Module title	**Modelling of Complex Systems**
Code	CO1
Degree Programme	Master of Science in Life Sciences
Group	Computation
Workload	3 ECTS (90 student working hours: 42 lessons contact = 32 h; 58 h self-study)
Module Coordinator	**Name**: Prof. Dr. Sven Hirsch **Phone**: +41 (0)58 934 54 44 **Email**: sven.hirsch@zhaw.ch **Address**: ZHAW Life Sciences und Facility Management, Schloss 1, 8820 Wädenswil
Lecturers	• Prof. Dr. Sven Hirsch, ZHAW • Dr. Simone Ulzega, ZHAW • guest lecturers
Entry requirements	• Students should have basic statistics experience at the bachelor level, including: descriptive statistics, correlation measures, probability distributions such as normal and binomial distribution, basics of probability theory. • Students should know fundamentals of ordinary differential equations as taught at the bachelor level. • Students will have to complete an entry self-test (Moodle) in advance of the module. Preparatory material is provided on the Moodle platform • Students will have to install a systems dynamics software and get acquainted with the software prior to the course (details will be provided on Moodle) • **See also information under "comments"**
Learning outcomes and competences	After completing the module students will be able to: • describe different aspects of system theory and assess where and how system theory is applied to real-world problems; • use a mathematical tool (Vensim) to model and simulate a dynamical system; • derive a system formulation from ordinary differential equations (e.g. chemical reaction); • perform parametric studies with the Monte-Carlo method and apply optimization techniques to fit model predictions to experimental findings; • model, analyze, justify and communicate a system autonomously.
Module contents	The course introduces basic mathematical tools and software used for the modeling and analysis of real-world systems in the context of life sciences. The following contents are taught in this course: • Introduction into system theory / system dynamics - What is a complex system? What is its purpose? - Overview and characterization of various systems (static/dynamical systems, discrete and continuous systems) - Introduction to mathematical models used for the modeling and analysis of systems, including differential equations. - Properties of linear, non-linear and chaotic systems - Qualitative methods for analyzing system models (graphs, feedbacks, active-passive Matrix, Vester's paper computer)

	• Introduction into tools and methods used for system analysis and modeling - Basic modeling using software tools (e.g. Vensim, Excel) - Control structures, Look-ups, data sampling, functions - Analysis of equilibrium and stationary states - Numerical integration methods - Introduction to stability analysis and convergence testing - Level of validity and detection of simulation-inherent errors • Advanced system dynamics techniques - Parameter optimization for fitting model behavior to experimental data - Monte-Carlo simulation to perform parametric sensitivity studies • Detailed case studies of systems and their modeling with examples from biomechanics, environmental sciences, biology, chemistry, industrial processes, and economics, e.g. plant dynamics, bacterial population behavior, drug reactions, or buyer/seller market dynamics • Practical communication and documentation of a model and of simulation results - argumentation and motivation of a model logic - visualization of the model structure and its behavior - formulation of hypothesis and testing by means of simulation
Teaching / learning methods	The course will be taught in short frontal sessions and by practical implementation sessions. The students will conceive and develop an own case study in a group work and will have time to work on the project in class under supervision.
Assessment of learning outcome	The students will develop an own model as a case study (practical study). The individual projects will be conceived and developed during the course (during the course two individual presentations are given by the student). The project will be finalized and documented after the module. 1. A report will be delivered one week after the end of the module (100%) 2. The final oral presentation is delivered during the course (pass/fail)
Format	7-weeks
Timing of the module	Autumn semester, CW 38-44
Venue	Blended learning format. Presence sequences take place in Olten
Bibliography	Course Book H. Bossel, Systems and Models, 2007, ISBN 978-3-8334-8121-5 Introductory material R. L. Flood, E. R. Carson, Dealing with Complexity: An Introduction to the Theory and Application of Systems Science, Springer, 1993 http://en.wikipedia.org/wiki/Systems_thinking D. Aronson, Overview of Systems Thinking, http://www.thinking.net/Systems_Thinking/OverviewSTarticle.pdf K. North, An Introduction to Systems Thinking, http://courses.umass.edu/plnt597s/KarlsArticle.pdf Important literature and lecture notes will be provided on Moodle

Language	English
Links to other modules	The concepts will handshake with the specialisation module ZHAW “Mathematical Modelling” and BECS4 “Optimisation Methods”
Comments	There is a participant limit in this module. Registrations will be considered as follows: 1. Students for whom BECS1 is a compulsory module 2. Students from the BECS-Cluster 3. Students who need the ECTS for the graduation in the semester concerned 4. The remaining places will be drawn by lot Whether participation is possible will be communicated by the end of week 37.
Last Update	18.04.2023