27%), followed by *Pseudovibrio* (~18%).

Even with the conservation of the core sponge microbiota, there is a high degree of variability between sponge species, particularly in the non-core, or lower-abundance bacterial species. It has been demonstrated that the sponge–host identity is the most important factor in determining microbial composition, suggesting that there is still far more to be discovered by looking at under-studied species.

Exploring the deep

It is only with relatively recent advances in sampling technology, the use of remotely operated vehicles (ROVs) and submersible vehicles, that the recovery of deeper water samples in good condition and from rocky seabeds, has been made possible. Previous to this, the only way to sample deep-sea animals was using trawls and dredges which damaged specimens and restricted use to softer seabeds where nets would not be damaged during sampling. Even so, much of our study has been of those animals found shallower than 1,000 metres, where now we are beginning to look deeper than this. Being able to sample these new environments provides access to more diverse sponges and brings with it the promise of a wealth of novel strains and compounds.

The use of ROVs for deep-sea sample collection is allowing our research team at the University of Plymouth to conduct the first in-depth investigations of a number of previously unstudied glass sponges (Hexactinellida), revealing information about their resident microbes and biotechnological potential. Much of the work previously describing sponge microbiota and novel antimicrobial discovery has been focused on sponges obtained from shallow waters. In addition, the Demosponge class of sponge has traditionally taken centre-stage in the hunt for novel bioactives. Occurring almost exclusively below 200 metres depth, the glass sponges represent an extremely under-appreciated organism in the ongoing search for bioactive molecules, particularly when considered in light of the knowledge that bacterial diversity in marine environments is known to increase with depth.

Potential novel bioactive compounds

It is suggested that with novelty of sample comes novelty of associated biologics. This assumption, explored with the use of both culture-dependent and -independent methods, is reinvigorating the quest for compounds in light of the 'great plate anomaly' (see box*), and in the process unravelling the hidden relationship between the hexactinellid sponge microbiota and its propensity for bioactivity.

With regards to the role of sponges specifically in the context of tackling AMR, it is interesting to note that, as yet, none of the compounds elicited by sponges or their microbiota have been translated into clinically approved antimicrobial drugs. Two compounds that have been marketed are Ara-C, with anti-cancer activity, and the anti-viral agent Ara-A. The scale-up of bioactive production, particularly where agents are sponge-derived, is hindered by a lack of biological material, yet theoretically this is more manageable where bacteria are the source.

*The great plate anomaly

Where the number of micro-organisms identified using non-culture based methods, like microscopy or molecular analyses, far exceeds the numbers that can be counted growing on culture plates.

This apparent disparity between the high number of discovered compounds and the number of approved therapies perhaps speaks of a wider problem inherent in the strategies currently employed in bringing drug candidates from bench to bedside, or in this case from the seabed to the bench. With large pharmaceutical companies reluctant to invest in antimicrobial development due to the low returns on investment, time-scales involved and the inevitable threat of resistance; this brings with it additional challenges in progressing potential leads through the pre-clinical pipeline.

Minimising the threat of AMR will undoubtedly require a multi-faceted approach, a key part of which will be provision of new classes of antibiotic. It is clear that (deep) sea sponges and their microbiota represent an extremely rich and still underexplored environment, but despite their bioactive productivity, there is still much to be discovered about these fascinating organisms. Their standing in the field of novel antimicrobial discovery is yet to be fully revealed.

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Matthew Koch is a Society for Applied Microbiology-sponsored PhD student in Mat Upton's lab at the University of Plymouth, where he completed his undergraduate degree in Biomedical Sciences in 2017. His work is focused on antimicrobial discovery from deep-sea sponges and their associated microbiota.


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Mat Upton is Professor of Medical Microbiology at the University of Plymouth. He joined the Society in 1991. Mat runs a programme of novel drug discovery and span Amprologix out of the university in 2018 to further develop lead antimicrobial candidate epidermicin.


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Kerry Howell is Associate Professor of Marine Ecology at the University of Plymouth. Her research is focused on the deep-sea environment. Specifically, understanding the diversity and distribution of deep-sea species and habitats, to support more effective conservation and management of this vast ecosystem.

What does a typical day (or week) involve for you?

Matthew: A typical week for me consists mainly of lab work, working with different sponge isolates and characterising the compounds they produce. This currently involves working with a lot of different media, taking the bacteria through fermentation steps as well as chromatography. Also involved in a week are analysing results, setting time aside to read papers and drinking my fair share of coffee.

What inspired you to become a microbiologist?

Matthew: The idea that somewhere out there in the global ecosystem exist the treatments for current (and future) health problems. I also liked the idea that there were these tiny lifeforms hidden from view that were so complex and that did things I didn't understand (and still don't!).

Ocean robots uncover microbial secrets

Susan Evans, Jim Birch, John A. Breier Jr, Michael Jakuba, Mak Saito and Julie Robidart

Fig. 1. **MAPS Marine Autonomous Plankton Sampler on the long-term buoy L4 of the Western Channel Observatory, English Channel.** James Fishwick, Plymouth Marine Laboratory

Life on Earth began in the sea, and the oceans continue to support life on our planet. Of particular importance is the ability of marine microbes to exist in a complex web of relationships where substances are continually transformed and exchanged.

For instance, some microbes take energy from the sun and convert carbon dioxide into biomass, while other microbes consume this biomass, releasing carbon dioxide into the atmosphere. This is an example of a biogeochemical 'cycle' that is central to all life on the planet, yet understanding how these microbes perform this cycling requires observation capabilities that are not yet fully developed. This is because understanding biogeochemical cycling in the ocean requires samples, taken at times and locations more frequently than the microbial signature is changing. This is a difficult proposition for typical ship-based sampling schemes.

Traditional oceanic sampling techniques involve deploying collection bottles from scientific research vessels. Once these bottles are onboard, the seawater is filtered and these filters are either processed aboard a ship or preserved for laboratory processing on shore. Sampling difficulties related to ship operations, ship cost, time-on-station and weather, can all impact how many samples humans aboard a ship can collect and process. The use of autonomous samplers overcomes many of these difficulties, by allowing a more persistent presence in the environment of interest, unaffected by weather or ship schedules. This persistent presence allows sampling at higher spatiotemporal scales (e.g. hourly and over several depths/days), which may provide insights into biogeochemical cycles that are hidden in the low-frequency sampling of ship expeditions. Many autonomous samplers can also be integrated into gliders or autonomous underwater vehicles (AUVs), allowing instruments to drift with ocean currents or sample

in remote regions. Here we provide an overview of three novel autonomous sampling devices that can be useful in molecular ecological studies, including the newer 'omics' investigations (metatranscriptomics, proteomics: or holistic RNA and protein studies).

MAPS and N_2 fixers

The Marine Autonomous Plankton Sampler (MAPS) is an autosampler developed by the National Oceanography Centre, Southampton. MAPS was designed to acquire planktonic biomass by filtering large volumes of seawater through commercially available cartridge filters, allowing cells > 0.2 µm in size to be collected and preserved. MAPS can filter and archive a two-litre open ocean sample every 30 minutes (Fig. 1).

As a major limiting nutrient in the ocean, nitrogen controls the magnitude of atmospheric CO_2 uptake and fuels the base of the food web in many marine environments. In addition to anthropogenic sources, fixation of N_2 gas by microbes can contribute to bioavailable nitrogen and primary production. As N_2-fixing microbes are typically patchy in distribution, the use of autonomous samplers is important in advancing marine N_2 fixation research.

During a cruise in 2017, MAPS was used to characterise and quantify the activities of marine N_2-fixing microbes. Hourly samples were collected over the 10 days across a range of high- and low-biomass regimes for metatranscriptomics and DNA analysis. Quantification of genes by quantitative PCR reported similar abundances relative to flash freezing, supplying datasets on micro-organisms in the North Atlantic. Now that MAPS has been proven in the field, it will be validated across a range of platforms in order to address needs in the fields of conservation (environmental DNA), biogeochemistry and aquaculture.

The ESP and ocean eddies

The Environmental Sample Processor (ESP) is an autonomous *in situ* water sample collection and processing device developed by Monterey Bay Aquarium Research Institute (MBARI). Using an electromechanical fluidic system, water samples are autonomously collected and filtered, and filters are then either preserved and stored, or processed on board. *In situ* analytics include array hybridisation with nucleic acid probes or quantitative PCR. A new generation of ESP was recently developed to be much smaller and fit within an MBARI-developed vehicle, the Long-Range AUV (LRAUV; Fig. 2), in order to perform high-frequency sampling within large, open-ocean oceanographic eddies.

These rotating water masses can be hundreds of km in diameter and are hotspots of microbial life due to the fact that the slow rotation of an eddy can bring cold, nutrient-rich water into surface layers from deeper depths. In these eddies, phytoplankton typically concentrate around 100–120 metres deep, in a layer known as the deep chlorophyll maximum. Understanding how eddies affect the deep chlorophyll maximum and influence ocean productivity is currently not well understood because of difficulties sampling these mobile features.

