Comprehensive Course Syllabus

Pathophysiology and Biological Systems Modeling

Course Description:
It is widely understood that cells contain networks of thousands of biochemical interactions, the subsequent result of evolution selecting for the organisms that survive. Advances in experimental technology have shown that these biological networks have evolved in a specific way to perform essential functions. This kind of thinking is a tangential departure from traditional physiology by incorporating the biochemistry and physiology of biological systems to interpret the outcomes. In this course, students will learn how to build models of biological systems by examining the inputs, studying the interactions of the system with external and internal factors and finally predicting the possible outcomes of the system. Students will combine their understanding of biological systems with technology and programming to build their models, which will be represented by a combination of three-dimensional models, computer simulations and Arduino based tools of system measurement. Emphasis will be placed on the biochemical, molecular and physiological changes that control homeostatic cellular mechanisms and permit survival of the system. The final unit will be a compilation of student projects to demonstrate how the individual biological systems integrate to sustain the function of the whole organism with minimal expenditure of energy. Students will also reflect on how biological systems are designed to allow their essential function to be insensitive to the naturally occurring fluctuations in the system.

Instructor:

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Meeting Days, Time and Room(s)
TBD

Text(s) / Materials:
Pathophysiology made incredibly easy! (Incredibly easy! Series) 5th edition by Lippincott

Essential Content:
I. Introduction to Biological Systems Modeling – Transcription Model
This unit will discuss the different perspectives and methods of modeling biological systems, using transcription and translation as a model. Students will learn the dynamics of a system, model effects of inputs on outcomes and understand the numerous molecules that play important roles in maintaining the efficiency of the system and reducing unnecessary energy expenditure.

II. Introduction to Biochemistry, Molecular Biology and Physiology of systems biology

This unit will cover a basic understanding of biochemistry, molecular biology and physiology of biological systems. Students will learn how these forces work together to resist natural fluctuations and preserve function. Emphasis will be placed on development of the system from the molecular to organismal stage.

III. Modeling of the cardiovascular and respiratory systems

Students will learn the basics of the cardiovascular and respiratory systems, and demonstrate their understanding through a combination of 3-D models, including heart models, computer simulations and/or Arduino measurement tools. The output of the cardiovascular system serves as input for the respiratory system and vice versa, which makes for a more efficient circuit. Emphasis will be placed upon how the system maintains efficiency of function, when this efficiency fails (for example heart attack or pulmonary embolism), and what can be done to modify the system to restore functionality.

IV Modeling of the urinary/excretory and digestive systems

The function of the urinary/excretory system in filtering and purifying the output of the digestive system will be outlined in this unit. Students will create models of disease development based on biochemical and molecular changes and justify the known methods of fixing the problems. Students will model kidney failure and justify dialysis as a treatment based on the internal chemistry of the system.

V. Reflecting on the models/troubleshooting

Students will be provided time to reflect on the different models they have created and brainstorm different ways to troubleshoot or solve problems. There will be some time for this in between units as well, but this unit provides opportunity for discussion and interaction among students.

VI. Neural network processing and AI

This unit involves the study of neural networks and their role in coordinating multiple systems through hormones. Students will pick different topics to model and culminate the unit by presenting their findings to each other. Emphasis will be placed upon understanding the biochemical and physiological inputs and outputs involved in maintaining the neural networks. Artificial Intelligence will also be discussed, with students discussing/modeling different applications of AI in physiology.

VII. Arduino based modeling – Heart rate and blood pressure monitors

Students will build upon programming provided to them to build Arduino heart rate monitors and blood pressure monitors which they will proceed to use to measure their heart rate and blood pressure before and after exercise. They will then correlate their findings to the neural controls that are responsible for maintaining these functions.

VIII. Application of modeling to the organism as a whole

Throughout the semester, students will reflect upon how their individual systems play a role in the overall function of the whole system, but there will also be some time dedicated for brainstorming and discussions on this topic toward the end of the course before they start their final project. Students will learn the importance of each system individually, and also as a part of a bigger system, the whole organism. It is important to understand this concept before venturing upon the final project of the semester.

