Conference UK Biofluids Network SIG

Thursday 12th September 2019

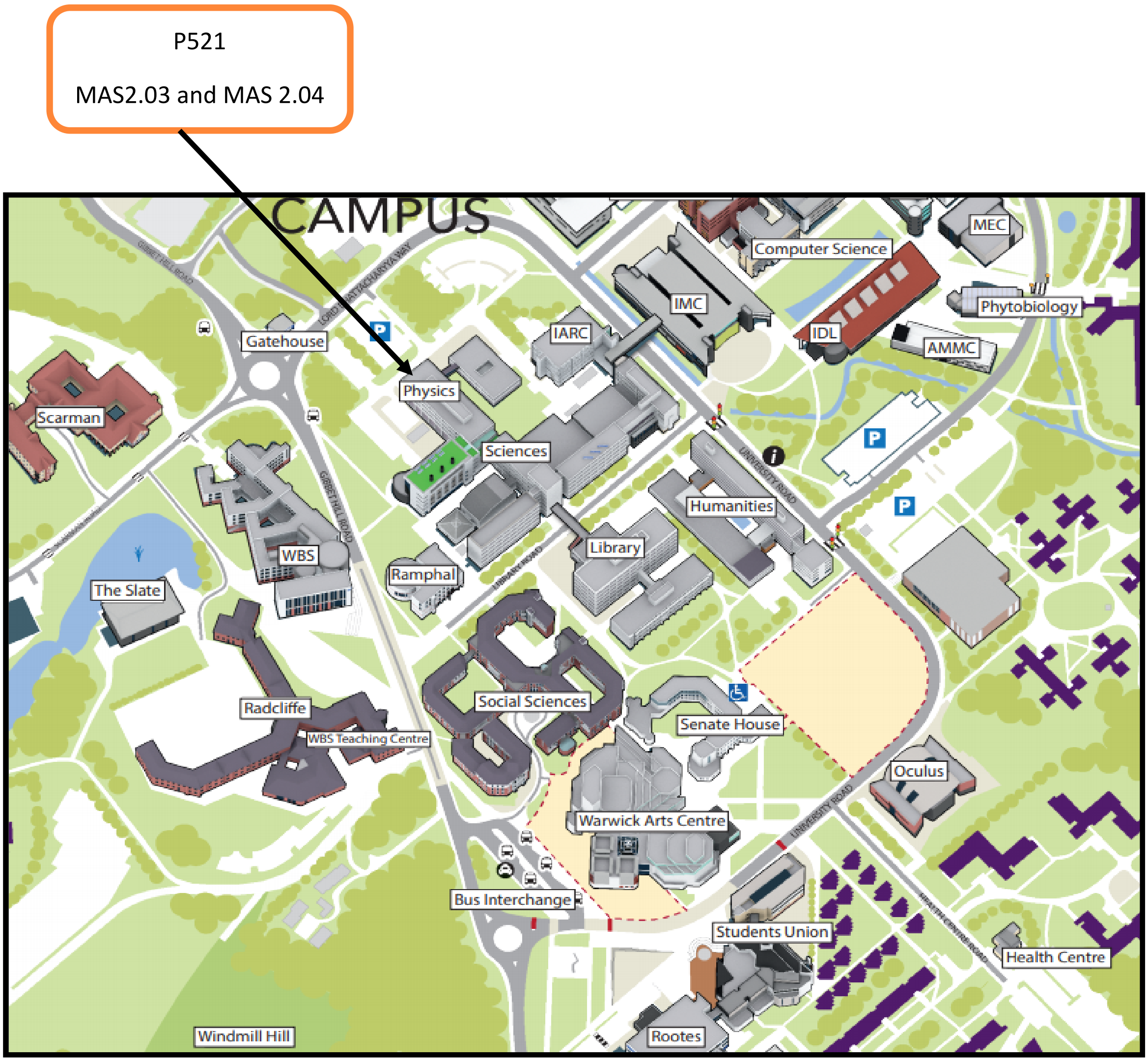
and

Friday 13th September 2019

WARWICK

THE UNIVERSITY OF WARWICK

Campus Map —
Thursday 12th September 2019



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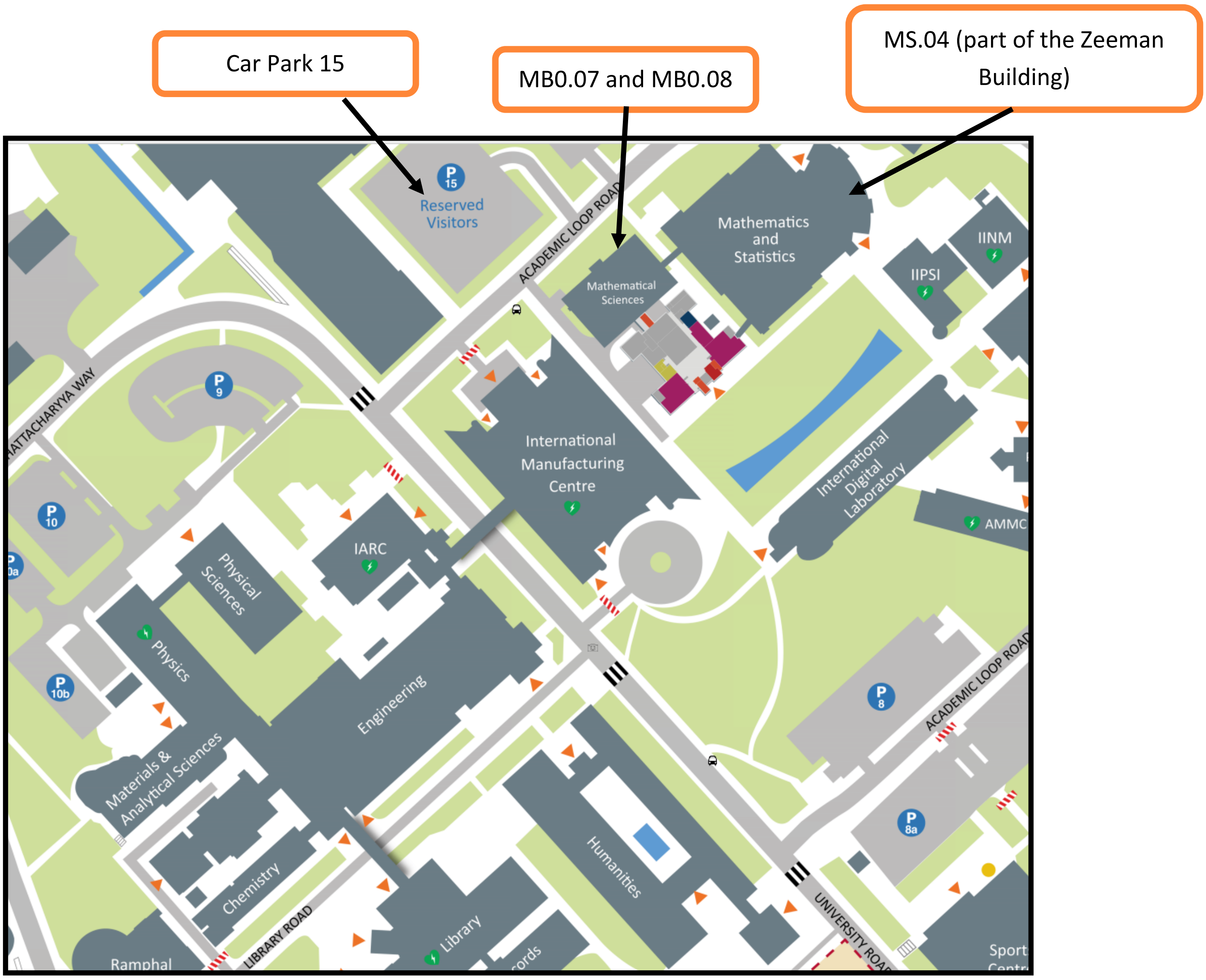
Thursday 12th September 2019

