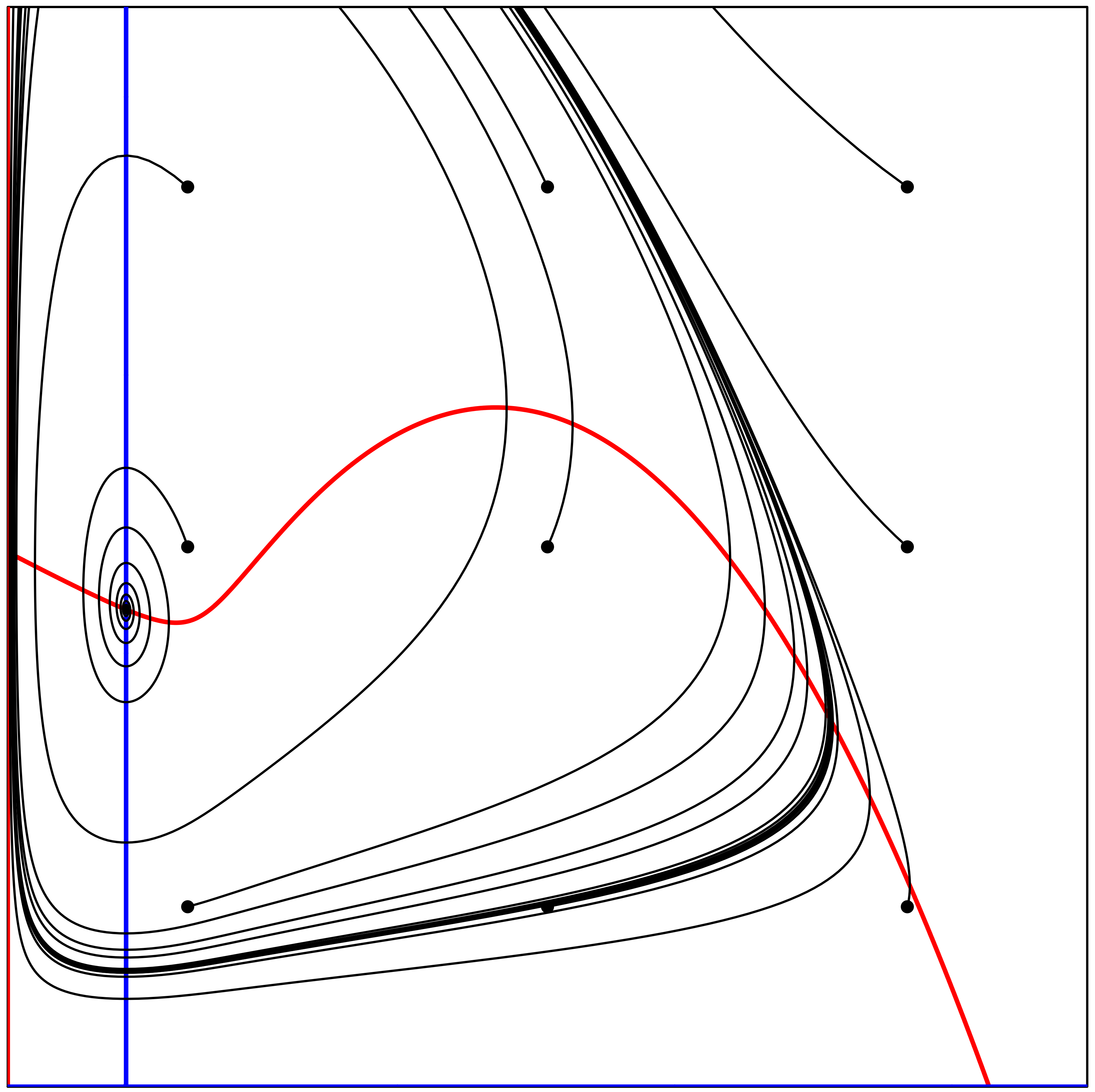
Biological Modeling of Population Dynamics 2024



Rob J de Boer, Theoretical Biology & Bioinformatics

Utrecht University

Aim of this course

Learn to use mathematical models as a tool for investigating biological questions

Learn to develop and analyze models (second hour)
Phase planes, steady states, stability, bifurcations, numerical integration.
Both on paper and with a computer (R).

