How do systems of molecules solve complex problems? At first, this may sound like a strange or perhaps misplaced question. Molecules don’t have brains or cognition. They are not capable of abstract thought. And yet, *molecular interactions* enable the fundamental processes that allow cells to be alive. (And this is no easy task!) In BIO 132, we will explore the foundational building blocks of life and come to appreciate that *biology* is essentially a system of molecules that solves intricate problems across vast scales of size and complexity.

In many ways, the problems that these molecules must solve represent the defining aspects of life. To be alive, all organisms must be able to gather energy from the environment and convert it into something useful. They must also transmit information through replication and communication. These tasks are accomplished by building complex systems out of simple tools comprised of even more basic building blocks. Remarkably, this is true (and similarly achieved) for all organisms — people, spiders, cats, dogs, pine trees, lobsters, redwoods, bacteria, amoebas, tulips, etc, etc, etc.

In BIO 132, we will explore the basic **building blocks of life** and ask: How are these building blocks used to build the cells and systems that define life? At the end of the semester, you will understand several fundamental problems that biological systems face and some of the **mechanisms** that they use to solve them. Among these will be how organisms:

- Store and maintain the information they need to be alive and how they pass that information to their progeny.
- Respond to their changing environment.
- Gather energy from their environment and make it useful.
- Use the shape and composition of molecules to enable life.
- Use simple blocking blocks to create (far) more complex systems that enable all of their activities.

**Professor Nathan Derr (he/him)**
Office Hours:  W 11-12, Th 1:00-2:00
Sabin Reed 435
nderr@smith.edu

**Class Lecture in Ford 240:**
Tuesdays & Thursdays 10:50 to 12:05

**Discussion sections in McConnell B05:**
Wednesday 1:20 - 2:35; 2:45 - 4:00
Thursday 2:45 - 4:00; 4:10 - 5:25

**Optional lunchtime conversations:**
Tuesdays 12:15 - 12:55
Chase-Duckett dining room C

**Class tutors:**
- Quinton Celuzza
- Sakina Ali
- Desiree Michel

Drop in tutoring hours posted on Moodle
Course Objectives

The central objective of this course focuses on understanding how the molecules of life build more complex systems that solve the inherent problems of biology. We will begin to appreciate what makes biology biology and not chemistry.

The insides of cells are a chaotic chemical soup. And yet, cells perform amazing things, ultimately allowing them to respond to their environment, gather resources, and produce offspring. To understand the foundations of living systems, we will explore at the introductory level how biologists think about:

- Information flow in biological systems
- The relationship between the structure and the function of biological molecules
- How energy and matter are harvested and transformed to fuel cellular processes
- How molecular-, cellular-, and systems-level biology relate.

We will also develop the following Smith College Essential Capacities:

- Ability to draw upon and convey knowledge
- Creativity, curiosity and innovation
- Critical and analytical thinking
- Resilience and resourcefulness
- Self-awareness as a learner

These goals will be met through a combination of course lectures, active learning exercises, course discussion sections, reflective writing, self and peer review, and formative and evaluative assessments.

Finally, a secondary goal of this course is to develop an appreciation for the most essential molecular and cellular mechanisms of living systems. Such appreciation will foster an understanding of how biology is affecting all aspects of our lives. Breakthroughs in myriads areas within biology over the past 50 years have led to unprecedented understanding and control over biological systems. The next 50 years will see major political, social and economic changes due to our new era of biological insight. While we will not focus on these topics directly, this course aims to provide the foundational scientific background necessary to appreciate how biology is being used in so many new, and critically important, ways.

DNA is composed of individual building blocks called nucleotides. The structure of these nucleotides, and the resulting 3D shape of DNA, allow DNA to be incredibly well suited for storing and transmitting biological information. But why? Figure adapted from: Watson & Crick, Nature, 1953.
Course Structure

In the Lecture portion of the course, we will explore the major themes of the course in a combination of lecture, group activities and discussions. In the Discussion Sections of the course, we will meet in smaller class settings to work with the major themes and solidify our understanding. We will wrestle with the main ideas of the course, aiming to both deepen our understanding of the concepts as well as apply them to relevant examples from biological systems. In the discussion sections, students will work in small groups of 4-5 students each and learn methods for constructive and interactive engagement with course material. These sessions additionally provide background and results learned from the science of teaching and learning. We will explore learning strategies transferrable to other biology, STEM, and college-wide courses. I want you to learn best practices for using your out of class time efficiently, competently, and with a greater self-awareness. My hope is that these skills will translate to all areas of your life, including going beyond the academic setting.

Please note that the lab (BIO 133) is a separate course, and is recommended, although not required, to be taken concurrently.