Room P521 (5th Floor in the Physics Building)

Room MAS2.03 and MAS2.04 (Materials and Analytical Sciences, Second Floor in the Physics Building)

Campus Map —

Friday 13th September 2019



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Friday 13th September 2019

Room MS.04 in the Zeeman Building of the Mathematics and Statistics Building, Second Floor

Room MB0.07 in the Mathematical Sciences Building, Ground Floor

Room MB0.08 in the Mathematical Sciences Building, Ground Floor

Programme

Day One: Thursday 12th September 2019

Venue: Room P521 (all day)

Venue: Room MAS2.03 and MAS2.04 for other activities during the day

	9.15-9.30 Registration: Room P521, 5th floor of the Physics Department	
	GROUP A	GROUP B
9:30-11.00	*Hands-on: Numerical Solutions of Low-Re flows* (Dave Smith; U. Birmingham) Room MAS 2.03/04	*Hands-on: Microfluidics* (V.Kantsler, M.Polin, S.Williams, S.Coppola, I.Lopez-Grobes) Room P521
11:00-11:15	Break	
11:15—12:30	*Hands-on: Numerical Solutions of Low-Re flows* (Dave Smith; U. Birmingham) Room MAS 2.03/04	*Hands-on: Microfluidics* (V.Kantsler, M.Polin, S.Williams, S.Coppola, I.Lopez-Grobes) Room P521
12.30-13:00	*Warwick Open Source Microscope* (Dr. Nick Carter, Centre for Mechano-chemical Cell Biology) Room P521	
13:00-14:00	Lunch	
14:00-15:15	*Hands-on: Microfluidics* (V.Kantsler, M.Polin, S.Williams, S.Coppola, I.Lopez-Grobes) Room P521	*Hands-on: Numerical Solutions of Low-Re flows* (Dave Smith; U. Birmingham) Room MAS 2.03/04
15:15-15.30	Break	
15:30-17:00	*Hands-on: Microfluidics* (V.Kantsler, M.Polin, S.Williams, S.Coppola, I.Lopez-Grobes) Room P521	*Hands-on: Numerical Solutions of Low-Re flows* (Dave Smith; U. Birmingham) Room MAS 2.03/04
17:00-18:00	Soundbite presentations (2 min) by workshop participants with beer and pizza, Room P521	
18:00-18:30	Research careers out of academia: Q&A with Dr. Gareth Rogers (CAIRN Res.). Room P521	

Programme

Day Two: Friday 13th September 2019

Venue for all talks and break: Room MS.04 in the Zeeman Building of the Mathematics and Statistics Building, Second Floor

Venue for lunch: Room MB0.08 in the Mathematical Sciences Building, Ground Floor

Venue for poster session: Room MB0.07 in the Mathematical Sciences Building, Ground Floor

8:30-9:15	Registration and Refreshments	Room MS.04
9:15-9:30	Introduction	Room MS.04
9:30-9.55	Prof. Stuart Humphries	Room MS.04
9:55-10:20	Emergence of ciliary coordination during development Dr. Kirsty Wan	Room MS.04
10:20-10:45	Correlation length of bacterial turbulence Dr. Vincent Martinez	Room MS.04
10:45-11:00	CAIRN Research Ltd	Room MS.04
11:00-11:45	Break and Poster Session	Room MB0.08 and MB0.07
11:45-12.10	Dr. Teuta Pilizota	Room MS.04
12:10-12:35	Haloarchaea Swim Slowly for Optimal Chemotactic Efficiency in Low-Nutrient Environments Dr. Lawrence Wilson	Room MS.04
12:35-13:45	Lunch	Room MB0.08
13:45-14:10	Hydrodynamics and phase behaviour of active suspensions Prof. Suzanne Fielding	Room MS.04
14:10-14:35	Simulations of interacting biofilaments Dr. Eric Keaveny	Room MS.04
14:35-15:00	Instabilities in bacterial hydrodynamics Dr. Eric Lauga	Room MS.04
15:00-16:10	Break and Poster session	Room MB0.08 and MB0.07
16:10-16:35	Stop-and-go droplets Dr. Corinna Maas	Room MS.04
16:35-17:00	The effective force of synthetic active particles Dr. Ivo Buttinoni	Room MS.04
17:00-17:10	Concluding Remarks	Room MS.04

Friday 13th September 2019

9.30 Optimised shapes for microbial chemotaxis

Prof. Stuart Humphries; U. Lincoln

Microbes exhibit a bewildering diversity of morphologies, but despite their impact on nearly all aspects of life, we have little idea why species take specific forms. Using experimental manipulation and numerical modelling we explore some of the determinants of chemotactic efficiency that appear to be driven by the shape of self-propelled microorganisms. We show that elongation and curvature have important effects and link these morphologies to shapes observed across bacteria in nature. As a wider set of evolutionary trade-offs between three tasks influenced by shape (efficient swimming, chemotactic efficiency, and reduced cost of cell construction) we show that curvature in particular can increase both swimming and chemotactic efficiency. We thus reveal a widely applicable selective advantage to microbial shape for chemotaxis.