Learn to rigorously interpret results from a mathematical model

Focus on **populations** (cells, prey & predators, bacteria, viruses, molecules)
Not on neurobiology, space, signaling networks, ….

General program

Mondays

13:15-15:00 Lecture and 15:00-17:00 Practical

Tuesdays & Thursdays

9:00-11:00 Lecture,11:00-15:00 Practical, 15:00-17:00 Self Study time

Try to read the book beforehand. Watch afterwards if necessary

https://video.uu.nl/channels/#2024-2-v-b-b2thec05

Practicals

Make exercises in small groups. Bring laptop.

Ask for help from TAs! Maarten Wunderink & Vince During

Structure of the course

First 6 weeks Math-reader and the BM-book
Last lecture and practical on Thursday Dec 19.

Exam in week 7 (on Thursday January 9).
Open book exam for math-reader only.
After the exam the master students leave us

Every week we jointly make a model during a lecture
Every two weeks groups hand in a report of a computer exercise (R markdown)
Bring your laptop to the practicals (and install Grind)
Every Thursday afternoon the TAs discuss one of the questions

Week 8-10 bachelor students work on a project and attend seminars.
Week 10: open book exam and presentation of project (in English)

Public home page

tbb.bio.uu.nl/rdb/bm/

Settings | dec | Editorial Manager® | dominant | pu | Axis labels in R plo... | tbb.bio.uu.nl/rdb/li...

Biological Modeling 2024

Reading | Viewing | Modeling | Info | Contact

Homepage Biological Modeling

The course Biological Modeling is given to Biology undergraduates with a minimal background in mathematics. The aim is that students learn to develop models defined as systems of ordinary differential equations (ODEs), and learn to interpret these models by finding steady states, phase plane analysis and computer simulation.

Learning goals:

- understand biological processes using mathematical models
- recognize and master classical mathematical models
- develop novel mathematical models from scratch
- simulate mathematical models on a computer
- be able to linearize models and apply local stability analysis (Jacobi matrix)
- be able to apply concepts like hysteresis, chaos, periodic behavior, complexity, attractor, and eigenvalue.

Theoretical research plays an important role in modern biology. The course covers a large number of mathematical models to show how one can describe and better understand the dynamics of biological populations. Examples of this population dynamics are: ecological food chains, epidemiological models, bacteria infected by phages, and populations of cells. Students are made familiar with the development and the analysis of mathematical models. After this course, mathematical models should no longer be considered a "black box". Results obtained by modeling can be critically evaluated based on the assumptions, the complexity, and exact equations of the model. In order to be able to determine the stability of equilibrium we cover a number of mathematical concepts: matrix, eigenvalue, linearization, partial derivatives, Jacobi matrix and complex numbers.

...urse, several mathematical models are developed from scratch. By deducing models from simple biological

.bio.uu.nl/rdb/bm/videos.html

Information

- Readers
- Introduction to R
- Formula sheet
- BM videos
- Math videos
- Tutorials
- Slides
- Models
- Projects
- Osiris Ba
- Osiris MSc
- ULearning

ulearning home page

Week 1: Making models and doing math

This week we will alternate between modeling (the BM book) and math (the math book).

- Monday 11 Nov Lecture 13:15-15h in BOL-0.204: Introduction
- Practical 15:15-17h in MIN-2.02: Questions & tutorials
- Lecture recording & Clips
- Tutorial: Nullclines and phase plane analysis
- Tutorial: Algebra
- Tutorial: Sketching functions

Math and Tutorials

Crash course into eigenvectors and eigenvalues required for stability analysis

Understanding concepts more important than math skills

Several tutorials to refresh your math skills (videos with **script**):

https://tbb.bio.uu.nl/rdb/bm/videos.html

Sketching functions with free parameters

Solving equations composed of variables and free parameters

Sketching nullclines and vector fields in phase spaces

Grind: R-script to solve and fit ODEs and to perform phase plane analysis

You are all supposed to know some R:

A (very) short introduction to R

Paul Torfs & Claudia Brauer

Install R and RStudio on your own device

Read the first pages of the Grind tutorial (read it again while doing a project)

