Graduate position: Barcelona Evolution of gene networks and the origins of organismal complexity.

1.Basic job and project description:

The position is the Autonomous University of Barcelona (UAB) and in the Centre de Recerca Matemàtica (CRM). The CRM is in the UAB campus.

-The main project questions are:

How should gene networks and cell interactions be organized to lead to biological complexity?

How is such organization achieved in evolution?

How does gene network organization affect variational properties of the phenotype (e.g. evolvability)?

Any other question of the applicants interest that is related to the previous questions.

We will use computational models of the genotype-phenotype map and computational models of evolution by natural selection to study such questions for the case of organismic complexity (e.g. anatomy). The genotype-phenotype maps models we develop are based on realistic gene network models of pattern formation and morphogenesis that lead to realistic 3D multicellular phenotypes.

The position is in Salazar-Ciudad's group and it entails obtaining a PhD from the UAB.

2. Background of the project:

There is no consensus definition of complexity, yet it is evident that organisms are complex and explaining such complexity is one of the most fundamental questions of biology. Morphological complexity has not increased in the evolution of all lineages and, in general, it is unclear whether there is a general trend of increasing complexity in evolution. Yet, one may ask about the mechanisms by which such complexity has increased in the lineages where it has increased. How complexity increases during evolution is necessarily related to development: any evolutionary change in morphology is first a change in the development that produces such morphology.

It has been argued that, in spite of the remarkable morphological complexity of organisms, their development is achieved through a limited number of cell behaviors and types of cell interactions. These cell behaviors would be cell division, cell adhesion, cell death, cell growth, cell contraction, extracellular signal and matrix secretion, extracellular signal reception and cell differentiation. In addition to cell behaviors, development involves interactions between cells, either mechanical or through extracellular signalling.

The questions we want to approach in this study are: how should these interactions and cell behaviors be coordinated to produce complex and robust morphologies? The question is, then, whether there are some logical requirements that developmental mechanisms should fulfill in order to lead to complex robust morphologies. Are there, for example, some requirements at the level of gene network topology or at the level of cell behaviors and their coordination during development?

If, as suggested above, pattern transformations in development involve a limited set of cell behaviors and cell interactions, then any mathematical model implementing those and intracellular gene networks should be able to reproduce, to a large extent, the range of pattern transformations possible in animal development. In this project we will use one such model, EmbryoMaker (Marin-Riera *et al*, 2015), to simulate a large number of possible developmental mechanisms and try to

discover what, if anything, do the mechanisms leading to robust complex morphologies have in common.

3. Job description

The main tasks of the student include using and modifying existing models of embryonic development (e.g. EmbryoMaker) in order to simulate the development of complex morphologies. These models will be combined with models of evolution, in a population context with mutation, genetic drift and natural selection on morphology (see for example Salazar-Ciudad and Marin-Riera, 2013). he gene networks found to lead to the development of complex and robust phenotypes in evolution would be analyzed to extract general regularities, if any, these gene networks need to fulfill. The main tasks, thus, consist in simulation, theorizing, data analysis, coding, literature searching, writing and presenting results in conferences. We seek candidates highly motivated for theoretical work and data analysis with a broad understanding of the evolutionary theory and/or developmental biology and/or modeling.

4. Requirements:

- Candidates should have a University Degree and a Master's Degree in biology, physics or mathematics within the European Higher Education System (minimum 300 ECTS) or equivalent by September 2019.

-Scientific programming skills or a willingness to acquire them is required.

-The most important requirement is a strong interest and motivation on science and evolution. A capacity for creative and critical thinking is also required.

5. Salary and conditions:

-The salary would be the standard one graduate students in Spain. Barcelona is a vibrant, multicultural hub with a high quality of life and a thriving cultural scene.

-Working time is of 37,5 hours per week.

6. The application must include:

-Application letter including a statement of interests and motivation.
-CV (including publications, the contribution of the applicant in each publication, degrees obtained, subjects included in degree and grades, average grade)

Foreign applicants, especially non-EU applicants, should attach an explanation of their University's grading system. All documents should be in English, no official translation is required in the initial application but may be requested afterwards.

-Applications should be sent to Isaac Salazar-Ciudad by email:

isaac.salazar@uab.cat

7. Starting:

The start date is negotiable between autumn 2019 and early 2020.

8. Work environment:

Salazar-Ciudad group is between the Genetics deparment in the UAB (www.uab.cat) and the mathematics research center, CRM:

www.crm.cat

and

http://www.crm.cat/en/About/People/Researchers/ISalazar/Pages/PersonalContact.aspx ItemId=CO009211

Being between two institutes implies interactions with evolutionary biologists, theoretical biologists and mathematicians. Although the CRM and UAB are independent institutions, they are 50m a part in space (the CRM is in the UAB campus). In addition, we have thigh interactions with developmental biologists at the University of Helsinki, where part of Salazar-Ciudad group still is (old webpage: http://www.biocenter.helsinki.fi/salazar/index.html.)

Both the CRM and Genetics department are very international and, thus, not being able to speak Catalan or Spanish is not a problem. Nearly half of the PIs in the CRM are foreigners. The everyday working language is English, and most administrative tasks, training and seminars arranged by the department and CRM are conducted in English.

The UAB is one of the largest and best Universities in Spain. As of 2012, the UABy consists of 57 departments in the experimental, life, social and human sciences, spread among 13 faculties/schools. There are almost 80 doctoral programs. The UAB has more than 40,000 students and more than 3,600 academic and research staff. UAB is a pioneering institution in terms of fostering research. There are many research institutes in the campus, as well as other research centers, technical support services, and service-providing laboratories. UAB is the best university in Spain according to the 2012 QS World University Rankings.

9. References:

Salazar-Ciudad I, Marín-Riera M.Adaptive dynamics under development-based genotype-phenotype maps. Nature. 2013 May 16;497(7449):361-4.

Marin-Riera M, Brun-Usan M, Zimm R, Välikangas T, Salazar-Ciudad I. Computational modeling of development by epithelia, mesenchyme and their interactions: a unified model. Bioinformatics. 2016