The ESP-LRAUV system was recently deployed north of Maui, Hawaii, in collaboration with the University of Hawaii's Simons Collaboration on Ocean Processes and Ecology (SCOPE) programme to study the microbial community directly associated with

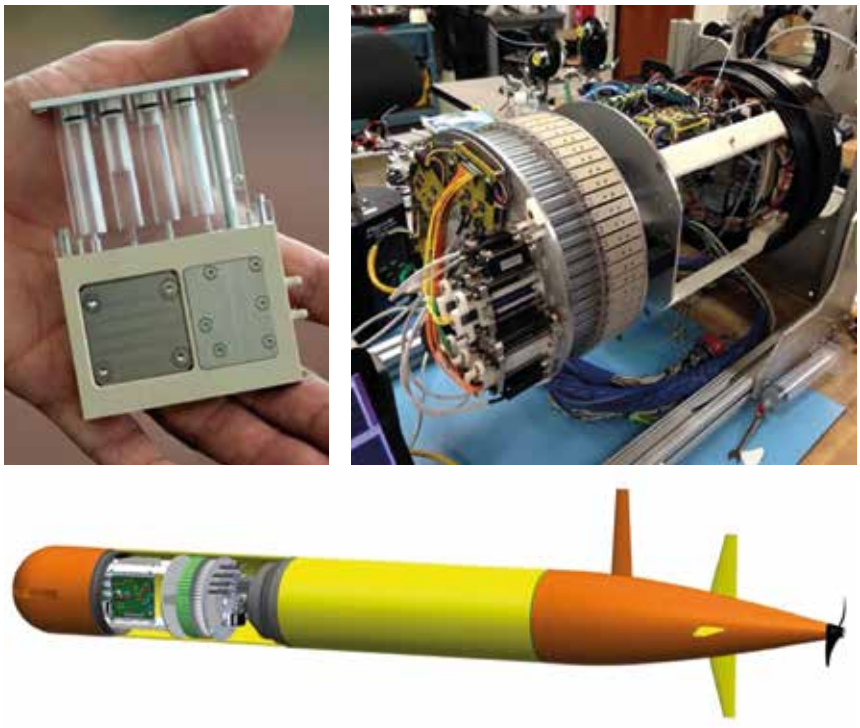

Fig. 2. **The latest ESP design is based on cartridges (upper left), 60 of which are loaded around a central ring (upper right). The lower panel shows how the ESP fits within the LRAUV payload.** Jim Birch, MBARI

eddies. In particular, researchers hope to understand how gene activation in marine microbes changes through a full day/night cycle, and how these changes ultimately affect the productivity of these ubiquitous eddy communities. The ESP-LRAUV found the deep chlorophyll maximum at the centre of an eddy, and began sampling every three hours for three full days, all while maintaining position at 100 metres depth, and within the eddy centre as the eddy slowly drifted west. Samples collected every three hours were preserved and returned to the laboratory for processing once the vehicle was recovered. Deploying this novel technology allows microbial samples to be collected within important features of the Earth's ocean circulation that have been difficult to sample repeatedly over a day/night cycle.

Clio and marine microbial mapping

Clio is an AUV developed by Woods Hole Oceanographic Institute (WHOI) and the University of Texas Rio Grande Valley (UTRGV). It was explicitly designed for ocean mapping of marine microbial communities and metabolic biomarkers (Fig. 3), and to reduce sampling time during vertical surveys from the surface to seafloor. *Clio* is a filtering and sampling machine the size of a large refrigerator. When deployed from a vessel, *Clio* can dive independently to a maximum depth of 6,000 metres and return within hours, collecting and preserving samples along the way. Hundreds of litres of seawater are filtered for each sample, allowing a wide range of biochemical measurements to be made from the particulate samples collected, even from depths where particulate matter is scarce. *Clio* significantly reduces the time required to collect these water column profiles, and the goal is that this increased sampling efficiency will facilitate a more thorough and rapid mapping of ocean biochemical processes. *Clio* also collects biomass samples suitable for omics investigations, allowing researchers to answer questions about the response of marine microbes to environmental stressors.

Previous global studies have mapped ocean structure and the distribution of major marine nutrients. However, a co-ordinated mapping of marine microbial community structure and markers of biochemical function has yet to be undertaken; though there is considerable potential and excitement about this possibility. A global dataset of marine microbial community composition and relevant biochemistry would be of tremendous value for improving and validating marine ecosystem and biogeochemical models.

Clio has been operational for a little over a year, and is being used in a study analysing the nutrient stress response in cyanobacteria communities in the Atlantic Ocean. As part of this study, it is being used for repeat profiles at the Bermuda Atlantic Time-series Study station until next summer when it will be used to create a sectional map of nutrient stress biomarkers from Bermuda to the North American continental shelf.

Future prospects

High-resolution autonomous sampling has already resulted in the discovery of 'pulses' of microbial activities that weren't previously predicted based on direct assessments of microbial physiology or in cultured representatives, as well as the validation of predictions resulting from nutrient controls and thermodynamics-based modelling in the deep sea. Coming years will yield more discoveries using ocean robots, giving microbial oceanographers new eyes to observe change in this complex environment. We envision that broader global omics observations will deliver a new understanding, leading to prediction of marine microbial dynamics in the coming decades.

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Fig. 3. **Clio, a biochemical mapping autonomous vehicle, preparing for launch from the R/V Atlantic Explorer at the Bermuda Atlantic Time-series Study station.** UTRGV

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Susan Evans is a microbial biogeochemist. Her research currently focuses on developing a DNA/RNA extraction chip and the early detection of harmful algae in shellfish farms using miniaturised impedance cytometry.

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Julie Robidart is a molecular ecologist in Ocean Technology and Engineering, leading a biosensor programme focused on the development and application of novel technologies for analysing marine microbes. Her research involves analysis of environmental metagenomic and metatranscriptomic datasets to inform probe design and development and optimisation of molecular assays for autonomous instrumentation.

Why does microbiology matter?

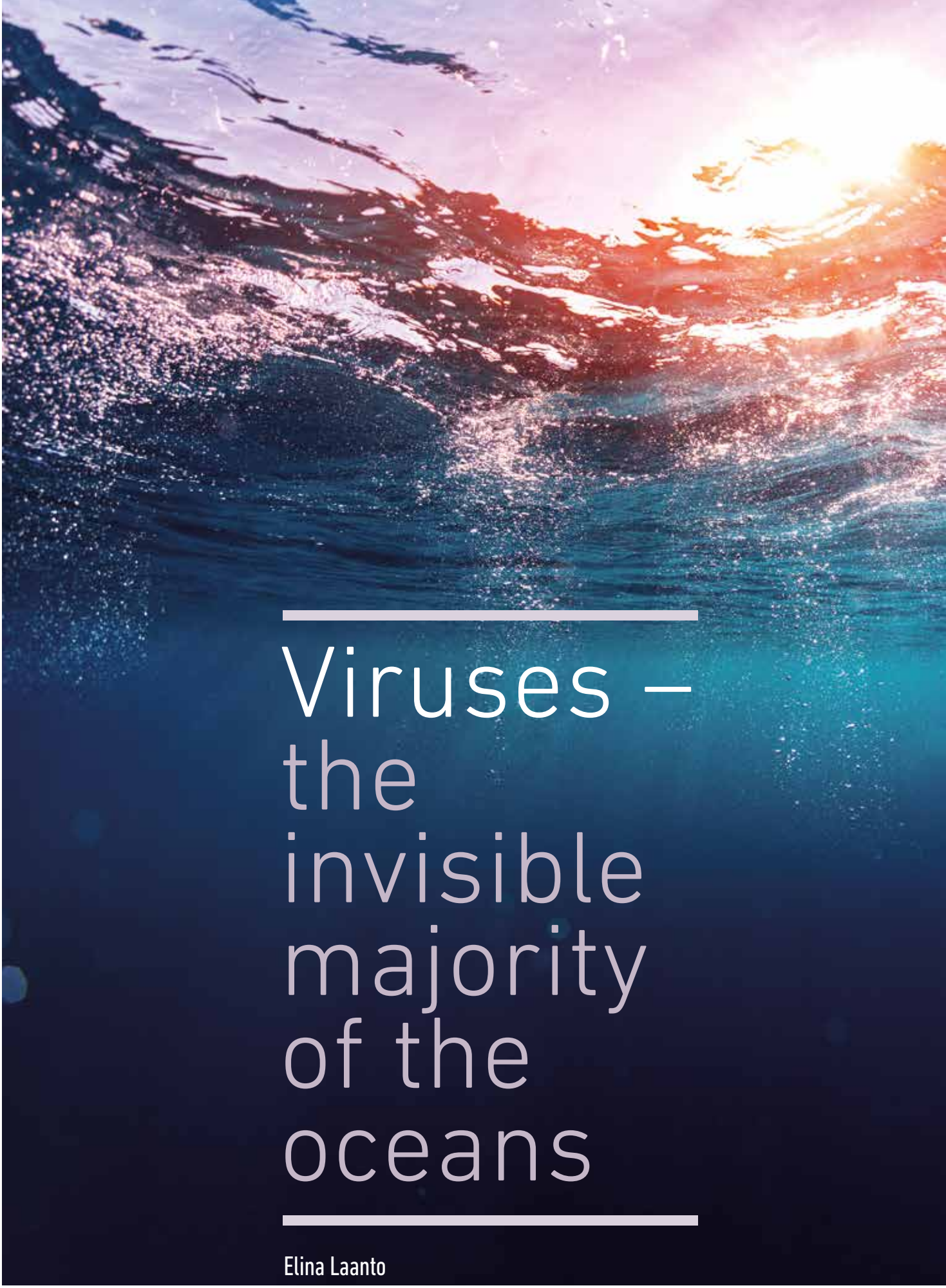
Susan: Microbes play a key role in maintaining life on Earth. Roughly half the oxygen produced on the planet every day is made by micro-organisms that live in the ocean!