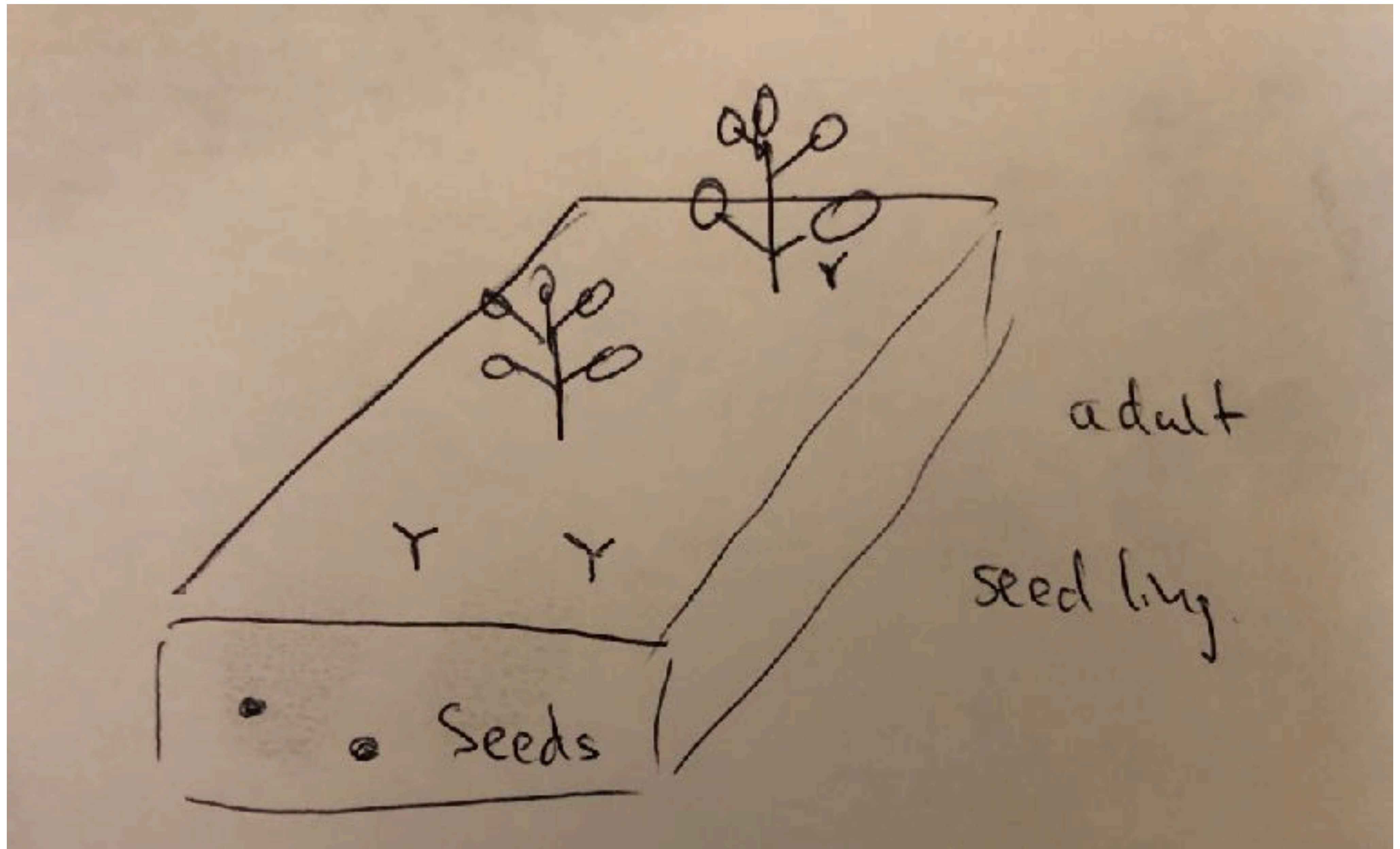
Install the required libraries (once). Source grind.R before you start (each time).

We do provide a **Mathematica** notebook on analyzing the Lotka Volterra model (Wolfram alpha).

