Determining functional RNA structure motif via deep learning

Main supervisor: Dr Ke Li: K.Li@exeter.ac.uk
Second supervisor: Dr Yiliang Ding (John Innes Centre): Yiliang.Ding@jic.ac.uk

Proposed start date: 1st July 2021 (flexible)
Length: 5 weeks

Project description: RNA structure plays an essential role in the post-transcriptional regulation of gene expression such as translation, splicing and RNA degradation. Recent advances in the high-throughput methods obtain the in vivo RNA structure information over tens thousands of RNA transcripts with nucleotide resolution. This "big data" from in vivo RNA structurome poses a challenge in determining a functional RNA structure motif from omics data. In this project, we will apply the state-of-the-art deep learning techniques including transfer learning to extract RNA structure motif associated with translation efficiency. The tasks include:

1. Apply deep learning techniques on both RNA structurome and translation efficiency data in yeast, plants (Arabidopsis and rice) and human cells (HeLa cells).
2. Identify the specific RNA structure features which are associated with highest translation efficiency and lowest translation efficiency, respectively.
3. Provide top 10-20 candidate RNA structure motifs for the wet-bench researchers in Ding lab (John Innes Centre, UK) to validate the selected RNA structure features from our machine learning pipeline.

Note that the experimental results will be fed back to our machine learning pipeline to further improve our machine learning algorithm. It is expected that this prediction-validation loop will be conducted for several times to maximize the performance of our pipeline. The functional RNA structure motif determined from our pipeline will provide new way to improve protein production through optimizing the RNA structure motif.

All the dataset required for this project are available. There are several datasets from different species such as yeast, Arabidopsis, rice and HeLa cells. The student could start with one set of data and extend to other species, if needed due to any COVID impact.

Do bacterial chromosomes age?

Main supervisor: Dr. Tobias Bergmiller: t.bergmiller2@exeter.ac.uk

Proposed start date: Flexible start date, suggested start date July 1st 2021
Length: 5 weeks

Project description: Mutations are fundamental factors of evolution. In particular bacteria, which are devoid of sexual reproduction in the common sense, rely on mutations to adapt to ever changing environments. Mutation rates are not constant, and there is a large degree of mutation rate plasticity between and within bacterial populations. In this project, we will investigate a particular mechanism that could affect the appearance of mutations in bacterial populations, which is the age of DNA template strands and their distribution at cell division. The semi-conservative nature of DNA replication implies that each newly replicated DNA molecule will consist of one "old" template strand and a newly replicated complementary strand. It was hypothesised that old DNA template strands could serve as "master templates" that are protected from mutations arising through DNA replication errors, the "Immortal Strand Hypothesis", which has yet to be tested experimentally.

In this project, we will investigate the nature of old DNA "Master templates" using Escherichia coli as model organism. Your role will be to experimentally measure mutation rates of DNA templates of different ages in bacterial populations. To do so, you will carry out conventional mutation rate assays using E.coli. We will then combine mutation rate assays with a technique that facilitates selective enrichment of bacterial cells based on the age of their DNA templates to measure age-specific mutation rate. Furthermore, you will get hands-on experience with microfluidic technology and single-cell imaging, and image DNA segregation in living E.coli cells.

In case of increased COVID restrictions, you will get hands-on experience in aspects of image analysis of images taken from dividing bacterial cells and their fluorescently labelled chromosomes.

The impact of climate change on thermoregulation of bumble bee colonies

Main supervisor: Dr David Horsell: D.W.Horsell@exeter.ac.uk
Second supervisor: Dr Steven Hepplestone: S.P.Hepplestone@exeter.ac.uk

Proposed start date: 14th June 2021 (flexible)
Length: 5 weeks

Project description: The objective of this project is to simulate the thermal properties of a bumble bee nest under changing environmental conditions. Bumble bees are one of the most important pollinators of food crops. They are also a key indicator of changes in the climate as the flow of energy into and out of a bumble bee nest forms a delicately balanced thermodynamic system. Too much or too little energy results in the death of a colony. Changes in air and soil temperature, humidity levels, and location and quality of food sources all have chance to tip this balance. Bee populations worldwide have been in sharp decline in recent years and changes in climate are more than likely to be the cause.