IX. Final project

The final unit will be comprised of student projects involving their choice of topics. An example for this unit would be the effect of various lifestyle changes (lack of diet and exercise) and biochemical factors (impaired kidney reabsorption) on the outcome of the renal system (possible kidney calculi or kidney failure). Students will also reflect on how biological systems are designed to allow their essential functions to be insensitive to the naturally occurring fluctuations in the system.

SSLS AND OUTCOMES:

IA. Students are expected to demonstrate automaticity in skills, concepts, and processes that enable complex thought by:

- *completing homework activities and assigned reading to support content,*
- *becoming adept at identified lab skills,*
- *learning how to model systems using computer simulations and building 3-D models*
- *demonstrating competence on quizzes, and*
- *applying content knowledge with novel scenarios and problems.*

IB. Students are expected to construct questions, forge connections and deepen meaning

- *informally in discussion groups, during set up and analysis of labs, and when observing data from experiments,*
- *while modeling systems in groups or pairs, and*
- *on formal assessments.*

IC. Students are expected to precisely observe phenomena and accurately record findings

- *through formative and summative assessments,*
- *through analysis and interpretation of data generated from lab experiments, and*
- *through demonstration of their models indicating structure-function integration*

ID. Students are expected to evaluate the soundness and relevance of information and reasoning

- *by evaluating sources for research papers,*
- *through analysis of experiments completed in lab, and*
- *through explanation of models of phenomena in biology.*

IIA. Students confront misconceptions

- *by completing pre-assessments,*
- *engaging in discussion in class, and*
- *completing a follow-up assessment to determine extent of resolution of misconceptions.*

IIIA. Students use appropriate technologies as extensions of the mind

- *through daily use of computers, including web sources and videos,*
- *by using the course website as a resource,*
- *by using computers to create graphical representations and perform other analyses of laboratory data, and*
- *through use of standard laboratory equipment.*

IIIB. Students recognize, pursue, and explain substantive connections within and among areas of knowledge

- *by studying the biochemistry behind the biology,*
- *by studying the connections between areas within biology, and*
- *by studying the connections between biology and mathematics/computer science*

IIIC. Students recreate models and systems in biology, such as evolution of cellular function, control of homeostatic mechanisms as well as modeling the relationship between structures and functions of biological systems, etc.,

- *with classroom discussion, projects, and activities,*
- *by building models of biological systems*
- *both informal and formal assessments.*

IVA. Construct and support judgments based on evidence

- *by laboratory exploration, constructing laboratory reports as well as identifying unknown concepts based on previous learnings.*
- *By building models and computer simulations and identifying structure-function relationships*

IVB. Write and speak with power, economy and elegance

- *By describing the processes involved in modeling and predicting outcomes based on external and internal factors*
- *By demonstrating understanding of applied Arduino technology and computer simulations through discussions*

VB. In order for students to make reasoned decisions which reflect ethical standards, and act in accordance with those decisions, students

- *are made aware of what plagiarism is, its ethical implications, and repercussions of plagiarizing,*
- *are made aware of the scientific and ethical significance of accurately representing data (vs. not skewing data to fit expectations), and are assessed for the authenticity of written work and the efficacy of analysis of lab experimentation.*

Instructional Design and Approach:
This course helps to fill a gap in our curriculum addressing an integration between math and science with respect to modeling systems. The course also provides opportunities for students to learn how to model biological systems and understand their efficiency of function in the face of natural fluctuations. This is also a cross disciplinary course, as the topics will require integration of understanding of the system from a biochemical, molecular, physiological and mathematical background. Connections between the systems modeling studied in this course will help students integrate the different components of a system as a whole, and understand how neuron processing activates or deactivates systems based on need in order to save energy. The focus is to move away from traditional formal assessments to hands-on assessments that require articulation of applied understanding.

