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Co-supervisor: Jingzhe Pan, Professor in Mechanics of Materials; Head of Mechanics of Materials (MoM) Research Group and Director of Research, College of Science and Engineering.

PhD project title: Behavioural and biomechanical analysis of socially induced changes in body and brain structure in desert locusts.

University of Registration: University of Leicester

Project outline

1. Project outline describing the scientific rationale of the project

All animals can tailor their phenotype to the environmental conditions they experience during their lifetime. Such phenotypic plasticity typically entails concerted changes in morphology, physiology and behaviour. SRO is using the Desert Locust *Schistocerca gregaria* as a model to analyse phenotypic plasticity that is induced by social experience. Locusts respond to crowding by radically transforming their body, brain and behaviour from a shy, lone-living *solitary phase* to a *gregarious phase* adapted for a life in dense migratory swarms [1]. This capacity underpins the infamous locust swarms that can devastate crops and pastures on a continental scale. SRO and TM have set up world-leading breeding facilities for generating both phases under precisely controlled laboratory conditions. TM has a strong track record in analysing the kinematics and biomechanics of limb movements in locusts and related insects [2].

The many lifestyle-specific adaptations of the two phases include body posture and locomotion [3]. Solitarious locusts walk infrequently and with a creeping gait, keeping the body close to the ground. Gregarious locusts use a rapid, stilted gait to cover huge distances by walking as wingless juveniles. These pronounced behavioural differences are paralleled by differences in the musculoskeletal machinery of the thorax. This machinery underpins both walking and flight, with several bi-functional muscles serving in both behaviours. Further anatomical correlates of the different life styles are evident in the locust head. Adult gregarious locusts have smaller heads but larger brains than age-matched solitarious locusts; the relative proportions of different brain regions also differ markedly [4]. However, we now have evidence that solitarious locusts, which are much longer-lived, far surpass gregarious locusts in brain size later in life.

In this project you will use X-ray computed micro-tomography (‘micro-CT’), a novel bioimaging technique that reveals internal structure in intact animals with micrometre resolution, to carry out the first simultaneous 3D computer reconstructions of the skeleton, musculature and central nervous system of the locust head and thorax. You will then apply Finite Element Analysis (FEA), a highly advanced computer modelling technique, to predict mechanical forces in the reconstructed skeletal structures. This will enable you to address fundamental questions about the scope and limits of structural plasticity in relation to behavioural plasticity along two broad lines:
(1) How does thorax structure differ between phases? How do skeletal differences relate to differences in muscle size and/or attachment angle, and to differences in posture and walking behaviour (limb joint angles and range of movements)? Are there structural compromises arising from the dual requirement for walking and flying? Do differences between the phases reflect different trade-offs between walking and flying?

(2) Are there differences in head anatomy that relate to dietary differences, such as bigger chewing muscles in gregarious locusts that in turn require stronger skeletal reinforcement? How does brain size and composition change over time in the two phases? To what extent is brain shape determined by head size and shape?


**Relevant BBSRC Strategic Research Priority:**
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Techniques that will be undertaken during the project.

- X-ray microtomography (of skeletal structure, brain, musculature and muscle insertions)
- 3D image processing and analysis (surface reconstruction, volumetric analyses of brain size and muscle development)
- Behavioural analyses (video tracking and analysis of limb movements).
- Finite Element Analysis (modelling of stress forces in the 3D-reconstructed skeletal skeletal structures)

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