UNICOP - Unification of modern Coexistence theory and Price equation

Taking place from **5 to 9 September 2022** at **iDiv, Puschstraße 4, 04103 Leipzig** and via Zoom:

https://uni-leipzig.zoom.us/j/62003434869?pwd=WnBoSTBQVGlaeU10UFpwcXZPU1pndz09

Meeting-ID: 620 0343 4869, Password: 113009

Directions when arriving in Leipzig. Hotel information.

Directions (link tba) to the restaurants (bookings are made under the name of “Dietel”)

Sunday dinner at 6 pm at	
Monday, 5 September 2022	
9:00	Registration, welcome, intro Marten Winter
10:00	Kelsey, Victor, and Brad will work from Liepzig all week. Seb will participate remotely, and Lynn will participate remotely after Tuesday. All discussions will be recorded, whenever possible, since it is unlikely that Swati will be able to participate in any but the latest sessions of the day due to the time difference. If Swati is available asynchronously, we can benefit from her thoughts and feedback between work days. Brad will send Swati an update at the end of each day (early morning on the US west coast), giving her the opportunity to comment or contribute ideas before the next morning in Liepzig. **Introductions**: Everyone will (re)introduce themselves, their backgrounds and research interests, and what they are hoping to accomplish with this project. Brad will summarise the context and objectives from the project proposal and discussions from previous online meetings in a slide presentation and PDF.
11:00	*Coffee break and email check*
11:30	**Scope**: We will discuss what is and is not relevant to the objectives of UNICOP, with particular focus on the flow chart of the proposal (page 4) as a starting point. Victor's expertise will be especially important here, and it will be useful to start with a discussion led by him on what a generalisation sketch is, and the role of a generalisation sketch in science. This discussion will naturally lead to the topic of how the objectives of UNICOP relate to eco-evolutionary theory (i.e., the relationship between the lower and upper box in the proposal figure). **Aim**: Clearly define what a generalisation sketch is and how it would relate to specific eco-evolutionary models and existing theory. What would this look like if it already existed? **Output**: Brad will take notes, potentially including the development of a more detailed proposal figure, all of which might be revised to form text for an eventual manuscript.

12:30	*Lunch*
13:30	**Context**: Having established our objectives and the relevance of a generalisation sketch, we will move on to discussing the current state of the art in eco-evolutionary theory. *It would be good for all of us to come prepared with our own reflections* (e.g., a paragraph or a few bullet points) on how synthesis between ecology and evolution is currently achieved in models in the literature, many of which were written by group members (expertise of Lynn, Seb, Swati, and Kelsey will be especially relevant here). **Aim:** Establish how, and to what extent, conceptual synthesis is achieved in current theory linking eco-evolutionary dynamics, and how synthesis differs from foundational theories of ecology and evolution separately (e.g., Price equation unifying foundational equations across evolutionary sub-disciplines). **Output**: Victor will take notes, with the idea in this case of having a summary written by the person with the most expertise in conceptual synthesis to highlight the most relevant ideas. Notes will include, as best as possible, identification of any holes or redundancies in existing theory. Models discussed by the group will be organised to support the text of a manuscript.
15:30	*Coffee break and email check*
16:00	**Basics**: With the state-of-the-art synthesised in the early afternoon, we move on to building the foundations for establishing what is axiomatic in evolution & ecology. Brad will lead a whiteboard activity to list the most basic assumptions necessarily found in all ecological, evolutionary, and eco-evolutionary models. Each proposed assumption will be critically analysed to evaluate whether or not it is truly fundamental (e.g., population variation of some entity 'z' may be fundamental to all evolutionary models, but this entity could be instantiated by quantitative traits or discrete alleles) and necessary (e.g., sexual reproduction might be commonly modelled, but is not required for ecology or evolution). **Aim**: Identify assumptions common to all eco-evolutionary models and begin dissecting these assumptions to identify what is foundational. **Output**: Lynn will take notes, which will include a list of model assumptions. A table and/or Venn diagram will be created with assumptions shared between or exclusive to ecology and evolution. The table might eventually be used as a manuscript figure, but the initial idea is to focus on isolating and mapping out key assumptions.
17:00	End of meeting day. Brad will send an update to Swati. If Swati is able, then she could comment on our progress and provide any feedback, and perhaps try to use our output to help get started on the Critical analysis (see below), specifically outlining ideas to recover ecological equations from first principles.
18:00	Dinner at