This project will focus on the thermodynamics of a nest with the aim to describe its regulation through thermodynamic processes alone. A finite difference model will be created using python to understand how the nest interacts with its environment under different conditions. This project would particularly suit students interested in applying physics concepts to biological systems and in building mathematical models to simulate real-world systems. There is great scope to try out new ideas as this is a little explored field of research. Ultimately, results from this project will help us to understand the energy requirements of bumble bee populations and how climate change could affect them. With such knowledge we will be in a much better position to manage populations for future food security.

The project is entirely simulation based and can be run on modest computer hardware. As such, we do not expect any impact from the current pandemic.

The role of perceptual processing in courtship behaviour

Main supervisor: Dr Laura Kelley: l.a.kelley@exeter.ac.uk

Proposed start date: Mid-August 2021 (flexible)
Length: 5 weeks

Project description: During mate choice in many species, the choosing sex (usually females) evaluate signals displayed by the courting sex to determine if a potential mate is of sufficient quality. In green swordtails Xiphophorus hellerii, freshwater fish native to Central America, females evaluate male quality by assessing the male's body size and the length of his extended caudal fin (or "sword") while males perform vigorous courtship displays.

The female's visual acuity (ability to perceive detail) influences her ability to assess size. Because acuity is distance-dependent, females should be able to more accurately gauge size from close up. Thus, when courting females alone, males should position themselves close to the female to appear as large as possible.

However, if other males are also present, males may alter their courting distance to look more desirable relative to other males. Due to a perceptual mechanism called proportional processing, precisely where a male should position himself to appear as large as possible relative to another male will depend upon the body and sword size of each male involved.

This project will examine how males of different sizes position themselves relative to females when alone versus in the presence of additional males by staging courtship encounters between male and female swordtails, and quantifying the courtship distance when one or multiple males are present. This project is the first to consider the role of proportional processing in a naturalistic mate choice scenario, and offers the opportunity to carry out behavioural experiments within a stimulating and supportive research environment.

If lab access is restricted, other lab members will stage the mate choice trials and the student will carry out video analysis. Alternatively, if preferred, the student can create and analyse a database examining how proportional processing may affect the results of binary mate choice experiments in previously published studies.

Male (top) and female (bottom) green swordtail

To be or nut to be; can we infer a squirrel's affective state from their foraging decisions under ambiguity?

Main supervisor: Dr Lisa Leaver: L.A.Leaver@exeter.ac.uk
Second supervisor: Prof. Mike Mendl: Mike.Mendl@bristol.ac.uk, Dr Liz Paul: E.Paul@bristol.ac.uk, Dr Vikki Neville: vikki.neville@bristol.ac.uk

Proposed start date: 1st June 2021 (some flexibility is possible)
Length: 5 weeks

Project description: An animal's survival depends on its ability to make good decisions. If it hears a rustle in the grass, should it forgo feeding in case there is a predator approaching, or assume it's just the wind and risk predation? The animal's emotional (affective) state is thought to provide a heuristic for rapid decision-making of this sort; a negative affective state reflects recent negative experiences predisposing cautious decision-making under ambiguity (a 'pessimistic' judgement bias). Although decision-making in judgement bias tests has been widely used as a measure of animal affect and hence welfare in captive species, there has been virtually no empirical investigation in wild animals. Such studies would allow hypotheses about the relationship between environmental conditions, animal state, and decision-making to be tested in a real-world situation, hence shedding light on potential adaptive functions of emotion. Wild populations of grey squirrels are abundant and will readily interact with experimental apparatus hence providing an ideal model for such studies. The aim of this project is to develop a behavioural task to investigate judgement bias in squirrels. This will involve training squirrels to make costly actions that could lead to either a high-value food item or low-value food item, and assessing whether and how quickly they execute these actions. The relationship between judgement bias and variables characterising the condition of the test environment and state of the individual will then be investigated.

Studies of personality in wild animals are a growing area of research in behavioural ecology. In case of increased COVID restrictions, measures of squirrel condition and behaviour could be extracted from existing squirrel video data and weight records to determine whether there are consistencies in behaviour across time ('personalities') and how they are related to squirrel condition.