Introduction to Mathematical Biology

Possible Project Topics

Below you'll find a list of possible projects but please do not take the descriptions literally. If you like one of these topics, its best to find the most current research papers that apply.

Project 1 – Immunology

Research the immune system and then read and understand papers like, "The role of models in understanding CD8(+) T-cell memory" by Antia et al. in *Nature Rev Immul* 5(2):101-111, 2005. "A basic mathematical model for the immune response" by Mayer et al. in *Chaos* 5:155-160, 1995 and "Modeling Dynamic Aspects of the Immune Response," in *Theoretical Immunology*, Vol I by A. Perelson, pp. 167-188.

Project 2 – Tumor Growth

Learn about the biology of tumor growth, invasion, and metastasis, then read and understand papers like, "A Reaction-Diffusion Model of Cancer Invasion", by Gatenby and Gawlinski in *Cancer Research*.

Project 3 – Cancer Immunology

Research the immunological implications of cancer and cancer treatment. Read and understand articles like, "A Validated Mathematical Model of Cell-Mediated Immune Response to Tumor Growth" by de Pillis et al in *Cancer Research* 65, 7950-7958, September 1, 2005 or "Modeling immunotherapy of the tumor-immune interaction", by Kirschner D. Panetta JC in *Journal of Mathematical Biology* 37(3):235-52, 1998.

Project 4 – Cancer Chemotherapy

Research traditional and novel chemotherapeutic strategies for cancer treatment. Read and understand articles like, "Optimizing Drug Regimens in Cancer Chemotherapy by an Efficacy-Toxicity Mathematical Model", by Iliadis et al., in *Computers and Biomedical Research* 33:211-226, 2000, or "A mathematical model for cisplatin cellular pharmacodynamics" by Ardith W El-Kareh and Timothy W. Secomb in *Neoplasia* 5(2) 2003. .

Project 5 – Mendel and the Laws of Inheritance

Research the science of population genetics. Review the models in chapter two of "Mathematics in Medicine and the Life Sciences," by Hoppensteadt and Peskin and find other such models in the literature.

Project 6 – Diabetes

Research type I and II diabetes. Read articles like, "A Model of β -Cell Mass, Insulin, and Glucose Kinetics: Pathways to Diabetes" , by Topp et al. in *J Theor Biol* 206(4): 6-5-619, 2000.

Project 7 – Infectious Diseases I

Learn about leprosy and tuberculosis. Read and understand "Leprosy and Tuberculosis: the epidemiological consequences of cross-immunity" by Lietman T. Porco T. Blower S in *American Journal of Public Health*.

Project 8 – Infectious Diseases II

Research HIV, progression to AIDS, and current treatment strategies, then read articles like, "A model for treatment strategy in the chemotherapy of AIDS," by Kirschner D. Webb GF in *Bulletin of Mathematical Biology* 58(2):376-90, 1996.

Project 9 – Receptor/Ligand Binding

Read some of "Receptors: Models for binding, trafficking, and signaling," by Lauffenburger and Linderman. Chose a project from this book and relate it to a specific system.

Project 10 – Dynamical Diseases

Michael Mackey is a mathematician who works in the Dept. of Physiology at McGill University. A particular interest of his is feedback mechanisms which have long time delays. Learn some of the physiology and mathematics from Mackey's papers: *Dynamical Diseases* in Perspectives in Biological Dynamics and Theoretical Medicine and *Dynamical diseases and bifurcations: understanding functional disorders in physiological systems* in Funktionelle Biologie & Medizin.

Project 11 – Ventilation Volume and Blood CO_2

High blood CO_2 stimulates the brain to signal for deeper breaths which over time lower CO_2 levels. Research this feed back system. Leah Keshet discusses a simple model for this system on page 27 of her book *Mathematical Models in Biology*. Find more realistic mathematical models for this system and discuss their implications.

Project 12 – Modeling Blood Cell Production

Research hematopoiesis and read articles like, " Cyclical neutropenia and other periodic hematological disorders: A review of mechanisms and mathematical models." BLOOD 92: (8) 2629-2640 OCT 15 1998 .

Project 13 – Regulation of Blood Glucose via Insulin

Read about how blood glucose levels are regulated. Also read the section on modeling glucose-insulin kinetics in Leah Keshet's book pages 147-148. Go through problem 26 on page 158 to get started and read articles like the ones referenced on page 163.

Project 14 – A Computer Model of Schooling Fish

Read the article, "Analysis of the behavior and structure of fish schools by means of computer simulation" in Vol. 3 of *Comments on Theoretical Biology*. This is a perfect project to try some simple computer simulations yourself, though this is not required.

Project 15 – Fluid Dynamics and Biology

Read parts of the book *Life in a Moving Fluid* by Steve Vogel and develop a project out of this book. Vogel is a professor in the Duke Department of Zoology and is an expert on this subject. This project could be easy or hard depending on how much you want to go into the mathematics of fluid dynamics. Some background in physics is required for this project.

Project 16 – Blood Pressure Oscillations

Research the cardiovascular system and dynamic models by reading articles like *Gain-induced Oscillations in Blood Pressure*," by Abbiw-Jackson et al. in the Journal of mathematical biology.

Project 17 – REM Sleep Cycle

Research REM sleep and read articles like, "A limit cycle mathematical model of the REM sleep oscillator system", in *Am. J. Physiol.* 251(6 pt 2):R1011-29, 1986.

Project 18 – Gene Regulation

Research gene regulation, a classic example can be found in the eubacterium *E. coli* system. Read articles like, "Demand Theory of Gene Regulation I. and II." in *Genetics* 149:1665-1691, 1998.

Project 19 – HIV Vaccination

Research HIV vaccines and read articles by Sally Blower on this topic.