Welcome to the bachelor and master course Biological Modeling. Due to the corona crisis the course will this year unfortunately be given online in MS-Teams. This guide will help you finding the materials you need to study on each day of the course. This guide will be updated frequently during the course: keep reading it from [tbb.bio.uu.nl/rdb/bm/StudyGuide.pdf](tbb.bio.uu.nl/rdb/bm/StudyGuide.pdf) (check the date in the title).

The first week we will cover most of the ‘Matrices Linearization and the Jacobi matrix’ book (hereafter called the ‘math-reader’, and during weeks 2–6 we will cover most of the ‘Biological Modeling of Populations’ book (hereafter called the ‘BM-book’). These books can be found on [tbb.bio.uu.nl/rdb/books/math.pdf](tbb.bio.uu.nl/rdb/books/math.pdf) and [books/bm.pdf](books/bm.pdf) respectively. Hard copies will be sold the week before we start (see below). In week 7 we will have the main exam (hopefully on campus) and in week 8-10 bachelor students will work on a project (and have an additional exam on Monday, November 2). The master students attending this course will not do a project, and most of them will also have to attend the Introduction Life Sciences (ILLS) course of the Graduate School Life Sciences (GSLS) during the first week (which means that they will partly have to design their own schedule from the double online education that week).

The basic scheme during the first 6 weeks will be an online practical from 15–17h on Mondays, and a question hour from 11–12h, and a practical from 12–15h on Tuesdays and Thursdays. Practicals are coordinated by Peter de Greef (p.c.degreef@uu.nl). Before the practical or question hour starts you are supposed to study particular sections from the books (as indicated below). With ‘study’ we mean that you should read and aim to understand these sections. In case some of the material is too difficult you can watch the accompanying video, in which we re-derive all the math in each section in a step-by-step manner. These videos are provided on the general website of the course [tbb.bio.uu.nl/rdb/bm/](tbb.bio.uu.nl/rdb/bm/) in the subdirectories [clips/bm](clips/bm/) and [clips/math](clips/math/) respectively, and have names corresponding to the chapter and section numbers in the two books. Dutch students can also watch the lectures that were recorded ‘live’ last year (in Dutch) on the following website: [lecturenet.uu.nl/Site1/Catalog/catalogs/thec-2019-2020](lecturenet.uu.nl/Site1/Catalog/catalogs/thec-2019-2020).

To refresh your required background for this course we provide links to a few tutorials in the form of videos with an accompanying pdf-file (called the script) on the website [bm/videosE.html](bm/videosE.html). There are tutorials on ‘Sketching functions with free parameters’, on ‘Solving equations composed of variables and free parameters’, and on ‘Sketching nullclines and vector fields in phase spaces’. If you lack experience in any of these topics please study these tutorials before the course starts (or during the first week). For at least some of you, reading the script will be more rewarding than watching the videos.

During the question hour we will form one large group in MS-Teams. In the chat-panel you can pose or ‘like’ questions, and we will provide answers to the questions that are ‘liked’ most. During the practicals you will work in small groups, and a group can post a question in the chat-channel. One of the teaching assistants will then join your group to help your team finding the answer to the question. The groups for the practical are formed beforehand. If you would like to join another group, please email Peter de Greef (p.c.degreef@uu.nl).

All of this information is also available via Blackboard. The books can be ordered from this website, [onlinesales.uu.nl/modeleren_wiskundereader_2020](onlinesales.uu.nl/modeleren_wiskundereader_2020) and can collected at the office of Rob Welschen, Koningsbergergebouw room 3.24, on Monday 24 August from 10-12h, and on Monday 31 August from 10-12h. Alternatively, the books can be downloaded from the general website of the course [tbb.bio.uu.nl/rdb/bm/](tbb.bio.uu.nl/rdb/bm/) (or from Blackboard).
Schedule

**Week 1: Monday August 31**
13:15–15h Lecture: we will start with an online lecture that will end with us together developing a model for a seed bank with sprouting seedlings and adult plants, and subsequently analyzing this model by phase plane analysis. This is an introduction to the major aim this course: we hope you will learn how to devise and analyze novel mathematical models for biological questions. This lecture will be recorded in MS-Teams and can be accessed via these two links:
1. web.microsoftstream.com/video/4d95840b-f369-4251-9099-724db88663b8
2. web.microsoftstream.com/video/ef352d70-6162-45b2-958c-1e312e0c6470

15–17h Practical: ask questions about the lecture. If you lack experience in sketching functions or solving equations, please study the corresponding tutorial(s).

**Tuesday September 1**
Before 11h: study the material on matrices and eigenvalues described in Chapter 2 of the math-reader (three videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make the exercises in Section 2.5 from the math-reader. If you lack experience in sketching functions or solving equations, please study the corresponding tutorial(s). You can obviously ask questions about these tutorials.

Afternoon: Reread the math-reader, study the tutorials you need.

**Thursday September 3**
Before 11h: study the material on matrices and eigenvalues described in Chapters 3 and 4 of the math-reader (one video and two videos, respectively). This covers all of the essential material on the Jacobi matrix, as Chapter 5 is a wrap up, Chapter 6 is an example, and Chapter 7 on complex numbers will probably be skipped this year. If you need further explanation attend the online question hour from 11–12h. The question hour was recorded: web.microsoftstream.com/video/89454931-2e15-4cf6-b86f-01dd76d2319e, note that the last half hour no more questions were asked.

12–15h Practical: make the exercises from Chapter 3 and 4. Subsequently study Chapter 5 from the math-reader (two videos). Make the exercises of Chapter 5.