The chart below provides an example framework for our explorations in BIO 132. Together, we will build a chart like this in BIO 132, providing a scaffolding for organizing the central concepts, and learning to apply and link them within all aspects of living systems. Understanding general approaches to the central ideas of biology will reduce our dependence on memorization, and allow us to explore how the most essential concepts in biology can be applied to the mechanisms of cells and organisms.

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Thinking about biological concepts in BIO 132

<table>
<thead>
<tr>
<th>Information flow</th>
<th>Structure &amp; function relationships</th>
<th>Conversions of energy &amp; matter</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>—Central Dogma</td>
<td>—Catalysis</td>
<td>—Coordination</td>
</tr>
<tr>
<td></td>
<td>—Signaling</td>
<td>—Energy input</td>
<td>—Inputs &amp; outputs</td>
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<tr>
<td></td>
<td>—Communication</td>
<td>—Energy output</td>
<td>—Integration</td>
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<tr>
<td></td>
<td>—Tree of life</td>
<td>—Transformations</td>
<td>—Feedback</td>
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<td></td>
<td></td>
<td>—Metabolism</td>
<td>—Transport</td>
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<td>—Photosynthesis</td>
<td>—Networks</td>
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<td>—Size scales</td>
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<td>—Complexity scales</td>
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<td>—Effects across scales</td>
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<td></td>
<td>—Shape</td>
<td>—Robustness</td>
<td>—Reactions</td>
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<tr>
<td></td>
<td>—Chemical groups</td>
<td>—Specificity</td>
<td>—Intensity</td>
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<td></td>
<td>—Time</td>
<td>—Versatility</td>
<td>—Location</td>
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<td>—Space</td>
<td>—Regulation</td>
<td>—Timing</td>
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<td></td>
<td>—Compartments</td>
<td>—Interactions</td>
<td>—Errors</td>
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<tr>
<td></td>
<td>—Organelles</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>—Cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>—Any other dependencies?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Put everything together to form a mechanism and/or a description of the big picture.
Course Assessment

Knowledge Check Quizzes (15% of the final grade)
There will be a Moodle-based quiz most weeks in the semester. These quizzes are NOT designed for me to check your knowledge, but rather for you to check your own knowledge. (This type of assessment is called a “formative assessment”, rather than an “evaluative assessment”). These quizzes will help you check your knowledge and assess your own progress towards learning and applying the course material. These quizzes are an opportunity to work with the foundational ideas and concepts in class on a recurring basis, ensuring that the class’ big picture ideas are part of your active thinking. This strategy helps you to “own” the course content, keeping it part of your active, working memory. In past semesters, students have found these quizzes very helpful for understanding the most important parts of class and for helping them assess which material is outside their comfort zone and requires more in-depth study. Because the quiz questions are similar to the multiple choice portion of exams, they provide an opportunity to better understand which material is challenging for you, providing immediate feedback on what you need to study more.

The quizzes are self-scheduled on Moodle, and I try to provide a large window of time in which you can take each quiz. The quizzes will generally open on Moodle on Friday afternoon and be available until 9:59 PM on the following Tuesday, giving you 2 weekend-days and 2 week-days in which to choose a time to take the quiz. The quizzes will have approximately 10-15 multiple choice question which are written in a format very similar to the multiple choice portion of exams. Each quiz question will be graded immediately by Moodle, and you will have multiple attempts to achieve the correct answer. The quizzes will use adaptive scoring, so selecting the correct answer on the first attempt is best. (You will get 3 points for answering correctly on your first attempt, 2 points on the second attempt, 1 points on the third attempt, and 0 points thereafter.) You must provide the correct answer before moving on to the next question. The 2 lowest quiz scores of the semester will be dropped and not counted towards the final grade.

Three Exams (15%, 15%, & 20% of the final grade):
Exams provide an opportunity to synthesize the course material, forming connections and applying your knowledge to new situations. They will cover material from class lectures, discussion sections and required readings and assignments. I want you to have the flexibility to take the exam at a time that works well for you, so that you can approach the exams calmly and confidently. Thus, exams are self-scheduled and can be taken over the course of the 7 day periods indicated in the course calendar. Exams have no time limit, but must be completed in a single seating.

Exams 1 and 2 will be given in Seelye Hall using the self-scheduled exam system in place there (Full details will be posted to Moodle.) Exam 3 will be administered during final exam period. You are given a multiple-day time period in which you will be able to access the exam (as noted on the class schedule). Exams will be multiple choice and short answer. Part of each exam will focus on content from the most immediate section of the course, and part will focus on “big picture” applications of course material. Exams are cumulative in the sense that the most important foundational concepts developed in the preceding parts of the class will be needed for future exams. A significant portion of the application-based questions will relate to context-specific examples of which you will be familiar from class. For exam 1, this will be drug design. For exam 2, this will be metabolic engineering, and for exam 3, it will be rationally designed cancer therapies. The context-specific questions provide an opportunity to synthesize course material and concepts and then apply them to a unified example of how biological systems work and how biologists are researching and interacting with biological systems. Exams 1 & 2 are worth fewer total points so that you have the opportunity to understand the exam format for this particular course.
Course Assessment, (continued)

