Exploring joint mechanics and the relationship between shape, strain and cellular behavior through life

Supervisory team:
Main supervisor: Dr Chrissy Hammond (University of Bristol)
Second supervisor: Prof Emily Rayfield (University of Bristol)
Prof Richie Gill (University of Bath)

Collaborators: Dr Niamh Nowlan (Imperial College London)

Host institution: University of Bristol

Project description:

Joints are a vital component of locomotion and feeding in all vertebrates. Joint pathologies are frequently seen during ageing, both in humans (a majority of people over 65 have osteoarthritis in at least one joint) and in most if not all vertebrate species, including pets, working animals and animals in the wild, significantly impacting mobility and quality of life. While we have a good understanding of the signalling required to initiate joint development, our understanding of how local mechanical and genetic cues shape the joint throughout the lifecourse is incomplete, but better understanding of this could help us improve joint health during ageing.

In this project we will build the first experimentally validated computational models of joint mechanobiology through the whole lifespan of a vertebrate, the zebrafish. To do this we will generate Finite Element models of wild type fish at key stages throughout their life to capture the mechanical performance of joints during development, maturity and ultimately ageing. This will be achieved by segmenting bone, cartilage, muscle and soft tissue data from micro computed tomography images of the joint of larval, juvenile, adult and aged zebrafish. We will collect 3 dimensional shape data, along with strain data from muscles to inform on jaw loading. We will validate these data with real data acquired from high speed videos of joint movement in zebrafish. The student will then test the relative impact of shape and material properties on joint strain in ageing wild type fish and those carrying joint mutations that are also seen in human populations. A major advantage of Finite Element Analysis (FEA) is the potential to isolate the effects of specific properties on the biomechanics of a biological system. Material properties obtained from different strains can be arbitrarily assigned and stochastically changed between FE models to quantify the effect of material properties on a particular FEA simulation. Material properties can be swapped between comparative models that significantly differ in shape in order to isolate the effect of morphology from those of material properties, on joint strain and function. These simulations can provide novel information regarding the impact of shape versus properties on the biomechanical performance of the joint, and give insight into why some mutants develop different pathologies. We can then test how to manipulate joint performance in silico.