Afternoon: study Chapter 2 from the BM-book (students that have attended our first-year Systems biology course will hopefully remember this introductory chapter, others can get help by watching the accompanying two videos). Study a tutorial and/or study Chapter 6 from the math-reader (one video).

**Week 2: Monday September 7**
Before 15h: study Sections 3.1 and 3.2 from Chapter 3 on density dependence in the BM-book (first 3 videos).

15–17h Practical: start with the exercises of Chapter 3 (questions 3.1–3.3). After completing question 3.3, make question 12.1 on fishing Herring (for help on installing and running Grind read the first page of Chapter 12 in the BM-book, and/or watch the videos on clips/grind).

**Tuesday September 8**
Before 11h: study Sections 3.3 to 3.4 from the BM-book (last 2 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make exercises 3.1–3.6 of Chapter 3 (make Grind question 12.1 after completing
When you are done with these exercises, sample the exercises you find most interesting from the extra questions 3.7-3.12 and/or make Grind question 12.2 (one video). Question 3.9 (regression to the mean) has an accompanying video. Question 3.12 (seedlings) is about the model we made for seedlings sprouting from a seed bank. Grind question 12.2 is on fitting the classic Gause data (parameter fitting is explained in in paragraph 14.7 and in an accompanying video).

Afternoon: self study time to catch up on the exercises. If you lack experience in phase plane analysis, please study the ‘nullcline’ tutorial.

**Thursday September 10**

Before 11h: study Chapter 4 on stability from the BM-book (4 videos). If you need further explanation attend the online question hour from 11–12h. The question hour was recorded: [https://web.microsoftstream.com/video/4c3738f3-0814-45b2-b5aa-08eaa15ffce0](https://web.microsoftstream.com/video/4c3738f3-0814-45b2-b5aa-08eaa15ffce0).

12–15h Make the exercises of Chapter 4. Question 4.3 (Whales) is an exercise to develop a novel model from scratch. Read the story in Question 13.2 and try to develop an intuitive simple model. Sketch graphs for how the relevant process like birth, death, and finding a mate depend on the whale density, and translate these graphs into simple functions (one video).

When you are done with the exercises of Chapter 4, sample from the extra questions 3.7-3.12 (one video) and note that 3.12 was made during the second lecture on Monday August 31 (see the link above), and/or make Grind question 12.2 (one video), or 12.4 (Smith Martin model: one video).

Afternoon: self study time to catch up on the math-book (Chapters 1–6), the tutorials, and the BM-book (Chapters 1–4).

**Week 3: Monday September 14**

Before 13:15h: study Section 5.1 on consumption from the BM-book (first 4 videos).

15–17h Practical: during the practical start with the exercises of Chapter 5 (if you have trouble making the Kingfishers model watch the video). If you lack experience in phase plane analysis, please study the ‘nullcline’ tutorial.

**Tuesday September 15**

Before 11h: study Sections 5.2 and 5.3 from the BM-book (next 3 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: finish the exercises of Chapter 5.

**Thursday September 17**

Before 11h: study Chapter 6 on $R_0$ from the BM-book (4 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make the exercises of Chapter 6.

**Week 4: Monday September 21**

Before 15h: study Section 7.1 on the functional response from the BM-book (first 4 videos).

15–17h Practical: make the exercises 7.1–7.5.
Tuesday September 22
Before 11h: study Section 7.2 from the BM-book (next 2 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make the exercises 7.1–7.10.

Thursday September 24
Before 11h: study Section 7.3 from the BM-book (next 2 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make the exercises 7.1–7.10.

Week 5: Monday September 28
Before 15h: study Chapter 8 on modeling chains from the BM-book until Section 8.4 (first 3 videos): the section on kinetic proofreading will be skipped this year (but is very interesting: last video).

15–17h Practical: make the exercises 8.1–8.6.

Tuesday September 29
Before 11h: study Section 9.1 on competitive exclusion until the subsection on 3D nullclines (2 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make the exercises 9.1–9.3.

Thursday October 1
Before 11h: study the remainder of Section 9.1 (3D + QSSA) and Section 9.2 on the Lotka-Volterra competition equations (next 2 + 1 videos). If you need further explanation attend the online question hour from 11–12h.


Week 6: Monday October 5
Before 15h: study Section 9.3 and 9.4 on Tilman diagrams (3 videos). Section 9.5 on the 4D Jacobian will be skipped this year (2 videos) if you find this interesting first study the tutorial and videos on somewhat simpler Tilman diagrams on the website (clips/tilman). If you need further explanation attend the online question hour from 11–12h.

15–17h Practical: if you have time make the exercises 9.7–9.9, otherwise finish the exercises 9.1–9.6.

Tuesday October 6
Before 11h: study Chapter 10 on large scale systems (4 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make the exercises 10.1–10.4.

Thursday October 8
Before 11h: study Chapter 11 on bifurcations (5 videos). If you need further explanation attend the online question hour from 11–12h.

12–15h Practical: make all exercises.

Week 7: Monday October 12
**Thursday October 15**  
Exam: 13:30-16:30h in THEATRON.

**Week 8: Monday October 19**  
13:15–15h Lecture: introduction of projects in MS-Teams (bachelor students only). This lecture will be recorded in MS-Teams.

Work on your project during the rest of the week.

**Week 9: October 26–29**  
Work on your project.

**Week 10: Monday November 2**  
Exam: 13:30-16:30h in Educatorium GAMMA.

**Week 10: Thursday November 5**  
Present your group’s project in MS Teams.