9.55 Emergence of ciliary coordination during development

Dr. Kirsty Wan; U. Exeter

Cilia are ubiquitous appendages that occur in many different organisms. Cilia-mediated flows are important for microscale transport and propulsion, and have also been implicated in developmental patterning in early mammalian embryos. The question of how ciliary coordination arises has fascinated and confounded researchers for decades – its mechanistic specificity and physical origins are only becoming clear in recent years. We highlight the case of the unicellular ciliate Stentor coeruleus, an emerging model ciliate famed for its large size (1mm when fully extended) and remarkable ability to regenerate and replace lost structures. One such structure is a prominent, anterior membranellar band comprising stacked rows of compound cilia, which generate large-scale feeding flows. Here, we follow the growth and de novo development of the Stentor membranellar band and propose new mechanisms associated with the attainment of ciliary coordination.

10.20 Correlation length of bacterial turbulence

Dr Vincent Martinez; U. Edinburgh

Dense suspensions of swimming bacteria display remarkable properties such as the appearance of collective motion, i.e. local bacterial ordering associated with a characteristic correlation length-scale, reminiscent of turbulent flow behaviour. Here, we investigate this phenomenon as a function of system-size and bacterial concentrations using video microscopy over very large fields of view (up to 3mm X 4mm). Using particle image velocimetry, we calculate the spatial correlation of the velocity vectors and extract a characteristic length scale L. At sufficiently, high bacterial concentrations, we found the length L is proportional to the smallest system size, i.e. here the height of the glass capillary. However, we found no saturation of L towards large system-sizes and L can reach ~500 mm, which is ~5x larger than the currently largest L reported for bacterial suspensions. This suggests the absence of an intrinsic length-scale of dense populations of such 'pusher-like' swimmers.

Friday 13th September 2019

11.45 Bacterial Swimming in Complex Environments

Dr. Teuta Pilizota; E. Edinburgh

For several decades now, self-propulsion of bacterium *Escherichia coli* and the chemotactic network that helps it navigate the environment have been of interest to physicists, engineers, biologists and medics. The network transmits chemical input signals from the environment to the bacterial flagellar motor and, by influencing the flagellar motor rotational direction, controls the whole cell swimming trajectories. Despite decades of research the multitude of biophysical models describing E. *coli's* swimming, do so for the case of simple dilute aqueous media and one chemical gradient. However, inside animals including humans, and in open environments, bacteria swim in a complex environment, either physically (e.g. mucus) or chemically (e.g. multiple gradients of nutrients, oxygen, osmolarity changes, etc.). When confronted with such environments, cells display behaviours that cannot be understood with current chemotactic models. For example, we have characterized the effect of osmotic upshifts on the network output, the single motor bias, as well as on the rotational speed of the motor. I will present these results and discuss how the observed response translates into directed swimming of *E.coli's* cells. Furthermore, recent experiments show that the bacterial flagellar motor, powering *E. coli* swimming, acts as a mechanosensor able to senses the torque on the motor. While the exact mechanism of mechanosensing remains unknown, we have recently found that (as a result) the motor is able to respond to changes in the shear flow. We have started characterising this response and I will present our findings. Given the intrinsic link between the motor speed and torque, it is plausible that the role of mechanosensing is to allow *E. coli* to explore complex fluids efficiently**.** Alternatively, our observation could be just a consequence of mechanosensing that can be exploited as a flow sensor, which I will discuss.

Friday 13th September 2019

12:10 Haloarchaea Swim Slowly for Optimal Chemotactic Efficiency in Low-Nutrient Environments

Dr. Lawrence Wilson; U.York

Archaea have evolved to survive in some of the most extreme environments on earth. Archaeal life in extremely nutrient-poor conditions gives the opportunity to probe fundamental energy limitations on movement and response to stimuli, two essential markers of living systems. Halophilic archaea are ubiquitously slow-swimming, in what is presumed to be a response to nutrient-limited conditions. They also possess genetic components for chemotaxis analogous to those found in bacterial species, suggesting that their chemotactic strategies must be both highly refined, and potentially similar to the 'run and tumble' or 'run and reverse' behaviours seen in eubacteria. However, existing work on halophilic archaeal motility suggests that cells move with long, meandering trajectories, changing direction very rarely. This is inconsistent with current understanding of how Brownian motion limits bacterial chemotaxis. Here we use three-dimensional holographic microscopy and computer simulations to show that halophilic archaea achieve chemotaxis with an efficiency ten-fold higher than common bacterial model systems. Their swimming direction is stabilised by their flagellar apparatus, enhancing directional persistence. Our experiments and simulations reveal that the cells are capable of slow but deterministic chemotaxis up a chemical gradient, in a biased random walk at the thermodynamic limit.

Abstracts

Friday 13th September 2019

13:45 Hydrodynamics and phase behaviour of active suspensions

Prof. Suzanne Fielding; U.Durham

In a talk comprising two parts, I will review recent progress modelling the hydrodynamics and phase behaviour of active suspensions. The first part will discuss continuum modelling, with a particular focus on the formation of coherent structures such as velocity rolls in active suspensions. The second will discuss particle-based modelling, with a particular focus on the phenomenon of motility-induced phase separation.