Julie: We wouldn't be here if it weren't for microbes making our planet hospitable!

What is your greatest achievement to date?

Susan: Submitting my PhD thesis on dimethylsulphoxide (DMSO) utilising bacteria in the ocean. I really enjoyed my project but there were many challenges along the way.

Julie: Learning to navigate academia and what to prioritise, in the old days before early career training was ubiquitous.



Viruses – the invisible majority of the oceans

Elina Laanto

Virus research has shown the great importance of viruses in marine ecosystems. While the astronomical number and diversity of ocean viruses provides endless possibilities for new discoveries, man-induced climate change could dramatically affect the delicate balance of virus–host interactions that play a central role in global biogeochemical cycles.

mihtiander/Thinkstock

It is astonishing to think of the effect oceans have on our lives. Life itself and the quality of it depend on the health of the world's oceans. Estimates indicate that over half of the planet's oxygen is produced by the phytoplankton living in ocean surface waters. The world's seas also serve as a major carbon dioxide (CO_2) sink by adsorbing the greenhouse gas from the atmosphere. Further, phytoplankton play an important role, using vast amounts of CO_2 for growing. CO_2 is later deposited to the bottom of the ocean by sinking with the decaying phytoplankton. Oceans hold 97% of the world's water and cover nearly three-quarters of the surface. Thus, it is no wonder that they absorb nearly half of the heat arriving from the sun. Heat is distributed all over the world via sea currents, which contribute to the temperate climate in northwest Europe, for example. Although it is evident that oceans are crucial for life in many ways, it has only been in the past three decades that we have recognised the key players influencing global-scale biogeochemical cycles and ocean productivity. They are the invisible, but highly influential, viruses.

The astronomical abundance and diversity of marine viruses

All cells are likely to be susceptible to infection by at least one virus. Although many viruses cause disease in plants or animals, the majority of viruses in the biosphere infect prokaryotes. It was three decades ago when Norwegian researchers excited the scientific community with the realisation that viruses are not only highly abundant, but also a major cause of mortality of the most abundant organisms in the sea; bacteria and archaea. This finding initiated research into marine viruses that quickly developed into a completely independent research field.

Viruses inhabit the world's oceans in great numbers. One spoonful of seawater can hold up to a billion virus particles – a number equal to one-seventh of the global human population! And the carbon carried in viruses is approximately equal to 75 million blue whales. Traditional and advanced research techniques have revealed the enormous genetic and morphological diversity of marine viruses. A typical isolated marine phage (a virus-infecting bacteria) has a head and tail structure, which is true for approximately 97% of all isolated and characterised phage. However, data suggests that the most abundant morphotype of marine viruses is actually a tailless capsid. The reason that this type is not frequently isolated remains to be understood. Several marine metagenomes have revealed that oceans host a large number of unknown viral populations. Thus, there is a great need for detailed studies on isolated viruses and their hosts to enable the identification of this so-called 'dark matter'.

Besides the genetic complexity of viruses, there are different life cycles that they can display, and it is probable that there is more variety in the life cycles that is not yet discovered. Let's look at a phage and its bacterial host as an example. The most thoroughly studied and understood examples are the lytic and lysogenic life cycles. In a lytic cycle, the phage enters the cell, the host's replication machinery is taken over by the invading phage genome and new phage particles are assembled. In the final part of the infectious cycle, the host cell is lysed and new mature phages are released to the surrounding environment. In a

lysogenic life cycle, a temperate phage enters the cell and its genome is integrated into the continuity of the host chromosome. In some cases, the phage genome can remain in the cell as an extrachromosomal element. Formed prophages can replicate with the host genome until a cellular or environmental stimulus induces the start of a productive lytic cycle. In many cases, prophages provide the host bacterium with beneficial genes. This so-called lysogenic conversion can enable, maybe most famously, the production of toxin genes that are important in the virulence of pathogenic bacteria. Prophages can potentially also enhance host survival during unfavourable conditions by suppressing metabolic activities, which is especially relevant in the fluctuating marine environment. The lysis–lysogeny decision has been extensively studied in a few example phage–host systems, but studies in marine systems are rare. Understanding how the environment modifies life cycle decisions is crucial for predicting how it might influence future virus–host interactions. Undoubtedly, the factors involved in life cycle decisions are of great importance to marine nutrient cycling, controlling the mortality caused by viruses.

Marine viruses are key players in food webs and biogeochemical cycling in the world's oceans

In the ocean, one of the major causes of mortality of micro-organisms is grazing by protozoa, which are then themselves consumed by plankton, fish and other larger organisms. An equally important cause of mortality is viral infection. Usually, the end of the infection cycle results in the death of the host. In addition to bacteria, the majority of which are photosynthetic cyanobacteria, viruses infect microzooplankton and other phytoplankton, a large proportion constituting eukaryotic algae. Hence, large double-stranded DNA viruses that infect algae are of special interest as, similarly to phages, they contribute greatly to the global environment.

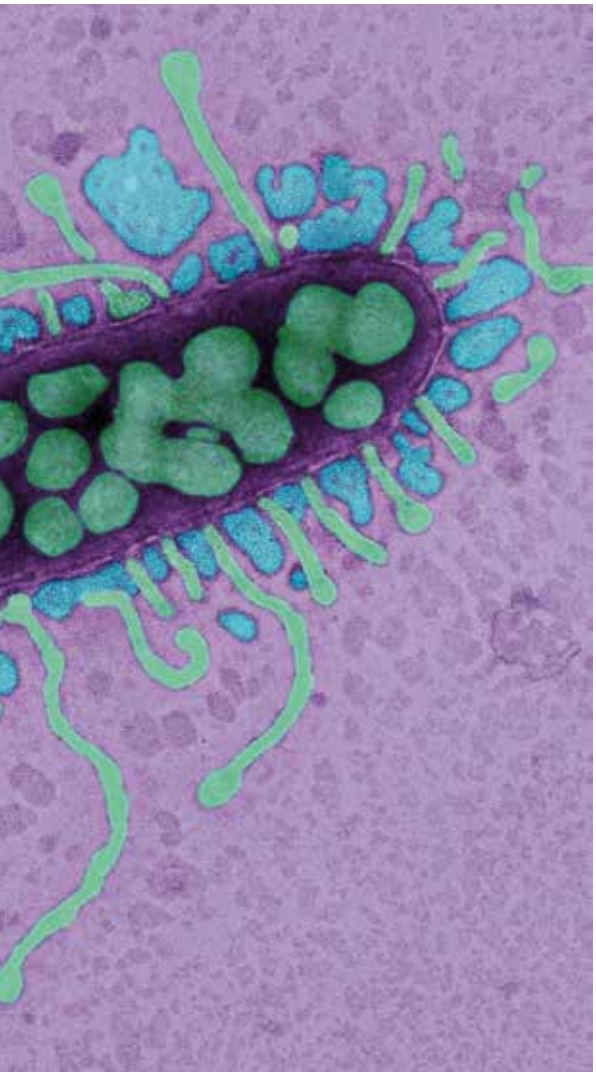
Viral lysis of microbial cells releases organic carbon and nutrients into the pool of dissolved organic matter (DOM). DOM is then re-mineralised by microbes within the microbial loop that can be considered as a recycling system of the ocean. This viral shunt keeps the carbon and nutrients available in the surface waters. Together, phages and other viruses significantly control the marine microbial populations; their role in the nutrient and carbon cycling, and in controlling the speed of these cycles

Coloured transmission electron micrograph (TEM) of pelagipodovirus HTVC011P pelagiphages (darker green) infecting a '*Candidatus* Phytoplasma' sp. bacterium (rod-shaped). This phage, discovered in 2013, mainly infects SAR11 marine bacteria, which were previously thought to be immune to viral infection. Magnification: x96,300.
Thomas Deerinck, NCMIR/Science Photo Library

is therefore central. Many studies have without a doubt shown that viruses shape aquatic microbial population size as well as determine ecosystem dynamics.