Meta-cognition and Big Picture Thinking (15% of the final grade)
Research on the Science of Teaching and Learning has shown that meta-cognition (the act of thinking about your thinking) is a crucial skill in becoming a better student and in learning new material. It is really important for you to learn to ask yourself (and answer accurately) “What course material is truly in my “comfort zone”? What material is on the “edge of my learning”? And what material is in my “growth area?” Once you identify where you need to focus your time, you can become a more efficient and productive student and scholar. Similarly, it is crucial that you develop productive techniques and strategies for moving challenging material from your growth area to your learning edge and onward to your comfort zone. To help you develop these meta-cognitive skills, we will use meta-cognitive assignments throughout the semester as an opportunity to intentionally think about and record our ideas about our learning. The goal here is to engage in meta-cognition, allowing you to develop skills in assessing your own learning and learning strategies for effective studying and problem solving while addressing challenging course concepts and material. We do this because research in the field of Teaching and Learning has shown that actively considering what you know, what you don’t know, and what you find challenging is a proven method for deepening your understanding of new material.

We will also use weekly assignments to think expansively about biology. These will be opportunities for you to practice Big Picture thinking about biology. These assignments will be based on questions that require your analysis and synthesis of various course material. Many of the questions involved will NOT have a single correct answer (or any correct answer at all)! Rather, you will determine what the correct answer is and then justify your answer drawing upon the concepts of the course. These questions will be good practice for the exams.

For these assignments, you will maintain a document on Google Docs with all of your answers over the course of the semester. There will be weekly questions and short answer writing prompts to address. Guidelines and formats for these assignments will be provided on Moodle. These documents will be shared with your discussion section group for peer learning. Answers to questions should use clear and concise language that is free of technical jargon. Grades will be based on honest good-faith efforts and completion of the assignments, and not on the writing or the specific answers supplied. I will check a subset of the assignments a few times during the semester; to get full credit, your answers must be up to date for those checks. If you are not up to date, you will have 48 hours to complete the assignment for partial credit.

Participation in discussion section (18% of the final grade)
The discussion sections are a powerful opportunity for mastering the course material through interactions with both me and your peers. To be successful, they require you to participate! This includes attending the discussion sections and being an active member of your discussion group. At the end of the semester, you will evaluate both your own participation and that of your fellow group members.

Office hours (2% of the final grade)
Office hours provide opportunities to clarify course concepts and reinforce the material we are learning. Many students are surprised at how helpful office hours can be! To encourage you to make use of this resource, a small portion of the final grade will be awarded to you for simply visiting office hours at least once during the course of the semester. Attending a bio lunch in Chase-Duckett counts as well. If your class or work schedule prevents you from coming to scheduled office hours, please email Professor Derr to schedule a separate appointment.
Extra credit for Bio 132

I provide 3 methods for earning extra credit in BIO 132. The most you can earn is a total of 3% extra credit added to your final grade in the course. Please note: This is enough to advance your grade by 1 increment. For example, from a B+ to an A- or a B to a B+. Please make use of this opportunity!

Option 1: Research seminars (1% maximum per seminar)

Attending research seminars is a great way to learn about how the most current research in biology is conducted and see first-hand how current work always relates back to core ideas in Biology (which are often the very same core ideas we focus upon in BIO 132!) Therefore, over the course of the semester, extra credit can be earned by attending research seminars, such as the Life Sciences Colloquiums on Mondays at 4:30 in McConnell 103 and the Life Sciences Lunchbag research talks at lunchtime on Mondays. For extra credit, the seminars must cover material related to BIO 132. In addition to attending the seminar, you must write a one-page summary of the seminar’s main points and how they relate to BIO 132. Each summary can provide up to 1% of extra credit per seminar. Students are limited to a total of 3 seminar summaries for extra credit. If there are multiple speakers on a given day, you must summarize all speakers for full credit. All seminar summaries are due at two times during the semester: 10/31 and 12/12. I know that the colloquium schedule frequently conflicts with work obligations and athletics and artistic endeavors. So, if your schedule does not permit you to attend these seminars, you may instead read about the speaker and their research and write a summary of your findings and how they relate to BIO 132. The full schedule of Life Science Colloquium speakers is posted on Moodle. Below, are just a few examples with direct relevance to our course.