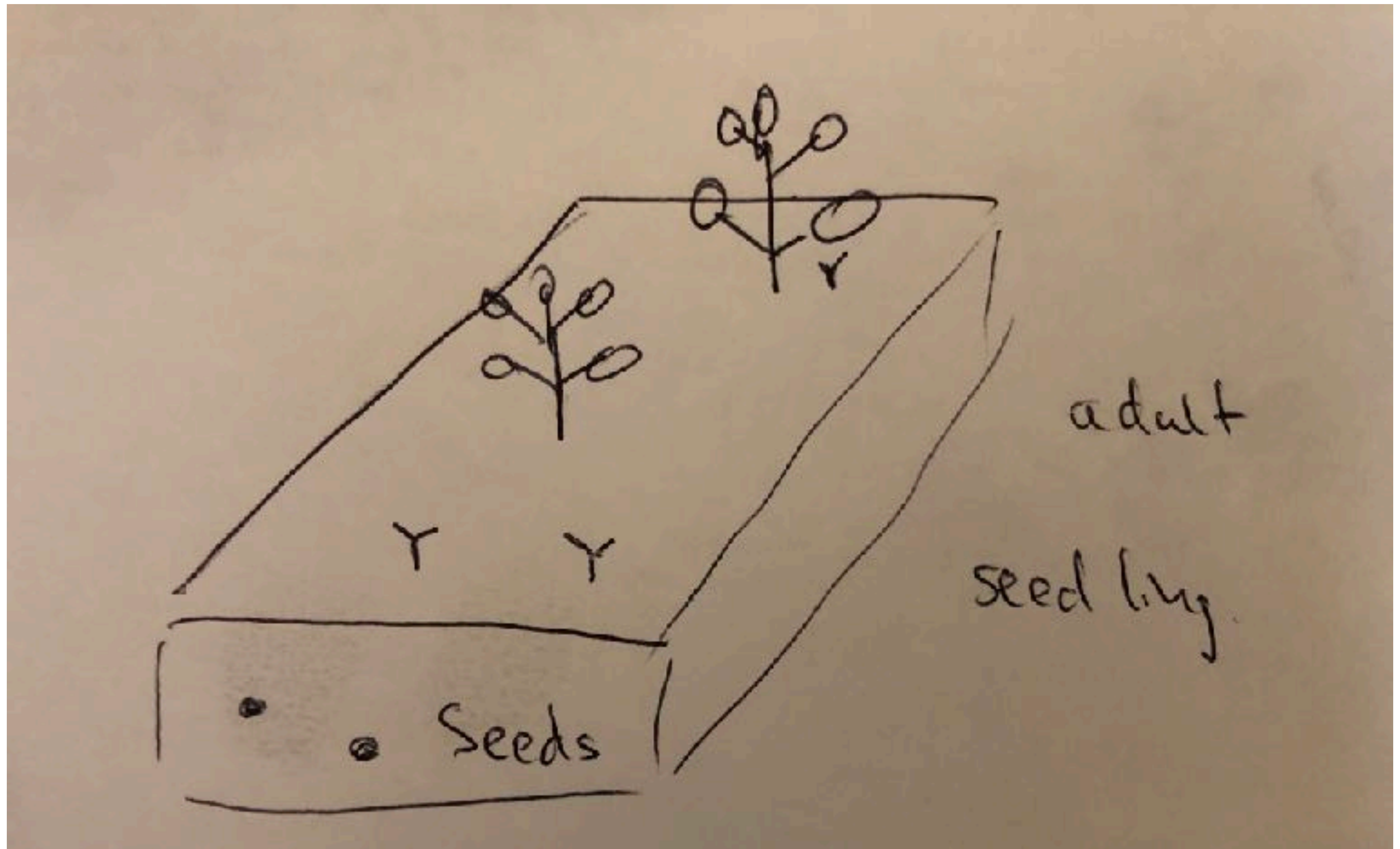
Make a model

Question 13.1. Seedlings over-shadowed by adult plants
Consider a field in which the seeds of one particular plant species are sprouting from a large slow seed bank. The seeds in the seed back are so long lived that the production of novel seeds by the current population hardly matters. On a daily basis a few seed sprout from the soil to form a small seedling that either dies or matures to become an adult plant (we ignore seasonality). Adult plants die (and produce seeds), and have to be replaced by novel seedlings that successfully mature. Since adult plants are larger than the small seedlings, seedlings growing under the cover of adult plants will receive less sunlight, and hence mature slower than those that directly exposed to the sun. Make a natural model for the number of seedlings and adult plants in the field.