Marine virus–host interactions are vulnerable

How global climate change affects marine host–virus interactions is largely unknown. There are several variables in the changing environment, such as temperature and salinity, which have a direct effect on the virus–host interactions that further impact the biosphere. It is speculated that marine viruses could have a broad spectrum of direct and indirect effects on climate change. In addition, the magnitude of these effects is not well assessed, which in turn results in the exclusion of viruses from most climate change models. Therefore, there is a growing need to understand the human-made effects to the level of detailed virus–host interactions. However, it is clear that climate change, acidification and pollution are going to change the dynamics of these small but important players. The importance of the viral populations in marine environments should not be neglected, and they should be considered in all models.



Oceans, as well as other water sources, undoubtedly remain the eternal garden for new discoveries, especially for virologists. The possibilities to expand our understanding not only about the biology of viruses, but also the complex web of interactions thriving in these important ecosystems, are perhaps endless.

Further reading

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Elina Laanto is a postdoctoral researcher working with phage-host interactions in aquatic systems.

On a typical day/week what do you do?

My day consists of a mix of office and lab work. Depending on the project, I do experiments in the lab or write papers. Much of the work is done together with the other members of the research group and collaborators, so there is a lot of communication during the day. I also supervise students in the lab and teach courses occasionally.

What do you find most enjoyable about your work?

I am fascinated by the complexity of bacteria and their viruses, and how little we understand about the microbial world. I feel lucky that I can work with such an interesting system, use my creativity for testing hypotheses, and answer questions and consider new ones.

Annual Conference **2019** #Microbio19

8–11 April 2019 – Belfast, UK

The Society's flagship annual event, Annual Conference 2019, is nearly here. Not only is the meeting taking place at the award-winning ICC Belfast in Northern Ireland, but we have one of the largest and most comprehensive programmes to date, with over 30 sessions taking place across four days.

Annual Conference attracts over 1,600 attendees for the UK's largest gathering of microbiologists and consists of symposia, workshops, forums, poster sessions and an exhibition.

You can find out all the information you need to know by visiting our website (**microbiologysociety.org/annualconference**).

Registration

If you haven't yet booked your place, please register online. You can do this up to two weeks before the event, but in previous years we have had to close registrations due to capacity, so don't delay.

To ensure the meeting remains of value for our broad microbiology community, registration prices have not increased from last year beyond the rate of inflation, and all our members are entitled to a discount. Moreover, we have introduced a new 10% discount for anyone registering for all four days of the meeting.

The following items are included in your registration fee:

- Admission to all scientific sessions
- Access to our professional development programme
- Full access to the trade exhibition
- Full access to scientific poster sessions
- Hot buffet lunch
- Tea and coffee breaks
- Two drinks during the drinks receptions each evening
- A delegate bag and conference material
- A hard-copy Conference programme guide
- Access to an electronic abstracts book
- Certificate of attendance
- Access to CPD points

Destination Belfast

If you're planning on extending your stay after the Conference, there are plenty of attractions to visit, such as the Titanic Museum, the Alexandra Graving Dock or Belfast City Hall, one of Belfast's most iconic buildings.

The Microbiology Society has partnered with Visit Belfast and offers all Annual Conference delegates access to exclusive offers for tours, attractions and restaurants in the city.

Learn more about these exclusive offers on the Visit Belfast website (**visitbelfast.com/delegateoffers**).

Social programme

Annual Conference is designed to offer ample opportunities for formal and informal networking for both early career and established microbiologists.

If you haven't already, don't forget to secure your space at our social programme events. There is limited space, and tickets are selling fast. You can select an event when registering your attendance. Find out more and book your place on our website.

CPD points

The Annual Conference has been accredited by the Royal Society of Biology (144 CPD credits), the Royal College of Pathologists (29 CPD credits) and the Institute of Biomedical Science (category: Professional Activity).

Those wishing to claim CPD credits should sign a daily register held at the Professional Development information desk, which is located in the main registration area in the Riverside Foyer. Further information can be requested by email (**profdev@microbiologysociety.org**).

Belfast Waterfront


surangaw/Thinkstock

To get the latest Annual Conference news and updates, follow us on Twitter **@MicrobioSoc** using the hashtag **#Microbio19**.

Professional Development

In addition to the scientific programme, the Society will be hosting a series of essential skills sessions for all delegates wishing to enhance their professional skills in microbiology. Full details of the sessions can be found on our website (**microbiologysociety.org/annualconference**). Please note, session spaces are allocated on a first come, first served basis. Please indicate your attendance when registering for the Conference.

Pre-Conference Networking Workshop
Sunday 7 April 2019 | 18:00–20:00

Essential skills: Managing a Research Laboratory
Monday 8 April 2019 | 10:00–17:30

Essential skills: Staying resilient in your career
Tuesday 9 April 2019 | 10:00–13:00

Essential skills: Research and publishing ethics: beyond plagiarism. What you need to know and why it matters.
Thursday 11 April 2019 | 09:30–12:00

Essential skills: CV Workshop
Thursday 11 April 2019 | 13:00–16:30

Essential skills: Peer Review
Thursday 11 April 2019 | 13:00–16:30

Prize Lecture Winners

Our 2019 Prizes Lectures have now been awarded and announced. All prize lectures will take place in the main auditorium.


The University of East Anglia

2019 Peter Wildy Prize

Professor Laura Bowater
University of East Anglia, UK


Keegan Houser, UC Berkeley

2019 Prize Medal

Professor Jennifer Doudna
University of California, Berkeley, USA


Peter Fineran

2019 Fleming Prize

Dr Peter Fineran
University of Otago, New Zealand


Gordon Dougan

2019 Marjory Stephenson Prize

Professor Gordon Dougan
University of Cambridge, UK

Poster Prizes

There will be three poster prizes available to recognise the best poster presenters over the course of the entire Annual Conference.

All poster presenters will be considered for the Microbiology Society Journals' **Most Promising Science Poster Prize**.

All members of the Early Career Microbiologists' (ECM) Forum who are presenting posters will be considered for the **ECM Forum Poster Prize**. This prize will be judged by the Executive Committee and will recognise the most promising ECM presenters.

Finally, all poster presenters will be entered into the **People's Choice Poster Prize,** which will identify the three most popular posters presented during the Annual Conference. All delegates will be asked to choose their favourite three posters that they visited and submit these on the voting slip provided in their delegate bag.

To get the latest news and updates, follow us on Twitter **@MicrobioSoc** using the hashtag **#Microbio19.**

Focused Meetings 2019

This year we have another fantastic series of Focused Meetings, created by our members, for our members and the wider microbiological community. These events are bespoke and tailored to the communities who attend them. All members get a discount when registering, so add the dates to your calendar and spread the word via your networks. You can visit our website (**microbiologysociety.org/events**) for updates on each event and follow the Society on social media for information.

Anaerobe 2019: Changing perceptions of anaerobic bacteria; from pathogen to the normal microbiota and back

#Anaerobe19

13–14 June 2019 | Jurys Inn, Cardiff, UK

microbiologysociety.org/Anaerobe19

Anaerobic clinical microbiology remains a challenge due to specialist culture requirements, coupled with the increase and spread of antimicrobial resistance. The normal human microbiota is primarily composed of anaerobic bacteria, and a source of life-threatening anaerobic infection.

More recent metataxonomic and metagenomic sequencing has extended interest in the potential role of the microbiota in a plethora of aspects of human health, from obesity to mental health. The successful use of faecal microbiota transplants for the treatment of clostridial infection also raises potential unchartered long-term consequences and possibilities.

This meeting will provide scientific insights into the future impact of anaerobic bacteria in human health and disease, addressing the implications of recent microbiota studies as well as the continued threat of emerging and re-emerging anaerobic infections.

British Yeast Group: Discovery to Impact

#BYG19

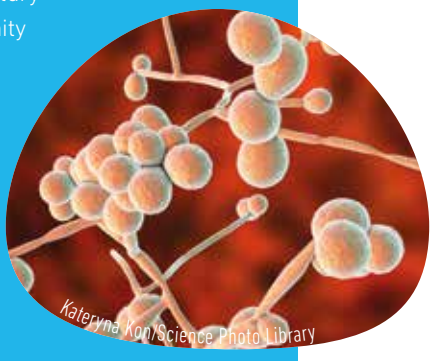
26–28 June 2019 | County Hotel, Newcastle, UK

microbiologysociety.org/BYG19

Yeasts are versatile, model, unicellular eukaryotes that have been extensively used for over a century to explore fundamental aspects of living systems. Annual gatherings of the British yeast community have taken place since the 1980s, and the Microbiology Society have been pleased to incorporate the last two British Yeast Group meetings in its annual Focused Meeting programme.