14.10 Simulations of interacting biofilaments

Dr. Eric Keaveny; Imperial College

Both passive (biopolymers and fibres) and active (cilia and flagella) filaments are prevalent in microscale biofluid systems. Simulating these systems, especially at large scale, remains a computational challenge due to numerical stiffness, coupled fluid-structure interactions, and constraints on filament deformation. In this talk, I will describe a newly developed and scalable numerical framework that addresses these challenges through a combination of unit quaternions, implicit geometric time integration, and quasi-Newton methods. Results obtained using the method will be presented, and in particular, we will show how differences across a suspension at the smaller scales associated with flagellar undulations can affect the overall large-scale collective dynamics in active fluid systems.

14:35 Instabilities in bacterial hydrodynamics

Dr. Eric Lauga; U. Cambridge

We highlight in this talk three instances where fluid mechanical forces lead to instabilities for flagellated bacteria. We first show how wall-cell hydrodynamic interaction can lead to a transition to a wall-bound state for the swimming bacteria. We next show how the the swimming of cells with multiple flagella is enabled by an elastohydrodynamic instability. We finally discuss collective instabilities for magnetic bacteria.

Abstracts

Friday 13th September 2019

16:10 Stop-and-go droplets

Dr. Corinna Maas; MPI Göttingen

Single cell organisms show a variety of swimming behaviours: e.g. persistent, helical, run-and-tumble or switch-and-flick, all dependent on intricate biophysical machinery and serving various strategies of navigation, e.g. persistence against external flow, efficiency of gradient sensing or expanding their range of exploration. Their locomotion has to adapt to low Reynolds numbers and highly viscous environments. An important aspect to the construction of biomimetic model swimmers is to mimic as many of those strategies as possible, based on simple principles of non equilibrium physics without requiring intricate biochemical machinery. Here, we present a system of active droplets, whose propulsion can be tuned from almost ballistic persistence over a reorienting mode to a "stop-and-go" behaviour by changing the viscosity of the bulk phase. We relate our findings to theory models of surfactant consuming droplets, where, depending on the Péclet number of the system, the growth of higher-order modes of interfacial instability can lead from steady propulsive flows to arrested droplets with symmetric extensile flows. We image these higher order modes in both flow and chemical fields simultaneously via multichannel fluorescent microscopy.

16:35 The effective force of synthetic active particles

Dr. Ivo Buttinoni; U.Oxford

Physical and Theoretical Chemistry Laboratory

University of Oxford, South Parks Road, Oxford OX1 3QZ, UK.

I will discuss the concept of effective (or internal) force in suspensions of synthetic active particles. Active colloids are self-propelled micro and nanoparticles that convert uniform sources of “fuel” (e.g. chemical) or uniform external driving fields (e.g. magnetic or electric) into directed motion by virtue of asymmetry in their shape or composition. As such, they are force- and torque-free objects. However, recent works have suggested that a self-propelling colloid can be understood as if it was driven by an effective force proportional to its swimming velocity.

We experimentally test this idea in loosely-packed crystalline monolayers that are easy to deform and where single particles can be tweezed or actuated without spurious effects near contact. We focus the attention on probe particles that are initially confined in a given lattice position. The probe particle is self-propelling due to the catalytic decomposition of H2O2 across a Pt-cap. The experimental results show that the active particle can remain caged in its lattice position or leave either by swimming between neighbours or by displacing colloids that are on its way. This behaviour depends on the free propulsion velocity and the density of the crystal. We measure the corresponding forces on a shadow system where the probe particle is externally driven by an optical tweezer. Ultimately, we elucidate the fundamental differences between driven and self-driven colloids.

Poster Session

1. A view to a kill: Using cutting edge microscopy to study predatory bacteria

Brock Elizabeth Emma

Antimicrobial resistance is a serious and growing threat. New methods to treat bacterial infections need to be developed to mitigate this threat and to enable the continuation of current medical practice. A number of alternative solutions are being investigated including new families of traditional style antibiotics, phage treatment and the use of predatory bacteria. As a graduate student at the University of York, my research focuses on investigating the predatory bacterial species *Bdellovibrio bacterivorous* with the hope of informing future clinical use. I am using a unique type of microscopy, holography, to track individual cells in 3D space. I am using this to study how *Bdellovibrio* swim and how they locate their prey. I am also using total internal reflection fluorescence microscopy (TIRFM) to investigate how *Bdellovibrio* penetrate prey cells including the investigation of the impact of prey cell geometry on predation success. I am using both *E.coli* and the Spirochete, *Leptospira biflexa* as prey cells. Spirochetes have a helical cell shape which presents an interesting saddle-shaped surface geometry in comparison to the less complex rod shape of *E.coli*.

2. Active vs passive bundling of prokaryotic flagella

Chamolly Alexander

A lot of recent research activity has addressed the swimming dynamics of single prokaryotic cells, in particular flagellated bacteria. These cells propel through viscous fluid by rotating heli- cal flagellar filaments. In particular, peritrichous bacteria, such as the oft-studied E. coli, have multiple flagella distributed essentially randomly on the surface of the cell body. During forward locomotion, their flagellar filaments form a helical bundle located in the cellâ€™s wake where all fi- laments rotate in synchrony. The exact dynamics of the bundle formation are complex, and most hitherto proposed models aiming for a detailed and complete description have involved an inter- play between a number of physical effects including long-range hydrodynamic interactions, elastic restoring forces and short-range steric interactions while respecting the overall force and torque balance between flagella and the cell body. In this study we aim to understand what fundamental physical mechanism triggers bundle formation in the first place. We distinguish between active bundling, induced by hydrodynamic interaction of the flexible flagella with each other, and passive bundling, triggered by advection of fluid around a moving cell body. We propose a minimal analytical model that involves only the essential hydrodynamics of flagellar propulsion and show that it is able to predict the formation of bundling, as well as the relative strength of both effects.

3. Swimming of Microalgae

Clowe Matthew

Many cells and microorganisms have developed the ability to swim. This is seen in both Prokaryotes such as E. coli and Eukaryotes such as many algal species. This ability to swim plays a vital role in many aspects of life such as being able to move towards food or evade predators and it even aids in fertility such as with swimming sperm cells. In this poster I will look at modelling a type of algal colony called Gonium pectorale. I will demonstrate how the complex geometry of Gonium can be modelled via a level set approach, and calculate its swimming behaviour via a nearest neighbour regularised stokeslet method.