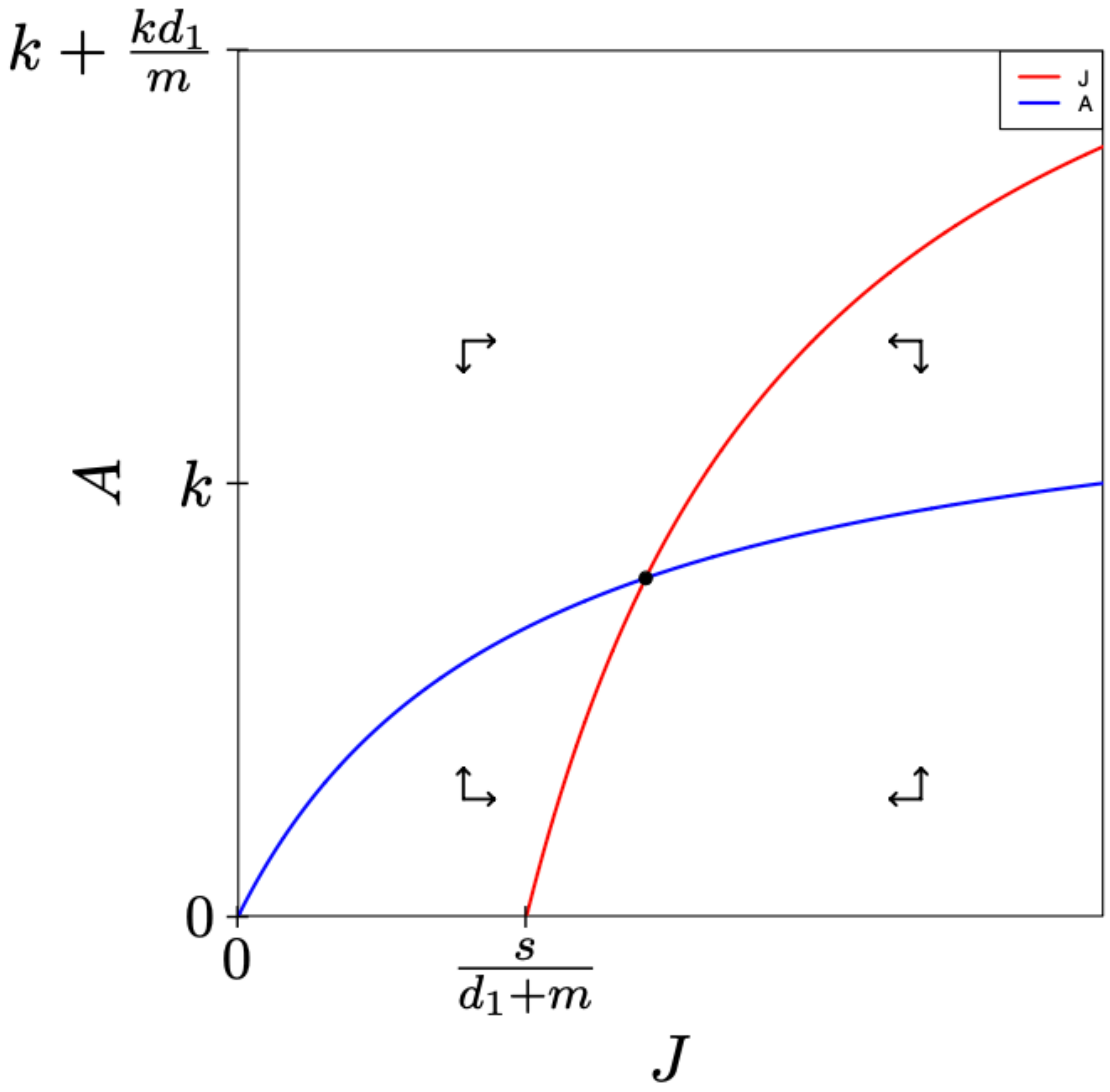
First define variables, processes, and then interaction functions