The 2019 British Yeast Group meeting, taking place in Newcastle, will explore the theme of 'Discovery to Impact'.

The programme will feature a range of keynote talks from invited speakers and will also give young yeast researchers the opportunity to present their research through a series of posters and offered oral presentations. The meeting will feature a varied social programme, offering delegates plenty of opportunities to make new connections, discuss research projects and to strengthen relationships in the British yeast community.



Member opportunity! – Society-Supported Conference Grants

Members can apply for our Society-Supported Conference Grant of up to £2,000, which can be used towards covering the costs of invited speakers' travel and accommodation. The deadline for the next round of applications is the **7 June 2019**, and you can find more information about the full eligibility criteria and the application process on our website (**microbiologysociety.org/ssconferencegrants**), as well as see a list of the events we have sponsored to date.

Keep up-to-date with events, follow the Society on Twitter: **@MicrobioSoc**

IMAV 2019: International Meeting on Arboviruses and their Vectors

#IMAV19

5–6 September 2019 | University of Glasgow, UK

microbiologysociety.org/IMAV19

The Third International Meeting on Arboviruses and their Vectors will take place between 5 and 6 September at the University of Glasgow. As we see the continuing transmission of pathogens such as dengue and chikungunya, and the emergence of other arboviruses, as well as progress in understanding vector biology (including ticks, mosquitoes, midges), this area of research remains of high importance and is continually evolving.

The many scientists and clinicians with different areas of expertise who share an interest in arboviruses need a dedicated forum to discuss viruses and vectors in depth. This meeting will provide the opportunity for people in the arbovirus research community to meet and exchange ideas.


ErikKartis/Thinkstock

Microbes in Medicine: A Century of Microbiology at Trinity College Dublin

#MicroMed19

24–25 October 2019 | Trinity College Dublin, Ireland

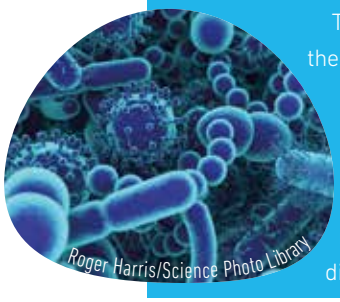
microbiologysociety.org/MicroMed19

The discipline of Microbiology at Trinity College Dublin celebrates its centenary in 2019, and this meeting will mark the occasion by focusing attention on the significant contributions that have been made by the College to microbial sciences.

The meeting will be a celebration of the strength of microbiology in Trinity College and in Ireland today and the unifying scientific theme of the meeting will be *Microbes in Medicine*.

It will bring together scientists and medical practitioners with an interest in pathogenic mechanisms and in the use of microbes and microbial products to treat and prevent diseases.

Highlights of the meeting will include sessions on recent advances in the application of genomics to study antibiotic resistance and virulence in pathogens, persister cells, gene regulation in pathogens and microbial cell surfaces. The importance of the human microbiota and how it differs between healthy and diseased states will also be explored.


Roger Harris/Science Photo Library

Antimicrobial drug discovery from traditional and historical medicine

#AMRmeds19

29 October 2019 | Ashmolean Museum, Oxford, UK

microbiologysociety.org/AMRmeds19

Approaches to natural product drug discovery currently focus on microbial secondary metabolites. An often-ignored database of antimicrobial compounds may lie in the plants, plant products and other natural materials used in historical pharmacopeias.

But while extensive efforts have been made to explore traditional medicines from Asia, South America and the Indian subcontinent for novel compounds, a concerted effort to characterise and exploit the natural products used in pre-modern European medical texts has not been made.

Given the presence in these texts of natural products with known antimicrobial and/or immunomodulatory qualities (e.g. *Artemisia* or *Allium* spp., honey), and a stalled antimicrobial R&D pipeline, a thorough scientific evaluation of European ethnopharmacology is overdue.

This meeting aims to establish a research network for microbiologists, chemists, botanists and historians of medicine, along with industry contacts. We aim define current expertise and to spark new collaborative and translational research in this area.


Mikola249/Thinkstock

Teaching Microbiology in Higher Education Symposium 2019 – an Annual Conference satellite meeting

After the success of last year's event, the Microbiology Society will be hosting its Teaching Microbiology in Higher Education Symposium at the ICC Belfast on Sunday 7 April 2019, as a satellite meeting before the Microbiology Society Annual Conference.

As many of our members are involved in teaching at some level, the Society's Professional Development Committee is committed to supporting and enhancing the careers of those active in teaching, as well as the wider membership. This year's symposium will create a thread, beginning with discussions around the teaching landscape and transitioning into higher education, and ending with preparing students for independence and postgraduate studies.

During the sessions, attendees will hear from speakers who have successfully built and maintained microbiology curriculums by focusing on developing engaging degree courses. Delegates will also hear about quality assurance, accreditation and creating a course that is current.

Last year, delegates were proactive in sharing their use of digital platforms and novel techniques in the lecture theatre, as well as in discussing external factors affecting teaching. This year, the symposium will aim to continue the exchange of ideas and support delegates in sharing different teaching methods in the lab and the lecture theatre.

The symposium will facilitate a space for microbiology lecturers to interact and be part of a network, and will aim to provide a platform for delegates to continue to share and discuss teaching practices after the event.

Posters submitted to the symposium will also be available for viewing during the Annual Conference.

Tickets are priced at £20. Find out more and register your place on our website (**microbiologysociety.org/teachingmicrobiologyinHE**).

Careers Focus: Networking

In the run up to the Annual Conference, as well as finalising your presentation and planning the talks you'll attend, it's worth giving some thought to networking. 'Networking' can conjure up images of awkward encounters and unnecessary schmoozing but really it comes down to meeting and getting to know people – building meaningful relationships that could lead to finding people to help you troubleshoot experiments, collaborate with, or even to become new friends.

If the thought of meeting new people at a busy conference fills you with dread, don't worry, most other people are nervous too! The good news is that networking is a skill, which means that you can improve the way you do it. Also, there's not just one way to network, so if seeing someone else in action is intimidating, bear in mind that there's likely a different way that works better for you! Just think about the different ways you've made connections with your colleagues and friends. When networking at a conference there are a few things that you should think about.

The approach

Before the conference, think about what you want to get out of it – who you want to talk to, and how best to approach them. To make sure you don't miss the opportunity, it can be a good idea to email ahead to arrange a time to meet at the conference if you know that someone you admire will be there.

The conference

At the conference, as well as attending the meetings you've already planned over email, don't forget to be open to other people approaching you. A friendly approach goes a long way, particularly when visiting poster presenters during breaks. However, do read other people's body language – if it doesn't look like someone wants to talk, think about going back to them later. When speaking with others, you may wish to prepare a brief summary of your work and goals – an elevator pitch – to ensure you get all your key points across; and don't forget to listen to the person you're speaking with too. Your conversation doesn't just have to be about work either; you can build rapport over anything from your recent sequencing misadventures to your pet cat – there's always something to talk about.

If you feel like the conversation is drying up, make sure you have some back-up questions to hand. Questions as simple as, "what did you think of the Prize Lecture?" or, "what's it like living in Aberdeen?" can work well. Finally, when the conversation has run its course, don't forget to have an exit strategy so you're not left with an awkward silence. Politely end the conversation, thank the other person for their time, and move on.

For more information on networking, check out our 'How to Network like a Pro' video on our YouTube channel (**microb.io/29hqRA8**).

The follow up

We mentioned earlier that networking is about building meaningful relationships. Not many relationships are built on just one encounter! Make sure to get permission to get the contact details of the people you speak to, so you can follow up with a simple email to thank them for their time and share any papers or details you might have discussed during your conversation. This way you can reinforce your conversations and develop the new connection.

If you're an early career researcher attending your first large conference, you might be interested in the pre-Conference networking event, hosted by the ECM Forum Executive Committee the day before the Annual Conference starts. The event will include some icebreaker activities, but has more importantly been very effective in helping people find other delegates to go to talks with in past years. Register during the Annual Conference registration process.

Open access and author rights

In the November issue of *Microbiology Today* we wrote about ways to choose a journal for your research, calling out 'openness' as one of the five criteria to consider. This follow-up article has been written to help you better understand the different types of open access (OA), and guide you through your rights as an author under the different sorts of licence publishers offer.

Open Access

OA has been around for more than 20 years and has accrued a lot of complicated terminology (Fig. 1). We'll start with the original Budapest Open Access Initiative definition of OA:

> *...free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself.*

The shorthand term for this definition of OA is **'libre'**. Any article published under a Creative Commons licence is libre OA, meaning that as well as being free to read, it's free to reuse. For more information about Creative Commons licences, visit the Creative Commons website (**creativecommons.org**).

