Modeling Shape and Size in Biological Development

24 - 28 August,Lorentz Center @Oort

Scientific aim

This online international summer school, which involved 66 student participants and 14 speakers from 12 countries, focused on multiscale mathematical and computational models in Developmental Biology. Such mathematical models, calibrated using specific experimental data, are capable of providing mechanistic understanding of how dynamic descriptions of microscale and mesoscale cellular and subcellular processes, such as cellular growth and division, cell movement and interaction with the extracellular matrix (ECM), mechanotransduction and chemical signaling between cells, etc., are coupled with each other to exhibit tissue dynamics at larger macroscale spatial scales. In particular, modeling of the growth and shape of organs and organisms during development was of special interest. The summer school focused on the development of mechanistic modeling skills of the participants through participation in several team projects, whereas the equally important integration of imaging and data analysis tools (e.g., deep learning) with modeling was illustrated in several keynote lectures. Mathematically, the school presented multiscale mathematical modeling coupling discrete dynamical systems with PDE models in space and time, development of novel mathematical, analytical and computational methods for stochastic dynamical systems, differential equations, novel sensitivity analysis methods, and so forth.

The main scientific aim was to contribute to establishing Multiscale Mathematical and Computational Developmental Biology as a field. The educational goal was to define the combination of theoretical mathematical foundations and practical computational methods, as well as the interdisciplinary collaboration skills required by researchers and students to be successful in this field. Participants of the summer school had very diverse backgrounds, ranging from mathematics and physics to experimental biology. For some students it provided the first very important experience of international, interdisciplinary scientific collaboration, even more valuable at this time due to the COVID pandemic.

The workshop and summer school consisted of pre-recorded educational and scientific lectures and hands-on research projects, each of which was supervised by one of the international speakers. James Sharpe, Director of the EMBL in Barcelona, gave a public lecture on the role of Turing patterns in the patterning of developing limbs. The week of intense discussions and collaborations was concluded with a session of short presentations by twelve student teams on the outcomes of their research projects.

Each of the student teams consisted of four to five students led by one of the speakers, in many cases with the help of their PhD students and postdocs. Prior to the workshop, the speakers presented an open problem to their teams, and introduced them to a mathematical modeling and simulation framework to address it. Then, with the help of the speakers and their assistants, the students worked on their own solution to the problem. It was amazing how much could be done in only one week, despite the difficulties of working in an online format with time differences. For example, the team led by Dr. Alexandria Volkening of Northwestern University introduced stochastic cell interactions into their agent-based models of zebrafish skin pattern formation. A team led by Dr. Richard Smith of the Max Planck Institute

for Plant Breeding Research in Cologne, Germany, introduced students to finite-element modeling of plant cell mechanics. The team led by Prof. Jeremy Zartman of Notre Dame University, IN, USA worked on modeling cross-talk between subcellular mechanics and chemical gradients, and a team led by Dr. Verônica Grieneisen of the University of Cardiff, UK, worked on modeling of organoids.

Besides the educational contributions, the workshop provided speakers and their PhDs and postdocs with an important opportunity to acquire hands-on experience of the main approaches of mathematical modeling and the underlying mathematical methodology (and open problems) as well as presenting polished final results at a conference or in a paper.

The summer school will lead to a practical textbook on computational and mathematical modeling in biology, that will be accompanied by hands-on examples and exercises based on online research and educational lectures, as well on some of the student projects presented at the workshop.

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Organization

Despite the obvious difficulties associated with running an online workshop, participants reflected on their experience as a very positive, useful and fun workshop week. Even social events were more fun than expected; we had coffee/late-night-snack breaks in the Leiden mornings, and even organized a workshop “dinner”/breakfast/lunch. The key challenge was, of course, to synchronize the different time zones without losing too much sleep. We solved this by having asynchronous, pre-recorded lectures that participants viewed in their local time zones, followed by synchronized Q&A sessions. The project teams independently found the best times for their discussion meetings, depending on the time zones of the participants. In some teams most participants were localized in a few nearby time zones, others were spread out all over the world. Quite a few of these teams made very good use of their geographical distribution, and handed over their work twice each 24 hours as a ‘scientific estafette’, in this way doubling their progress!

In the post-workshop questionnaire some participants asked that in virtual workshops the talks should be made available one week before, as the project work was indeed difficult to combine with listening to the talks in a relaxed manner. As organizers we certainly agree with that: it was also hard for us to stay up to speed with all lectures, even if for all speakers it was a challenge to get their lectures prerecorded in time, as we were all getting used to the software and the concept of a virtual workshop overall.

During and before the workshop, we made use of Kaltura Capture for the pre-recorded lectures. Plenary Kaltura Liverooms were set up, in addition to break-out Liverooms for the individual sessions. We encouraged teams to make use of these liverooms in order to create an open atmosphere where team members could once in a while join the discussions of other groups. In practice, this was hard to get to work, as it felt a bit awkward to suddenly appear

and ‘eavesdrop’ in the midst of another team’s discussion. We set up Slack channels to encourage interaction and communication which was very popular. We have since heard that new videoconferencing innovations such as Sococo and Networkapp now help to make the experience somewhat more similar to attending a conference in person.

In the short-term, we plan to make the lectures publicly available online, as a resource for students and researchers. In the long-term, we plan to integrate these into a textbook and online resource. The student participants have written reports on their research projects. Of these, selected projects will be invited to contribute detailed, hands-on tutorials for the book, based on the work they have done during the workshop. In weekly meetings the organizers are working out the details and planning the next steps.

Lorentz Center (distant and online) Support

The Lorentz Center team did a tremendous job in supporting the development of this workshop. At the time of the workshop, virtual workshops were a novelty to everybody involved. Despite this, the Lorentz Center team already had some really good advice for us, e.g., to work with synchronous and asynchronous events and to make optimal use of synchronous time. We all had to invent a lot and this worked out really well with only minor mishaps, of which the main one (the public lecture had to be postponed by one day) was entirely out of control of everybody involved – a Kaltura-server problem in the US. One small piece of advice/idea we would have is to send participants a small ‘welcome package’, e.g., consisting of an LC name badge, a pen, a notebook and printed program. Such a small ‘goodie bag’ could really make participants feel welcome and bring more of the LC ‘look-and-feel’ to the participants of a virtual workshop.

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