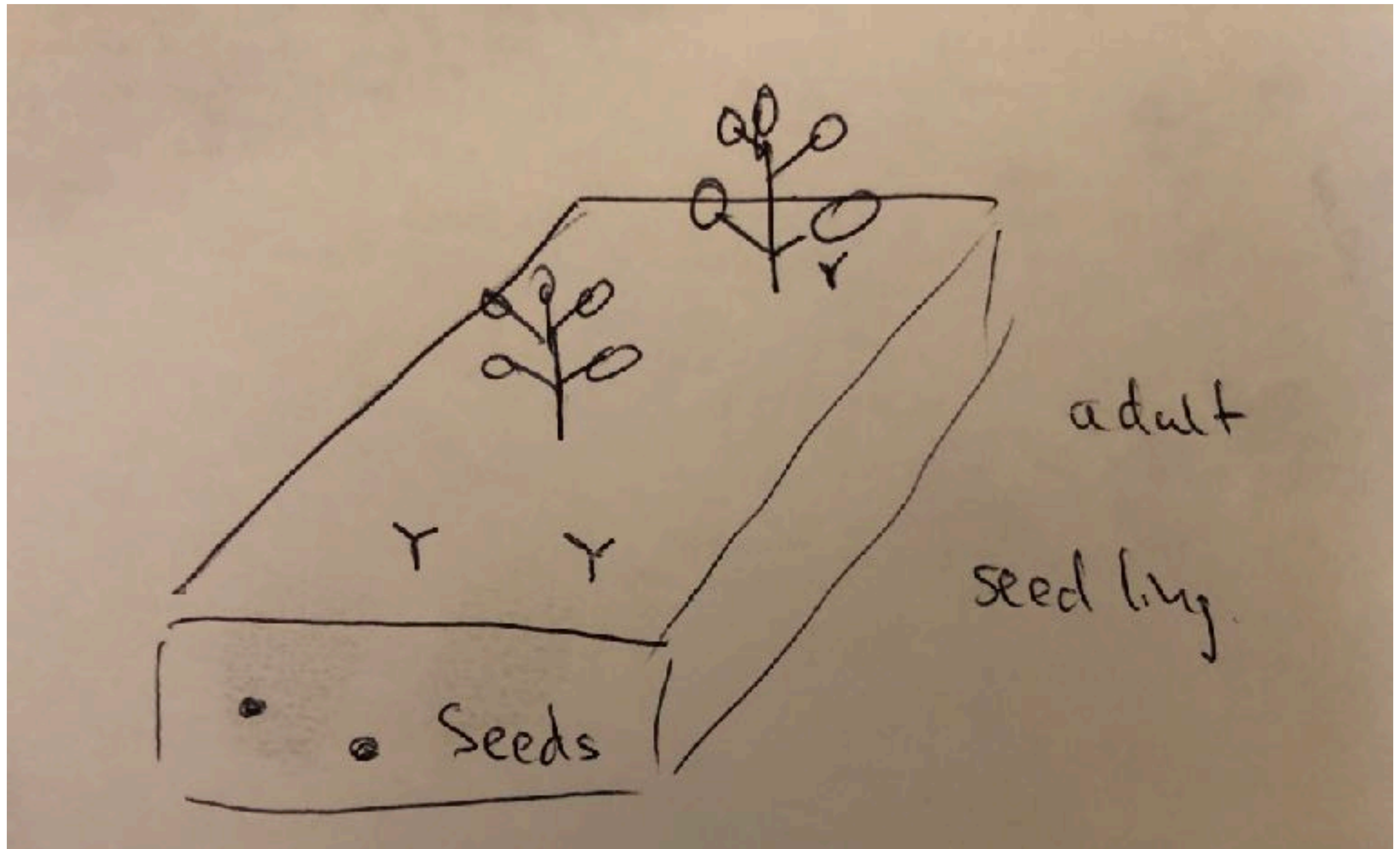


First define variables, processes, and then interaction functions



Question 3.12. Seedlings over-shadowed by adult plants
Figure made with the model `seedling.R`:





Similar models?

Progenitors of red blood cells (RBC) in the bone marrow.
Release of RBC into the circulation depends on oxygen levels (EPO),
i.e., on the concentration of circulating RBC.

Thus high RBC (adults) levels repress formation of adults from progenitors (seedlings)

Progenitor T cells maturing in the thymus, and emigrate into periphery.
Successful entry into peripheral pool depends on the pool size.

`Ecological' models or thinking applying to populations of cells (and molecules)