Some publishers make copyright articles free to read, but not free to reuse; articles in the Microbiology Society journals, for example, all become free to read 12 months after publication. This is commonly known as '**gratis**' or '**bronze**' OA. While gratis currently accounts for most OA articles, many advocates consider it to be inadequate because the copyright licence puts limitations on reuse.

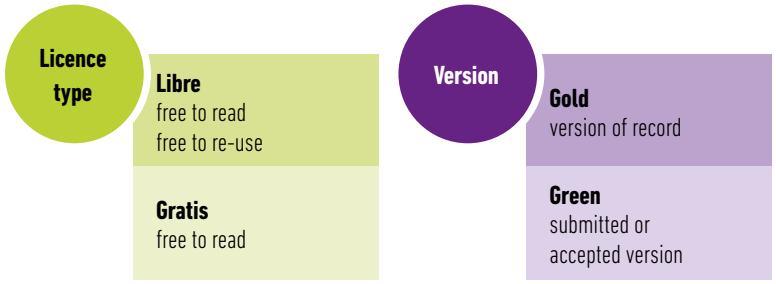


Fig. 1. The four key terms defining varieties of Open Access

As well as classifying OA by the licence type (libre or gratis), you can also define articles by *what version* becomes OA. '**Gold**' means that an article's Version of Record (VOR) – that's the version published in the journal after copyediting and typesetting, with a DOI and other identifying information – is available as libre OA. '**Green**' means that a version of an article that is *not* the VOR is available in a repository, again under a libre licence. Green OA might apply to the submitted version appearing as a preprint in a repository like bioRxiv (**biorxiv.org**), or to the authors' accepted manuscript in an institutional repository. Some publishers place an embargo on when authors can make their accepted manuscripts available in a repository, meaning that the article can't be publicly available for a specified period after publication. The Society's journals, however, allow authors to post their accepted manuscripts on the day of publication, without embargo.

It is of course possible to also classify OA by business model. A full run-down of the different OA business models is beyond the scope of this article, but some terms you might see include:

- APC: Article Processing Charge; the APC is the main way in which Gold OA is funded.
- Hybrid: a journal which permits a mix of subscription articles and Gold OA articles.
- Diamond or Platinum: a pure OA journal which does not charge APCs.

For more information about the Society's approach to OA in our journals, visit our website (**microbiologyresearch.org/about/open-access-policy**).

Authors' rights

Creative Commons licences are part of the definition of libre OA. All Creative Commons licences mean that authors retain their own copyright and provide for some level of reuse of the article by third parties. There are two

primary variants you are likely to come across:

- CC-BY (attribution) allows free reuse of the work as long as the original article is properly referenced.
- CC-BY-NC (attribution, non-commercial) still requires citation of the original article, but restricts reuse of the work to non-commercial activities.

OA is still a minority of the millions of articles published every year. For traditional access articles you won't be signing a Creative Commons licence, but will instead be asked for either a Copyright Transfer Agreement, or a Licence to Publish.

Like many modern journals, the Society's hybrid titles *Microbiology*, *Journal of General Virology* and *Journal of Medical Microbiology* request that authors who are not opting for OA sign a **Licence to Publish**. Signing a Licence to Publish means that you retain your own copyright and have granted the publisher the right to publish and sell subscription access to the article as part of the journal. As the copyright owner you have the right to reuse your own article. If you want to reuse a figure in future work, for example, you can do so without asking the publisher for permission.

Some journals still ask authors to give them copyright over articles by signing a **Copyright Transfer Agreement**. This means that the publisher owns the copyright for your work, and you will generally have only very limited reuse rights.

Some institutions and funders are very picky about what kinds of licence you sign before publishing your work: be sure to check with your librarian if you are unsure of what's required.

Microbiology and the UN Sustainable Development Goals

To celebrate our 75th anniversary in 2020, we are launching a wide-ranging programme of events and activities to showcase why microbiology matters and to demonstrate the impact of microbiologists past, present and future.

Microbiologists are involved in addressing challenges that vary from urgent problems demanding immediate solutions, such as new and emerging diseases, through to long-term issues, like antimicrobial drug resistance, food security and environmental sustainability. This was demonstrated by Sir Alexander Fleming, the founder and first President of the Microbiology Society, whose discovery of the world's first antibiotic has saved countless lives and transformed modern medicine.

The Society is approaching its 75th anniversary year in 2020, and to mark this occasion we are embarking on a project that will celebrate and champion the role of microbiology in addressing the world's biggest challenges, within the global framework of the United Nations Sustainable Development Goals (UN SDGs).

The UN SDGs

The UN SDGs are a collection of 17 global goals and 169 targets, adopted by all Member States of the UN in September 2015. They are the successors to the Millennium Development Goals launched in 2000, but are more comprehensive, covering economic, social and environmental issues, and are far more ambitious. The UN describes them as:

> *"the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. The Goals interconnect and in order to leave no one behind, it is important that we achieve each Goal and target by 2030."*

The Goals apply universally – this means that rather than being framed primarily as a means to aid developing countries, the onus is on all countries, rich and poor, to meet the SDGs nationally as well as internationally. This requires member states to align the 2030 Agenda to their own national policies. Accordingly, SDG national implementation plans have been developed by the governments in the UK and Ireland.

United Nations

A Sustainable Future: the role of microbiology in achieving the UN Sustainable Development Goals

Science, technology and innovation are recognised in the 2030 Agenda as key to implementing the SDGs. Although the Goals are broad and interconnected, there are specific targets where the expertise of microbiologists is particularly relevant. For example, in recent years the Society has harnessed the scientific knowledge of our membership to inform and influence policy relating to antimicrobial resistance (SDG 3), climate change (SDG 13), biofuels (SDG 7) and food security (SDG 2).

The aims of the 'A Sustainable Future' project are to actively demonstrate the value and raise the profile of microbiology in achieving the SDGs with decision-makers within the UK and Republic of Ireland, as well as raising the profile of the SDGs within the microbiology community. Building up to our 75th anniversary in 2020, we will be engaging with members on this project and identifying opportunities to engage with a range of SDG stakeholders.

The 'A Sustainable Future' project will promote knowledge exchange and multi-disciplinary collaborations by bringing together members, microbiologists, scientists, industry, non-governmental organisations (NGOs), and policy-makers, to champion the importance of microbiology in sustainable development. This will drive us towards the Society's vision of a world in which the science of microbiology provides maximum benefit to society.

We are currently seeking members' views on the project scope – if you have a background or currently work in an area of microbiology that relates to sustainable development and would like to contribute to this project, please contact our Policy Team (**policy@microbiologysociety.org**).

Please visit **microbiologysociety.org/SDGs** for further details on the 'A Sustainable Future' project including opportunities to contribute.

Why being a member of the Microbiology Society matters

We know you value different aspects of your membership depending on your interests and stage of career. Here we highlight the key benefits of membership, identified by members, that may help you too.

The Society helps you get connected... and here are some of the ways

If you're looking to broaden your networks to find new work opportunities and new collaborators, or simply want to be part of our wider community, we can help.

> *conference content, networking and learning opportunities have all been excellent...*
> **Lidia Lasecka**

> *membership enables me to stay connected to others working in my area...*
> **Grace Taylor-Joyce**

Our members-only directory enables you to create your own profile to enhance your presence within our community, or use it to find other members who share similar interests and expertise.

> *because I am new to the Microbiology Society it was important to me to update my entry to give me a wider presence within the Microbiology community and to make it easy for colleagues to connect with me...*
> **Alexander Lorenz**

> *I've updated my profile to keep in touch with current and future colleagues...*
> **Conor Feehily**

Get to meet and know a wide range of other professionals from around the world.

as a microbiologist doing my work in the UK I really value the wide networks of other microbiologists membership of the Society helps give access to...
Nizar Saeedi

You'll learn more with us

The Society conferences and meetings programme bring experts in their fields from around the world into one room. You can listen, question and meet them in a relaxed and informal environment.

membership has allowed me to meet the experts, build my network and get valued feedback...
Abdu Aldarhami

membership helps me get close to research I wouldn't normally have the chance to
Max Addison

Make sure you log into the 'Mi Society' area of the website, where you can see exclusive members-only content, opportunities and discounts.

We'll support you to get to where you want to go

If you're looking to develop a specific skill, funding for a specific purpose or even a role with more responsibility, we can help. We have a generous grants programme, numerous professional development opportunities and a variety of ways to become more closely involved in Society affairs.

it's been great to share experiences and learn from others...
Ed Cunningham-Oakes

the Society's grants allow me to train and attend things I wouldn't normally get the chance to...
Connor Bowen

the early careers opportunities are great
Francesc Coll I Cerezo

As you can see, there's plenty on offer through membership of the Microbiology Society. Whether you're a new member or one who has been with us for some time, we encourage you make the most of your membership.

The majority of our members come into the Society through word of mouth. So if you've enjoyed your experience of membership, don't forget to tell your friends and colleagues about it too.