4. The behaviour of Chlamydomonas reinhardtii in viscosity gradients

Coppola Simone

Viscotaxis is the response a microswimmer has to a viscosity gradient. Such gradients are extremely common in nature, yet not a lot of work has been done to investigate experimentally how microswimmers behave in such circumstances. Recently, however, theory and numerical simulations studies have shown that viscosity gradients generate torques and velocity distributions which would cause microswimmers to perform viscotaxis and concentrate in a region of high viscosity [1].

In order to investigate experimentally the effects of viscotaxis, microfluidics experiments were performed using the green alga Chlamydomonas reinhardtii, since it has been shown that its velocity is linearly dependent on the viscosity of the fluid in which it is swimming [2].

We thus studied how the concentration profiles in the suspensions of algae are affected by the viscosity gradients, and compare our experimental results with numerical simulations for active Brownian particles to corroborate the observations.

[1] M. E. Cates and J. Tailleur, Motility-Induced Phase Separationî, Annual Review of Condensed Matter Physics, 2015.

[2] B. Qin, A. Gopinath, J. Yang, J. P. Gollub, and P. E. Arratia, Flagellar kinematics and swimming of algal cells in viscoelastic fluidsî, Scientific Reports, 2015.

5. Oriented suspension mechanics for pathogen detection

Cupples, Gemma

Flow linear dichroism is a biophysical spectroscopic technique that exploits the shear-induced alignment of elongated particles in suspension. Motivated by the broad aim of optimising the sensitivity of this technique, and more specifically by a handheld synthetic biotechnology prototype for waterborne-pathogen detection, a model of steady and oscillating pressure-driven channel flow and orientation dynamics of a suspension of slender microscopic fibres is developed. The model couples the Fokker-Planck equation for Brownian suspensions with the narrow channel flow equations, the latter modified to incorporate mechanical anisotropy induced by the particles. The linear dichroism signal is estimated through integrating the perpendicular components of the distribution function via an appropriate formula which takes the bi-axial nature of the orientation into account. For the specific application of pathogen detection via binding of M13 bacteriophage, it is found that increases in the channel depth are more significant in improving the linear dichroism signal than increases in the channel width. Increasing channel depth to \(2\)~mm and pressure gradient to $5 \times10^4~$Pa/m essentially maximises the alignment. Oscillating flow can produce nearly equal alignment to steady flow at appropriate frequencies, which has significant potential practical value in the analysis of small sample volumes.

6. FAST and NEAREST: Computational tools for biological fluids

Gallagher Meurig

This poster showcases two freely-available software packages, FAST and NEAREST, designed to enable easy analysis of biological fluids problems.

7. As the worm turns: Circular Milling in S. Roscoffensis

George Fortune

Circular milling, a stunning manifestation of collective motion, is found all across the natural world, from fish shoals to army ants. It has been recently observed that the plant-animal worm Symsagittifera roscoffensis exhibits circular milling behaviour, both in the lab in petri dishes but also on the beach in shallow rock pools. We further investigate this phenomenon from a fluid dynamical viewpoint, demonstrating experimentally the effect that the circular mill has on the surrounding fluid. We then consider a reduced theoretical model that treats a circular mill as a rigid rotating disc generating a Stokes flow. Although the model simplifies the real life problem considerably, we show that it captures the experiments remarkably well and hence can be used to reveal new biological insights about circular milling.

8. Multilayered bacteria leads to biofilm formation

Grobas Lȯpez Iago

Some species of bacteria show a flagella-driven group form of surface motion when they invade soft tissues. This kind of motility is called swarming and is known for its high resistance to antibiotics. Swarming bacteria can form multiple layers when they are in a confined space. This multilayer formation is also present in biofilms which also have a lower susceptibility to antimicrobials. However, this link between swarms and biofilms have not been explored yet. In our work, we have recreated a soft tissue infection by inoculating the model organism *Bacillus Subtilis* in a soft agar plate containing a gradient of the antibiotic kanamycin. In this scenario, we observed that the swarm forms a second layer in the region close to the kanamycin by locally increasing the cell density and maintaining its motility. Two days later, in the region where the transition to the double layer happens first, the swarm develops wrinkles which are biofilm-like structures. This directly links two forms of microbial communities which are highly resistant to antibiotics: swarms and biofilms.

9. Efficient Methods for Elastohydrodynamic Problems

Hall-McNair Atticus

Flexible filaments are ubiquitous in the natural world, and thus a clear understanding of their behaviour is paramount in many biological problems. Models for simulating the dynamics of these filaments, whilst plentiful, have historically been mathematically complex and numerically expensive. In this work, we reformulate the governing elastohydrodynamic equations via integral operators, discretised using the method of lines, alleviating computational cost. Non-local hydrodynamics are considered, enabling the simulation of larger arrays of filaments interacting, which produces complex flows and non-trivial filament geometries.

10. Effect of scattering on diffusive transport of microswimmers in complex environments

Jakuszeit Theresa

The impact of broken detailed balance has been a major interest when studying microswimmers in recent years. Active propulsion as performed by bacteria and Janus particles, in combination with hydrodynamic interaction at boundaries, can lead to the breaking of time reversibility. For example, bacteria approaching a flat wall are hydrodynamically attracted due to their surrounding flow field and will accumulate at the boundary before eventually escaping thanks to rotational diffusion. However, in microfluidic devices with pillars below a critical radius, self-propelled particles can slide along the surface of a pillar without becoming trapped over long times. A recent computational and theoretical study showed that the macroscopic transport is very well described by a model based on Run-and-Tumble particles with microscopically derived tumbling frequencies and reorientation functions arising from obstacle-induced tumbles, which can be adapted to different scattering rules. To test the theoretical predictions, we study the effect of a porous medium on the diffusion of bacteria in microfluidic channels filled with varying densities of pillars. We compare the model bacterium E. coli and the soil bacterium P. putida, as well as wild-type and smooth-swimming mutants to study the role of tumbles in an obstacle lattice. This work may shed some light on how active transport can be adapted to porous media such as soil.