Tuesday, 6 September 2022

09:00	**Candidates**: Building off of our work from Monday afternoon, we will continue

	our critical analysis of assumptions until we are able to propose a draft of candidate axioms underlying fundamental equations of ecology and evolution. The set of axioms should be fundamental in the sense that any possible eco-evolutionary model must include all of them. **Aim**: Build a list of statements that are true for all eco-evolutionary systems, separated into those applicable to ecology, evolution, and joint models. **Output**: Kelsey will take notes, and we will produce a draft list of axioms.
11:00	*Coffee break and email check*
11:30	**Reflect I**: In the brief time preceding our meeting with Luise, we will step back and reflect on our current progress. We will specifically assess what we have learned from the first day and a half and decide if any adjustments need to be made. If everything is on track, or if some novel insights have already been generated, then we can think about how the output content mentioned above might form the basis of a paper (e.g., a perspective, or note). **Output**: Brad will take note of any ideas or decisions made.
12:15	Reimbursement Q&A with Luise, please bring your documents
12:30	*Lunch*
13:30	**Critical analysis I**: Here we will begin to build upon the axioms that we identified by attempting to recover the Price equation and Chesson's version of Lotka-Volterra (or perhaps, less ambitiously to start, an exponential growth equation with density dependence) from first principles. It might make sense to split up into groups, with those of us who have more experience with the Price equation in one group (e.g., Victor, Lynn, and Seb), and those with a bit more experience with community ecology in the other (e.g., Kelsey, Brad, and Swati). This isn't necessary though, especially since there is a lot of overlap here in everyone's experience. It might be more sensible for all of us to start with the Price equation, which will probably be the lower hanging fruit.
15:30	*Coffee break and email check*
16:00	**Critical analysis II**: In the later afternoon, we will continue with our attempt to recover fundamental equations in ecology & evolution from first principles. By this point in the afternoon, we can hope to reconvene (if in groups) and be able to summarise how foundational equations of evolution and ecology can be derived from our axioms. **Aim**: Demonstrate how to recover the fundamental equations of ecology and evolution from first principles. **Output**: We should be able to have two mathematical derivations, which will greatly contribute to the main objectives of this project and potentially be used in a future paper. Brad will collect progress made in the form of notes, sketches, or summaries, and pass these on to Swati.

17:00	Sightseeing tour of Liepzig (to be confirmed). Lynn will be leaving Liepzig at this point (or sometime during the day) and will finish the meeting remotely.
	Dinner at restaurant

Wednesday, 7 September 2022

09:00	**Synthesis**: Here we will begin the attempt to derive unknown results from the axioms established the previous day. To do this, we will first consider the range of possible approaches that could be used. The Price equation has been formulated and expressed in different ways (e.g., statistics, geometry, information theory). Recent work, for example, has shown the fundamental connection between the general form of the Price equation and d'Alembert's principle of physics (Frank, SA. 2015. *Entropy*). Having rederived fundamental equations already, if all has gone well, then we should be in a position to think about what the best formal approach might be to derive results that acheive a synthesis between ecology and evolution. Each of us can bring our expertise to considering different approaches (e.g., Victor, Swati, and Brad might be best positioned to propose approaches, while Kelsy, Seb, and Lynn might be more able to evaluate their potential for success), but the objective is to focus broadly and explore different potential avenues to derive new results. **Aim**: Propose and critically evaluate different potential approaches to deriving results from fundamental axioms. **Output**: Ideally, we will decide on one approach for deriving new results, and be able to provide clear reasons for what it is the best of available options. Notes from this section will be directly applicable for deriving new results and might be useful for a future manuscript.
11:00	*Coffee break and email check*
11:30	**Reflect II**: In the brief time before lunch, we will again step back and reflect on our current progress. A specific goal here is to decide whether or not we are ready to move on to looking at the structure of a unifying equation in the afternoon, or if it is necessary to instead focus more time on fundamental axioms, recovering existing results, and synthesis. **Output**: Brad will take note of any ideas or decisions made.
12:00pm	*Lunch*
13:00	optional: iDiv seminar series
14:00	**Structure**: In our proposal, we reasoned that the Price equation is the logical starting point for a foundation of fundamental equations in ecology and evolution. Entities in the Price equation are flexible (i.e., they can represent individuals, alleles, etc.). The recursive nature of the equation allows for multiple levels of entities, which allows processes such as selection to be defined at multiple scales of biological organisation (e.g., population level and

	within-individual), separated into different equation terms. For a successful unification, we need to figure out the entitites, scale, and terms at which we will conceptualise population change. It might be, e.g., that unification of ecological and evolutionary processes from first principles will require an expression of the Price equation that includes more than two terms, and/or describes change over more than one scale of biological organisation (e.g., species and individuals). In this session, we will attempt to resolve these issues, assuming that they are not self-evident from our work in the morning (which seems unlikely). **Aim**: Determine appropriate entities and scale of organisation for a unifying equation of ecological and evolutionary change. **Output**: We hope to resolve the structure of a unified equation, including how such an equation relates to the Price equation, how biological entities are to be represented (e.g., species and individuals), and what terms are needed. Notes from this section will be directly applied to addressing our fundamental goal and be used in a future manuscript.
17:00	End of meeting day. Brad will collect notes from Synthesis and Structure and send them to Swati, who could contribute insights for the next day's work.
18:00	Dinner at