If you have any questions about membership and what it can do for you, please contact us: **members@microbiologysociety.org**.

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Early Career Microbiologists' Forum Update: The first two years of the ECM Forum

This ECM Forum update is a special one. We have now celebrated over two years since the inaugural Committee members took office. A huge amount has been achieved since January 2017, and I wanted to use this column as an opportunity to reflect on this.

From its earliest stages, the Forum has been influenced heavily by the key aims of the Chair, Helen Brown. Helen applied for the position because she wanted to help early career researchers to have a voice in Society decisions, as well as to develop her own microbiology network. She was clear that she wanted to integrate the Forum within the Society during her term, ensuring it would become a staple that continued beyond the scope of her two years.

The Committee has grown considerably under Helen's guidance. It was composed initially of five early career members who represented the Forum on the Publishing, Policy, Communications and Conferences Committees, as well as an International representative. Keen to increase our relevance to undergraduates, we soon added another committee member, tasked with improving our engagement with this career group.

The Committee expanded further in the following year, with the introduction of representatives for the Finance and Operations Committee, as well as one for each of the four Divisions. The Division representatives were recruited to ensure that the viewpoint of early career researchers was heard across all areas of the Society, as well as bringing their personal expertise to the planning of the ECM Forum Summer Conference.

The Summer Conference, spearheaded by Amy Richards, was covered in November's issue of *Microbiology Today*, but suffice to say it has been one of the major achievements of the ECM Forum to date. It gave early career members the chance to deliver presentations in a relaxed environment, while also building and strengthening their networks. Helen says the Summer Conference is the one part of her term as Chair of which she is most proud, especially as it demonstrated just how engaged and active ECM Forum members are within the Society.

The Forum has also cemented its presence at the Society's flagship Annual Conference, with a poster prize exclusively for ECM Forum members and taking charge of running the pre-Conference networking event. A number of members also participated in the Conference co-chairing scheme, enabling them to experience chairing a session under the guidance of the organisers. This is an incentive available only to ECM Forum members and is gaining momentum year on year.

ECM Forum members have the opportunity to experience chairing a session under the guidance of the organisers through the Annual Conference Co-chairing Scheme.

Helen's aim of integrating the ECM Forum within all parts of the Society has without doubt been achieved. ECM Forum members have conducted interviews with Society Prize winners, participated in focus groups and produced articles for the Society's blog, Microbe Post. In the future, Helen hopes that there will be even more engagement with early career researchers, emphasising that the Society is acutely interested in what we have to say. She is confident that the incoming Chair, Amy Richards, will steer the Forum in the right direction, continuing to build on these successful foundations.

Rebecca Hall
Communications Representative,
ECM Forum Executive Committee

Membership Q&A

This is a regular column to introduce our members. In this issue, we're pleased to introduce Alya Redhwan.

Where are you currently based?

In Riyadh, Kingdom of Saudi Arabia. I work as an assistant professor of microbiology at Princess Nourah Bint Abdulrahman University (PNU).

What is your area of specialism?

My research in microbiology focuses on bacterial pathogenesis and its virulence factors.

And more specifically?

The bacterial secretion system is my topic of interest, especially type three secretion systems and the associated pathogenesis, and the potential therapeutic applications.

Tell us about your education to date

I completed my undergraduate study at King Abdulaziz University in Jeddah, with a major in Microbiology. I then moved to the UK to pursue my higher education at Nottingham Trent University where I completed my MSc in Biotechnology and my PhD under the supervision of Dr Alan McNally, as part of his group focusing on a project characterising a novel type three secretion system in the non-pathogenic *Yersinia enterocolitica* strains.

Where did your interest in microbiology come from?

I was a curious child, always trying to find an answer to every single question and wondering about nature and science in general. Once I joined a college and began lab work, I discovered a whole new world, or universe, existing beyond the naked eye. Further along in my studies I was inspired by the fact that bacteria possess and inherit genetic information the same as we do and I was, and remain, fascinated.

What are the professional challenges that present themselves, and how do you try to overcome them?

Having difficulty accessing the laboratory environment once I came back to my home country. However, I've overcome the challenges by seeking scientific collaborations at the national and international level, in addition to establishing a Microbiology and Immunology research unit at the Health Science Research Centre at PNU.

What is the best part about 'doing science'?

The challenge, and the adventure linked to it. Things start to interest me less and I lose passion when the aspects of risk and adventure are lost.

Who is your role model?

I don't have a specific role model in my life, as I learn from every person I encounter in my life.

What do you do to relax?

Biking.

Alya Redhwan

What one record and luxury item would you take to a desert island?

A fiction novel and my wrist watch.

Tell us one thing that your work colleagues won't know about you.

My quiet childhood, and a lot about my personal life.

If you weren't a scientist, what would you be?

An artist.

If you would like to be featured in this section or know someone who may, contact Paul Easton, Head of Membership Services, at **p.easton@microbiologysociety.org**.

Mi Society – member opportunities

Mi Society is an online area that enables you to manage your membership the way you want to. It's the place where you can update your details, register to attend events, apply for grants and, most recently, a home for our Members' Directory that allows you to connect with your fellow members.

What next?

You, as a member, are at the heart of everything we do. As we develop, expand and strengthen networks available to our members, champion microbiology and reinforce our long-term sustainability, we need a dedicated platform where you can keep yourself up to date with all the latest opportunities to engage and tools that will enhance your professional development.

What's new in Mi Society?

Here's just some of what you will find when you next visit Mi Society:

- **Current opportunities** – a dedicated area where you can see how you can get more involved with Society activities and, in some cases, give something back.
- **Networking opportunities** – find out if any of the Society Champions, Society staff and other members will be at any upcoming events you are planning to attend.
- **Tools to support you** – The stress toolkit, for example, for members giving guidance on how to access support when under pressure.
- **Member benefit highlights** – We regularly showcase benefits that you perhaps don't know about so you can make use of these.

Log in to Mi Society microbiologysociety.org/login when you next visit the website.

Roadshow 2019: Microbiology and our membership matters

As part of our commitment to developing, expanding and strengthening the vast networks and opportunities available to our members, the Microbiology Society is pleased to announce a series of events led by President Professor Judith Armitage FRS throughout the UK and Ireland in 2019.

As we attempt to reach the wider membership and bring members (and non-members) together locally, this is an opportunity to engage in interactive discussions, network with fellow local members and meet new President Professor Judith Armitage. The Microbiology Society Team will also be on hand to answer any questions that you might have.

By attending the Roadshow, you will learn more about how you can make the most of your membership, how you can get more involved with Society activities locally, projects that the Society is working with its members on and planned activities to celebrate our 75th Anniversary in 2020.

As she tours the country, Judith aims to make sure the voice of the Microbiology Society is heard. She hopes to meet members, both nationally and internationally, Presidents from sister microbiology societies, as well as other related societies. Judith believes this will ensure the Society continues to provide its members with the platform needed to ensure all areas of microbiology are supported.

President Judith Armitage. Royal Society

All events are free to attend and are open to members and non-members.

Key dates*

12 March 2019 University of Leeds, UK
Keynote talk: Embracing the diversity of microbes and the diversity of microbiology
Professor Judith Armitage

13 March 2019 Newcastle University, UK
Professor Judith Armitage

October 2019 Dublin, Ireland
Keynote talk: TBC

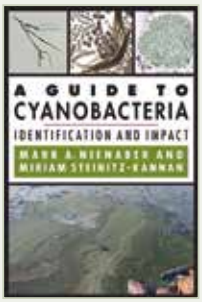
November 2019 University of Plymouth, UK
Keynote talk: TBC

November 2019 Location TBC
Keynote talk: Why microbiology matters in the food sector
Bizhan Pourkomailian, Global Restaurant and Distribution Food Safety Director, McDonald's

We are inviting requests from members to host a Roadshow in 2020, which will also form part of our 75th Anniversary celebrations. We are particularly interested in hearing from members who are in Wales, Norwich and Birmingham. For more information about the Roadshow please visit **microbiologysociety.org** or contact Erin Taylor, Member Engagement Manager at: **e.taylor@microbiologysociety.org**.

*To be confirmed – check the website for the latest details.

Reviews



A Guide to Cyanobacteria: Identification and Impact

Written by Mark A. Nienaber and Miriam Steinitz-Kannan

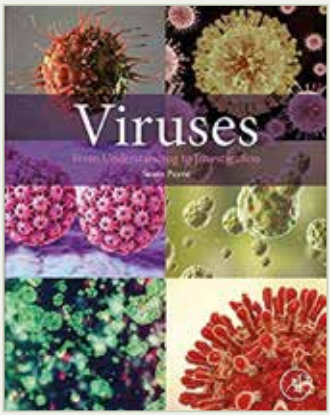
$20.00 ISBN: 978-0-8131-7561-4

Most members of the public are not aware of the important role cyanobacteria play in the environment. This is an excellent book which provides a useful introduction to these organisms for members of the general public interested in ecology and microbiology. Included is a useful introduction on cyanobacterial physiology, including some of the toxins produced by certain species which can impact human and animal health. More detailed information on the physiological characteristics of different cyanobacteria is provided for academics trying to identify strains in the environment, or individuals working in industries affected by cyanobacterial outbreaks, such as farmers and water companies. This is aided by clear descriptions and photos. I would thoroughly recommend this book for anyone interested in these fascinating organisms.