In this course, students will engage with the material in a variety of ways. They will initially gain a basic understanding of the core concepts of biochemistry, molecular biology and biological systems, then get to work building models of biological systems. They will spend a significant amount of time creating 3-D models, computer simulations and Arduino based measurement tools that demonstrate their understanding of homeostatic controls of cellular mechanisms. After building the individual models, students will spend time integrating these models into a whole organism by expanding their models to represent how system function is preserved in the face of fluctuations (natural state), and how, when this is not possible, diseases or pathological conditions are manifested as noticeable symptoms.

Student Expectations:

1) Late work:
Students may submit work late with a penalty of 10% each day the assignment is late up to 3 calendar days maximum. Once any assignments are returned to students with grades/comments, this late work will not be accepted. Once the deadline has passed, a zero will be assigned.

Computer problems of any kind (including document corruption, hard drive failure, problems with uploading to Moodle) will not be treated as acceptable excuses for submitting late work. This being the case, it would be wise to make a backup copy of any computer work that you do for this course, and we suggest ensuring that you've received return receipts in your email from Turnitin. However, if you are having problems getting your work in, it is recommended that you talk with your teacher.

2) Attendance:
See the IMSA handbook for official attendance policy. If you have a counselor excused absence, or an unexcused absence, you will not be able to make up the missed work. This includes earning a zero on any tests or quizzes given during the missed period.

If you have an excused absence, be sure to contact your teacher to find out what you will miss. If that is not possible, you should see your teacher as soon as possible to discuss your absence. It is **your responsibility** to follow up on what you missed in class.

3) Plagiarism:
Plagiarism is unacceptable and will be dealt with as per IMSA policy on academic dishonesty. Plagiarism includes, but is not limited to, knowingly using another person's work – whether it is a student or a research paper – as your own, improper citations and bibliographic information, improper use of secondary sources, or any other behavior that is deemed dishonest.

Assessment Practices, Procedures, and Processes:
Assessments may include quizzes, tests, presentations, projects, writing assignments, and homework. We will also be gauging student progress with respect to both learning skills and mindset, as highlighted in the Standards of Significant Learning.
Tests are used to examine factual knowledge and problem solving. Also, students will be asked to apply knowledge gained in class to address novel situations (approximately 30-40% of any individual test grade). We call this ability 'transfer' and tests generally prompt a developing skill over the course of time.

Written reports are used to examine both communication and critical thinking skills in students. Students will be asked to forge connections between the lab activities or literature research and a broader context in the field of Biology. This sort of work mimics science practice and expands student thinking in science.

Projects and Presentation: This category of student work examines model building and critical thought. This complements reports as students must draw upon various activities and knowledge to construct holistic models that represent their understanding.

Various categories of work are not weighted to calculate the student grades in this course. Instead, a running total of all work is maintained to reflect on student grades. An approximate contribution percentage of categories of assessment toward the final grade is:

- Formative assessment: projects, reports, presentations: 60%
- Summative assessments: tests and major projects: 40%

Grading generally follows the scale:

90% and above = A
80-89% = B
70-79% = C
Below 70% = D

Major assessments will be graded and returned to students for review as soon as possible. This will usually be seven to ten days for tests, major projects and reports. Formative work that demands quick turnaround time to support continued student progress will be given priority in grading.

Sequence of Topics and Activities 17 weeks

I. Introduction to Biological Systems Modeling – Transcription model
1 *week*
II. Introduction to Biochemistry, Molecular Biology and Physiology of systems biology
2 weeks
III. Modeling of the cardiovascular and respiratory systems
3 *weeks*
IV Modeling of the urinary/excretory and digestive systems
2 weeks
V. Reflecting on the models/troubleshooting
1 week
VI. Neural Network Processing and AI
2 weeks
VII. Arduino based modeling – Heart rate and blood pressure monitors
2 weeks

VIII. Application of modeling to the organism as a whole
2 weeks
IX. Final project
2 weeks

Each unit will include readings, interactive discussions, hands-on labs and summative assessments which include regular checkpoints every week either verbal or lab based, to make sure that students are not overwhelmed and are on schedule with their understanding The modeling units are given extra time because students will be building models and need to articulate their learning.