Thursday, 8 September 2022

09:00	**Derivation I**: Having established axioms, decided on an approach, and identified the best structure, we will begin the process of deriving the logical consequences, and ideally a unified equation. This will involve a lot of work on the whiteboards, and depending on the outputs from previous days, might be best attempted individually or in smaller groups before sharing ideas and approaches. The ideal result of this kind of exploration would be a formal equation (or even a set of inter-related equations) between evolution and ecology that is universal, but the first step is to use the work of the past three days to demonstrate some novel result(s) of broad relevance. **Aim**: Derive novel results from established axioms, synthesis, and structure. **Output**: All attempts at deriving novel results, which will inevitably include errors and dead ends, will be recorded as notes. Any avenues that look like they might lead to exciting breakthroughs will be recorded for Derivation II.
11:00	*Coffee break and email check*
11:30	**Reflect III**: In the time before lunch, we will once reflect on our current progress. If some novel result has not been achieved, then are we likely to do so with the time we have left in the week? If this appears unlikely, we could consider whether or not it would be better to draft a manuscript from what has been acheived to write up as a perspective or note. If we believe that we are close to a breakthrough, then we might prefer to continue through this section and the next. If we have already discovered some theoretical novelty

	of importance or interest, then here we can discuss our approach to writing. **Output**: Brad will take note of any ideas or decisions made.
12:30	*Lunch*
13:30	**Derivation II**: This will be a continuation of the morning's work. Depending on the outcome of our reflection prior to lunch, we might decide to either continue working on achieving a novel result, or we might instead attempt to work out a plan to draft what we have as a manuscript.
15:30	*Coffee break and email check*
16:00	**Dissemination**: Regardless of where we are in terms of progress, here we can discuss what results from the week could be used to draft a manuscript. If at all possible, a very initial outline of the manuscript can be created, and we can work out the contributions from group members. **Aim**: Draft a plan for writing up a manuscript. **Output**: Manuscript outline.
17:00	End of meeting day. Brad will summarise and send notes to Swati.
18:00	Dinner at restaurant

Friday, 9 September 2022

09:00	**Planning**: We can use this time to further plan for a manuscript, the next UNICOP meeting, and what we will do in the intervening time. Unless we are particularly close to some kind of a breakthrough, this is probably a better use of our time. If we have not accomplished as much as we had hoped, then we might need to reconsider our expectations and what will be most productive in future meetings. If we have exceeded our expectations, then we might likewise want to consider branching out beyond our initial goals. **Aim**: Develop a concrete plan for what to do in the next meeting, and in the intervening time.
11:00	*Coffee break and email check*
11:30	**Outline**: If there is time before Kelsey, Victor, and Brad need to prepare to leave Liepzig (checkout is listed at 10 SEP), then we can use this time before lunch to fill in the outline of an initial manuscript or get the ball rolling with some writing or reference organisation.
12:30pm	Lunch

13:30	**Writing**: This will be reserved for either writing (e.g., begining an introduction to a manuscript) or continuing to attempt a derivation of novel results from the previous day's efforts, whichever option is most likely to be productive with the remaining time that is left. This activity can be done independently if necessary, or with a reduced group, if some members need to prepare for travel. Any remaining task that requires, or would benefit from, having more than one of us in the same room should take priority here. We will also use this time to summarise the events and progress of the entire meeting, which will later be written up as a formal report. **Output**: Notes for a final report on week 1 progress.
15:30	*Coffee break and email check*
16:00	**Summary**: Any remaining questions or loose ends should be tied up at the end of the day before the end of the last meeting day.
17:00	End of meeting day
18:00	*Dinner at restaurant*

Participant list

First name	**Name**	**Institution**	**Email**
Alexander (Brad)	Duthie	University of Stirling	alexander.duthie@stir.ac.uk
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Kelsey	Lyberger	Stanford University	lyberger@stanford.edu
Swati*	Patel	Oregon State University	patelswa@oregonstate.edu

* Remote participation