Dr David Lea-Smith
University of East Anglia

For more reviews, please visit the online issue of *Microbiology Today* at **microbiologysociety.org/microbiologytoday**.

In the February 2019 online issue, read reviews of *Climate Change and Microbial Ecology: Current Research and Future Trends*, by Arindam Mitra, and *Viruses – From Understanding to Investigation* by Christopher Ring.



Comment

Mixotrophic plankton – the perfect beasts of our oceans

Aditee Mitra

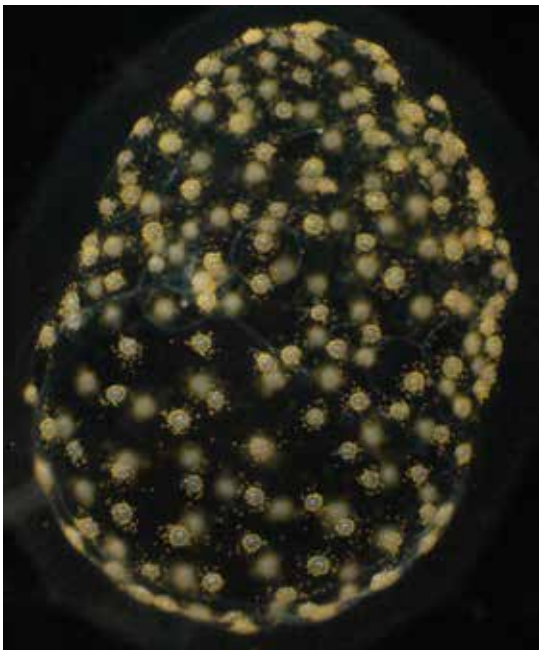
Oceans play a fundamental role in our lives, from being a source of food to a place to rest and relax when on holiday. Indeed, 40% of humans live within 100 km of the sea. Humans are fascinated with life in our oceans; dolphins, sharks, fish, the mysteries of the deep.

However, what is not well appreciated is that all these enigmatic marine megafauna, and indeed we (humans), are ultimately dependent on single-celled marine microbes drifting in the oceans (microplankton). When first formed, the Earth's atmosphere was akin to that of Venus, comprising primarily carbon dioxide. Over millions of years, single-celled plankton have helped remove the carbon dioxide in the Earth's atmosphere producing the oxygen that we and other animals consume. Even in today's world, 50% of the oxygen we breathe in is produced by these microbes. Further, various products that we use in our daily lives, such as toothpaste, food colorants and cosmetics, include components from plankton.

What do we know about plankton?

Microplankton are either bacteria-like or are eukaryotes belonging to the kingdom Protista. For the last 100 years, protist plankton communities have been typically categorised into two groups: animal-like microzooplankton and plant-like phytoplankton. Microzooplankton are the ancestral forms, and the phytoplankton arising from these are the more recent forms. Over the last seven years we have shown that this plant–animal dichotomy is not applicable to the oceanic plankton communities. Most protists labelled as phytoplankton, and at least 50% of those labelled as microzooplankton, are actually mixotrophs. Mixotrophs mix different trophic strategies in the one cell; i.e. they can hunt like animals and photosynthesise like plants within their single cell.

Scientists have known about the mixotrophs for decades. However, the assumption was that these were 'freaks' or 'curiosities' of nature, inferior organisms in comparison with the pure forms. I came across the concept of mixotrophy in plankton during my PhD work on microzooplankton. I thought it was curious that these organisms which could engage in different strategies to gain nutrition were considered as freaks and not major players in marine ecology. The Leverhulme Trust funded our International Networking Grant application in 2011, and over the following three years we got together experts from Australia, Asia, Europe and America. We amassed data – phenomenological and numeric, field and laboratory – and collectively realised that the traditional paradigm where mixotrophs were considered to be freaks was wrong. We have now mapped the



The eSNCM Collodarian with symbionts sampled from the bay of Villefranche. Andreas Norlin and Joost Mansour; MixITiN ESRs

distribution of mixotrophs across global oceans from the poles to the equator and have found these to be ubiquitous in our seas and oceans during each and every season. We have shown that mixotrophs are actually the norm – they are the perfect beasts of our oceans. With this new mixotroph paradigm, we overturn over a century's understanding of how life in our oceans work.

The new mixotroph paradigm

Once we had a new paradigm, the next question was could we put all mixotrophic protists into one group within a food web simulator? To find the answer, we started with a single-celled protist and followed a dichotomous key approach. The first question we asked was whether the protist could photosynthesise. If the answer was 'no', we got the purely heterotrophic microzooplankton. If they could photosynthesise, we then asked if the protist could eat as well; a 'no' gave us the traditional 'pure' phytoplankton. A 'yes' gave us the mixotrophs. If the mixotrophs have their own chloroplasts then we call them constitutive mixotrophs. Most of the Harmful Algal Bloom (HAB) species fall within this category. However, another group actually need to acquire phototrophic capabilities by 'stealing' chloroplasts from prey: these are non-constitutive mixotrophs (NCMs) and they operate rather like asset-strippers in business. Some NCMs are not fussy about who they acquire phototrophy from – these are the generalists. This group includes *Strombidium* and *Laboea* which are good fish-food. Other NCMs are specialists. Some specialist NCMs, like *Mesodinium* and the toxic *Dinophysis*, 'steal' body parts (plastids) while the biogeochemically important groups like the forams and radiolarians 'enslave' entire colonies of phototrophic prey. We have shown that depending on how the marine food web is configured within a simulator, the predictions of which community dominates the system changes drastically.

Why has it taken so long to appreciate the importance of mixotrophs?

Field and laboratory studies in marine systems have typically focused on either the phototrophic phytoplankton or the phagotrophic microzooplankton. When conducting experiments, scientists have not typically considered the possibility of mixotrophy in these protist plankton. If we do not look for something then we will not find it. By analogy, if you do not see a Venus flytrap capturing an insect, it would not be categorised as a carnivorous plant, the terrestrial mixotroph, that it is. Our text books are out of date. So are aspects of science underpinning environmental policies. And long-term monitoring, used for climate change, has been only looking at a fraction of the whole picture. So what next? We have recently been awarded a Marie Skłodowska-Curie Actions International Training Network grant. Within this grant we are developing new tools, experimental protocols and ecosystem simulators to study marine plankton ecology. We are also training the next generation of marine scientists in deployment of these tools to explore the new paradigm.

Further reading

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Aditee Mitra is a Systems Dynamics Modeller and a champion of marine mixoplankton, the perfect beasts of our oceans. She has experienced life outside of academia as a Media Fellow (BBC Countryfile), Biodiversity Officer, and Journal Managing Editor, Oxford University Press (OUP). Currently, she is a Senior Lecturer at Swansea University and a Visiting Professor at the Université Libre de Bruxelles. She leads the MSCA MixITiN project on mixotrophic plankton (**www.mixotroph.org**).

MICROBIOLOGY SOCIETY

Exhibition and Sponsorship Opportunities

The Microbiology Society holds a number of conferences and events throughout the year, including the Microbiology Society's hugely successful Annual Conference. There are a wide range of options to suit all budgets, including multi-event packages.

Annual Conference

8–11 April 2019, ICC Belfast

The Microbiology Society Annual Conference is our flagship event welcoming over 1,400 delegates and brings together influential researchers, academics and scientists from all areas of microbiology. It is an energetic, engaging and welcoming three-and-a-half days designed to offer you the opportunity to connect with conference delegates, a great platform to showcase your products and generate business leads.

Focused Meetings

June–November 2019 (various locations)

The Microbiology Society Focused Meetings are smaller events designed to discuss the hot topics within key areas of microbiology. The events are usually held in smaller venues such as universities or hotels and aim to offer exhibitors a targeted opportunity to engage with key contacts and generate business leads within a friendly social setting.

Early Career Microbiologists' (ECM) Forum Summer Conference

20–21 June 2019, Dublin

The Microbiology Society Early Career Microbiologists' (ECM) Forum Summer Conference is a unique peer-run event, offering early career individuals the chance to connect with industry. It aims to raise the profile of exhibitors amongst this target group, offering an opportunity to educate and create a contact base of future microbiologists.

For further information please contact **exhibitions@microbiologysociety.org** or visit **microb.io/EFeb19**

MICROBIOLOGY SOCIETY

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Registration closes:
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