11. SPT: Slender Phoretic Theory of Chemically Active Filaments

Katsamba Panayiota

Artficial microswimmers have the potential to revolutionise non-invasive medicine and microfluidics. A large class of these these swimmers self-propel by generating concentration gradients in a surrounding solute, and recent work has suggested that fabricating such swimmers from flexible, thermoresponsive filaments allows their precision navigation. In order to efficiently model such swimmers, we develop a Slender Phoretic Theory (SPT) for the chemohydrodynamics of microscale autophoretic filaments of arbitrary centreline, as a one- dimensional substitute for inefficient numerical solution of 3D partial differential equations. We show that, unlike other slender body theories, azimuthal effects that appear at first order for curved shapes have a leading order contribution to the swimming kinematics, and consider the effects of curvature for U-, S- and helical filament shapes.

12. Swimming eukaryotic microorganisms exhibit a universal speed distribution

Lisicki Maciej

One approach to quantifying biological diversity consists of characterising the statistical distribution of specific properties of a taxonomic group or habitat. Microorganisms living in fluid environments, and for whom motility is key, exploit propulsion resulting from a rich variety of shapes, forms, and swimming strategies. Here, we explore the variability of swimming speed for unicellular eukaryotes based on published data. The data naturally partition into that from flagellates (with a small number of flagella) and from ciliates (with tens or more). Despite the morphological and size differences between these groups, each of the two probability distributions of swimming speed are accurately represented by log-normal distributions, with good agreement holding even to fourth moments. Scaling of the distributions by a characteristic speed for each data set leads to a collapse onto an apparently universal distribution. These results suggest a universal way for ecological niches to be populated by abundant microorganisms.

13. Emergence of phytoplankton patchiness at small scales in mild turbulence

Mazza Marco

[1] R. E. Breier, et al., Proc. Natl. Acad. Sci. USA 115, 12112 (2018)

Sailors have known for millennia that periodically the seas appear of unusual color and can even turn red. These large swaths of colors stretching for tens or hundreds of km are caused by countless microscopic organisms called phytoplankton. These are microscopic algae that use sunlight to produce energy. They are the base of the marine food chain, and produce 50% or more of the oxygen in the atmosphere. Phytoplankton often encounter turbulence in their habitat. The spatial distribution of motile phytoplankton cells exhibits patchiness at distances of decimeter to millimeter scale for numerous species with different motility strategies. The explanation of this general phenomenon remains challenging. We combine particle simulations and continuum theory to study the emergence of patchiness in motile microorganisms in three dimensions, by including hydrodynamic cell-cell interactions, which grow more relevant as the density in the patches increases. By addressing the combined effects of motility, cell-cell interaction and turbulent flow conditions, we uncover a general mechanism: the coupling of cell-cell interactions to the turbulent dynamics favors the formation of dense patches [1].

14. Finite Element Modelling of Microswimmers with Applications in Reproductive Biology

Neal Cara

The journey of the human sperm to the egg is a complex and extremely important process. Sperm cells must navigate the intricate geometry of the fallopian tubes, generating active bending in order to swim through cervical mucus - a highly viscous, rheologically complex fluid. With rates of male infertility rising, it is becoming increasingly important to understand how sperm swim, and what might affect this process. While the field of microswimmers has gained significant attention in recent years, there are still several drawbacks to many of the ways in which we model swimmers. For example, methods are often computationally expensive, and many make the assumption that the fluid is Newtonian, despite the fact that this assumption has been shown to be invalid. Here we present a new method which utilises a combination of the finite element method and an elastohydrodynamic integral formulation to describe sperm cells swimming within non-Newtonian fluids. The integral formulation is a particularly efficient way of modelling the active flexible flagellum of cells, accounting for the hydrodynamic interactions between them (Hall-McNair et al. 2019). The finite element technique has been chosen due to its ability to handle the non-linear equations associated with non-Newtonian fluids. It is formulated in such a way that the solution can be calculated on a coarse mesh, for decreased computational costs compared to more commonly used body-fitted meshes.

15. High-throughput digital holographic microscopy for studying predatory bacteria

Rodriguez Erick

As antibiotic resistance is becoming increasingly common, the idea of using competitive and predatory microorganisms to treat infections is gaining attention. Microbiological and genetic approaches have helped scientists to explain the lifestyles of these predatory therapeutic agents, but many questions about their hunting methods will only be answered by developing new physical methods.

The center of interest of this project is to develop high performance software to track predatory bacteria (Bdellovibrio Bacteriovorus), while interacting with its prey, in three dimensions using digital holographic microscopy.

16. The Effects of Complex Rheology on the Swimming Dynamics of a Flagellated Alga

Ewan Rycroft[1], Mark Haw[2], Mónica S. N. Oliveira[1]

[1]James Weir Fluid Laboratory, Department of Mechanical and Aerospace Engineering, University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ, UK

[2]Department of Chemical and Process Engineering, University of Strathclyde, 75 Montrose Street, Glasgow, G1 1XJ, UK

The rheological make-up of the medium in which microorganisms live has a great influence on their motility and swimming dynamics. An understanding of these effects is key for the enhancement of applications such as artificial swimming, micro-robotics and targeted drug delivery as well as giving us a fundamental understanding of microscopic swimmers. In this work, we examine the effects of rheological characteristics, such as viscosity and viscoelasticity of the medium, on the swimming dynamics of a eukaryotic bi-flagellated puller alga, *Dunaliella salina*. We employ microfluidic chambers of rectangular cross-section and use microscopy and image analysis to quantify the swimming kinematics such as velocities, orientations and beat frequencies. We make use of dilute algae suspensions, in which alga-alga interactions can be neglected. We observe analogous algae swimming velocities and orientations in Newtonian (*Ficoll PM400*) and viscoelastic (*Polyacrylamide*) solutions across a substantial range of fluid viscosities. In all cases, swimming velocities decrease as the viscosity is increased up to a point where velocities plateau, exhibiting an approximately constant velocity for high viscosity solutions. Interestingly, we observe a difference in the viscosity-dependence of flagella beat frequencies between the two solutions, with frequency remaining constant when elasticity is present but decreasing with increasing viscosity in Newtonian solutions.

17. Collective Dynamics of Model *Pseudomonas aeruginosa*

Shendruk Tyler

Many baciliforms employ multiple motility strategies. For example, the infectious Gram-negative, rod-shaped bacterium *Pseudomonas aeruginosa* swims, swarmings, hyperswarmings, slides, walks, slingshots and twitches. Twitching-mode motility is surface-mediated, flagella-independent form of translocation, which relies on type-IV pili actively extending, anchoring to the surface and retracting to produce a jerky crawl with frequent reversal events. Twitching motility is particularly critical in virulence of many pathogens since it enables rapid dissemination and invasion, redistributing cells on surfaces prior to colony and subsequent biofilm formation. We combine molecular dynamics and rule-based simulations to study twitching-mode motility of model baciliforms and show that there is a critical surface coverage fraction above which the nature of twitcher dynamics fundamentally changes. Our work shows that even when biological complications, such as multiple motility modes, reproduction, biosurfactants, bacteria-secreted polymeric trails and nutrients competition, are neglected collective effects above the critical surface coverage. Our results demonstrate dynamic clustering of twitcher-type bacteria with polydomains of local alignment that exhibit spontaneous correlated motions, similar to rafts in many bacterial communities, arising from purely physical mechanisms. While this does not imply twitchers "swarm"—exhibit bacterial turbulence—it does reveal the early stages of collectivity in pre-biofilm twitching communities and provides additional details on Lévy statistics observed in ensembles of *P. aeruginosa.*

18. New methods to harvest micro-algae in suspensions using depletion Interaction

Taghi Naoual

[1] G. Chen et al., journal of Nanomaterials, 38 (2014)

[2] Lekkerkerker, H.N. and Tuinier, R., 2011. Colloids and the depletion interaction (Vol. 833), Springer.

As our consumption of energy keep increasing, developing renewable and environmentally friendly sources of energy to replace fossil fuels has become a major concern worldwide. Therefore, a lot of research are focusing on biofuels to replace it. Currently, biofuels are primarily produce from agricultural products. However, these raises ethical concerns as it competes with the food market. For that reason, researchers are focusing on producing biofuel using oleaginous microalgae that store lipids. Those lipids are considered as a promising alternative to fossil fuel. However, the algae biofuel sector is still under development and the current production price is still too high. This is due to the huge energy cost linked to the different stages of production, especially the harvesting step. This step is crucial as it separates the liquid growth media from the algae.

To harvest microalgae, there are two most commonly used methods which are centrifugation or filtration. Those methods are very energy costly due to the low sedimentation velocity of microalgae, their colloidal character with repelling negative surface charge, and more importantly the low biomass concentrations that require the processing of large volumes of water. Therefore, a pre-harvesting step can be added to concentrate the cells. This pre-harvesting step can be in the form of flotation or flocculation. To the best of our knowledge, only enthalpic flocculation methods have been described in the literature, using positively charged poly-electrolytes to flocculate the negatively charged algae in the algal suspension [1]. Here we report, for the first time, the use of negatively charged poly-electrolytes, including xanthan, to induce creaming of the negatively charged algae, based on entropic depletion forces [2].

19. Hydrodynamic synchronisation of cilia in strong confinement

Tanasijevic Ivan

Cilia, hairlike appendages of some microorganisms, exhibit an interesting collective behaviour called a metachronal wave where the neighbouring cilia beat in constant phase difference. To explain this sort of behaviour, complicated, elastic filaments with complex and still debated driving mechanism, are replaced by spheres forced to move along circular trajectories. Two main features of cilia that are known to lead to hydrodynamic synchronisation near a single wall are the elastic compliance of the orbit (elasticity of cilia) and the modulated forcing (power/recovery stroke). This project considers these minimal models of cilia placed between two infinite parallel walls. The models were adapted to this situation for examining the robustness of the mechanisms to strong confinement by comparing the results with the corresponding ones in the presence of a single wall. Our theoretical calculations suggest that, in a biologically relevant situation, the force modulation is more likely to be the dominant mechanism for synchronisation.

20. Geometry and Hydrodynamics of Bundles of Bacterial Flagella

Tatulea-Codrean Maria

The vast majority of motile bacteria exploit chirality in order to break symmetry and generate propulsion at low Reynolds number. Spirochaetes have developed corkscrew -shaped bodies, while other bacteria with simpler bodies can assemble and actuate helical filaments called flagella. In the case of multi-flagellated bacteria, the filaments are swept behind the cell body and rotate together in a bundle, which leads to a period of straight swimming called a "run". To change swimming direction, at least one motor must switch its sense of rotation, upon which the associated flagellum will leave the bundle and generate a force imbalance. The subsequent reorientation of the cell is called a "tumble".

The ability of multi-flagellated bacteria to bundle and unbundle their flagella is crucial to their run-and-tumble mobility. However, it is remarkable that the cell can bring multiple helical filaments into a coherent bundle, despite the lack of coordination between molecular motors. This is intriguing because the filaments could, in theory, tangle around each other due to their helical geometry. The hydrodynamic benefit of having multiple flagella, as well as the associated risk of geometrical tangling, depend on both the shape and number of flagella. At one extreme, we know that straight flagella could not intertwine, but neither could they propel the cell forward in a viscous fluid. Similarly, one flagellum could never tangle on its own, but neither could it generate a propulsive force as large as a bundle of flagella. We will present some theoretical results about the role of flagellar geometry and number on the robustness of tangle-free bundling and the hydrodynamics of the bundle.

21. Bacterial magneto-convection

Thery Albane

Dense suspensions of swimming bacteria are known to self-organise and display unsteady dynamics. We use microfluidics experiments to show that a uniform distribution of magnetotactic bacteria is rendered unstable by a magnetic field perpendicular to channel walls. A state of bacte- rial magneto-convection results, wherein bacterial plumes emerge spontaneously perpendicular to the wall and develop into self-sustained flow convection cells. Using a theoretical model based on hydrodynamic singularities, we capture quantitatively the instability and the observed long-time growth of the plumes.

22. Colloidal transport in heterogeneous landscapes of micro-swimmer activity

Williams Stephen

Chlamydomonas reinhardtii, a unicellular biflagellate alga, is widely regarded as a model organism for a broad range of biological and physical studies, from plant photosynthesize to flagellar synchronization, motility (e.g. bioconvection, phototaxis) or active matter. Recently, hydrodynamic entrainment was shown to dominate the effective diffusion of micro-particles embedded in homogeneous suspensions of the algae. Microscopically, the colloids exhibit a dynamics akin to a jump-diffusion process, with successive entrainment events (jumps) interspersed with normal diffusion (slightly enhanced by the far-field flows of the swimmers). In this work we now explore experimentally the effect of spa- tially heterogeneous algal suspensions on the dynamics of weakly Brownian par- ticles by confining the system within quasi-2D microfluidic chambers. In such geometries, the interaction of the swimmers with the confining walls, the inter- action of the swimmers with the confining walls create a heterogeneous and anisotropic background of diffusion for the colloids. This leads to spontaneous active-passive segregation where the colloids accumulate at the boundaries. This effect can be tuned by fixing the surface-to-volume ratio of the confining channels and can be harnessed to spontaneously demix the active-passive suspension. We rationalize our observations by resolving spatially and temporally the colloidal kicks statistics. Although relatively basic, this experimental system exhibits highly non-trivial out-of-equilibrium dynamics which opens the way to a better understanding and control of passive matter transport by active entities, with potential important applications to e.g. intracellular transport, targeted drug and biomarker delivery or the autonomous depollution of soils.

Attendee List

Full Name	Email	Affiliation
Alexander Gareth	G.P.Alexander@warwick.ac.uk	University of Warwick
Avery Natasha	navery.197@gmail.com	University of Bristol
Bearon Rachel	rbearon@liverpool.ac.uk	University of Liverpool
Bees Martin	martin.bees@york.ac.uk	University of York
Brock Emma	emma.brock@york.ac.uk	University of York
Buttinoni Ivo	ivo.buttinoni@chem.ox.ac.uk	University of Oxford
Chamolly Alexander	ajc297@cam.ac.uk	University of Cambridge
Clowe Matthew	mxc985@student.bham.ac.uk	University of Birmingham
Coppola Simone	S.Coppola@warwick.ac.uk	University of Warwick
Cortese Dario	d.cortese@exeter.ac.uk	University of Exeter
Cupples Gemma	G.Cupples@bham.ac.uk	University of Birmingham
Das Debasish	dd496@cam.ac.uk	University of Cambridge
Dvoriashyna Maria	md855@cam.ac.uk	University of Cambridge
Dyson Rosemary	r.j.dyson@bham.ac.uk	University of Birmingham
Fielding Suzanne	suzanne.fielding@durham.ac.uk	Durham University
Fortune George	gtf22@cam.ac.uk	University of Cambridge
Fung Lloyd	Lloyd.fung@imperial.ac.uk	Imperial
Gadelha Hermes	hermes.gadelha@bristol.ac.uk	University of Bristol
Gallagher Meurig	m.t.gallagher@bham.ac.uk	University of Birmingham
Graham Jeremy	j.graham@cairn-research.co.uk	Cairn Research
Grobas López, Iago	I.Lopez-Grobas@warwick.ac.uk	University of Warwick
Hall Madeleine	mgh17@ic.ac.uk	Imperial College London
Hall-McNair Atticus	axh968@student.bham.ac.uk	University of Birmingham
Humphries Stuart	shumphries@lincoln.ac.uk	University of Lincoln
Jakuszeit Theresa	tj295@cam.ac.uk	University of Cambridge
Kantsler Vasily	v.kantsler@warwick.ac.uk	University of Warwick
Katsamba Panayiota	p.a.katsamba@bham.ac.uk	University of Birmingham
Keaveny Eric	e.keaveny@imperial.ac.uk	Imperial College London
Kennedy Duncan	dk350@exeter.ac.uk	University of Exeter
Lauga Eric	E.Lauga@damtp.cam.ac.uk	University of Cambridge
Lisicki Maciej	mklis@fuw.edu.pl	University of Warsaw
Maaß Corinna	corinna.maass@ds.mpg.de	MPI-DS Göttingen
Maretvadakethope Smitha	sm6412@ic.ac.uk	Imperial
Martinez Vincent	vincent.martinez@ed.ac.uk	The University of Edinburgh
Mazza Marco	m.g.mazza@lboro.ac.uk	Loughborough University
Montenegro-Johnson Tom	t.d.johnson@bham.ac.uk	University of Birmingham
Morozov Alexander	Alexander.Morozov@ed.ac.uk	University of Edinburgh
Neal Cara	cvn368@bham.ac.uk	University of Birmingham
Pilizota Teuta	teuta.pilizota@ed.ac.uk	University of Edinburgh
Polin, Marco	m.polin@warwick.ac.uk	University of Warwick
Pushkin Mitya	mitya.pushkin@york.ac.uk	University of York
Rodriguez Erick	eers500@york.ac.uk	University of York
Rycroft Ewan	ewan.rycroft@strath.ac.uk	University of Strathclyde
Shendruk Tyler	t.n.shendruk@lboro.ac.uk	Loughborough University
Smith Dave	d.j.smith.2@bham.ac.uk	University of Birmingham
Southern Emily	emily.southern17@imperial.ac.uk	Imperial College London
Taghi Naoual	n.taghi@qmul.ac.uk	Queen Mary University of London
Tanasijevic Ivan	it279@cam.ac.uk	University of Cambridge
Tatulea-Codrean Maria	mt599@cam.ac.uk	University of Cambridge
Thery Albane	at830@cam.ac.uk	University of Cambridge
Townsend Adam	adam.townsend@imperial.ac.uk	Imperial College London
Wan Kirsty	k.y.wan2@exeter.ac.uk	University of Exeter
Williams Stephen	s.williams@warwick.ac.uk	University of Warwick
Wilson Laurence	laurence.wilson@york.ac.uk	University of York
Yihong Shi	YXS704@student.bham.ac.uk	University of Birmingham