September 9
Sofia Annis ’11
Next-generation sequencing of mitochondrial subpopulations

September 30
Susan MacLauchlan
Hematopoiesis and rheumatoid arthritis

October 21
Lynn Adler
Floral traits mediating Pathogen Dynamics in Pollinators

October 28
Nathan Derr
Force Integration and teamwork among molecular motors

November 4
Radhika Subramanian
Spatial organization of cell division

November 18
Daniel Hebert
Cellular secretory protein maturation

November 25
Sabrice Guerrier
Topic: TBD
Extra credit, (continued)

Option 2: Following tangents and going deeper (1% maximum per summary)

One of my favorite parts of BIO 132 (and of being a scientist!) is engaging in speculative discussions about topics we don’t fully understand. How can we reason our way through a new idea based on the foundational knowledge of biology we are cultivating? Therefore, when a question arises in class or discussion that none of us can answer, a student may do a literature search on the topic and summarize the answer in a short (~1 page) summary that will be posted on Moodle. Determination of whether the topic merits investigation and whether it is suitable for extra credit requires approval. The student who asks the question has first rights to the topic, but if it is not pursued, another student may complete it. The summary should be made within two weeks of the class period of when the question was asked. It should address the answer to the question and must specially address how the answer relates to course material and concepts. 1% of the final grade per question can be earned. Each student is limited to a maximum of 3 summaries for extra credit.

Two mammalian cells with specifically labeled components are shown. The cell's DNA is cyan, and the cytoskeletal filaments of actin are purple, while the cytoskeletal filaments of microtubules are yellow. Why do cells need (cyto)skeletons? And what do the different types of skeletons do? Image by Torsten Wittmann.
Extra credit, (continued)

Option 3: What are researchers working on now? (1% maximum per summary)

While we know a lot about Biology, don’t be fooled: everything we cover in this class is still an open area of research! Learning about current research efforts and how they relate to the foundational concepts we cover in BIO 132 is a great way to make connections about the material, understand techniques for asking and answering research questions and learning about scientists and how they do their work. We will cover about 15-18 different topics in this class. At the end of each topic, I will post names, links, and research areas for a small number of people conducting current research in the topic area. For extra credit, you may read the short biographies about these researchers and investigate their research through their websites, popular and semi-popular press articles about them and their efforts, and the research reports they publish. Please write a 1 page summary of what you learn and how it relates directly to ideas discussed in class. A sample of the starting information I will provide is shown below.

Current research on BIO 132 topics:
Scientists who investigate the **cytoskeleton and motor proteins**

Derek Applewhite
https://www.reed.edu/biology/professors/applewhite.html

Eva Nogales
http://cryoen.berkeley.edu

Radhika Subramanian
http://www.hms.harvard.edu/dms/bsbs/fac/subramaninan.php

Sam Reck-Peterson
http://reck-peterson.ucsd.edu

Kathy Trybus
http://physioweb.uch.edu/faculty-profile?user=Kathleen_Trybus

Ahmet Yildiz
https://www.yildizlab.org
Readings and Resources

In BIO 132, we use a variety of resources.

- **The textbook** for this course is:
  - You may use either the Hardcopy textbook or the e-Book. Information about purchasing either is available in the bookstore.
  - Several copies are on reserve in Young Library.
  - Weekly assigned reading should be completed before class (see below for guidelines). Questions related to the readings will sometimes be part of the weekly assignments.
  - See the course calendar for specific reading assignments and dates.

- Sometimes the textbook can be boring or confusing, and it’s helpful to have other resources for explaining ideas or double-checking our knowledge. So, sometimes **Short videos** will be assigned. I also recommend these as ways to reinforce what you are learning and reading in BIO 132.

- If you find other good videos and study resources, please tell me about them so that I can compile a list for this class and future classes!

- We will also rely heavily on **Moodle**
  - Moodle will be used for posting course materials and for course emails.
  - Since we don’t have a Twitter or Instagram or Facebook for BIO 132, please be sure to check Moodle and your email regularly for BIO 132 notifications and information.

For the assigned readings, I suggest:

- **Before class:** Read the “Chapter Review” at the end of the assigned chapters. Work through it carefully to get a sense of the topics covered. Next, write down and define all of the words in **Bold** in the assigned chapter. These techniques will help prepare you for lecture and start to give you a sense of the most important material we are covering.

- **After class:** Carefully read over the relevant sections of the book that directly correlate with what was covered in lecture. From this exercise, generate what you think are the key points or main concepts emphasized, significant questions or trouble areas you experienced, and whether connections between previous lecture material can be made. Write this all down in your notes. It is essential that you develop an awareness of what material is in your comfort zone and what material is in your growth area. The most important learning occurs when you wrestle with ideas and think carefully about what makes sense and what does not make sense to you. What can you do to reconcile the material that challenges you?

- **Helpful hints.** I know from past experience with this course that re-reading the textbook multiple times as a study strategy is seldom effective. This kind of approach can make the material feel familiar to you, but **familiarity** is not **understanding**. It is much better to take a more active approach: start by taking notes on the reading. Can you summarize and re-write the key points in your own words without using technical language? Can you reproduce the figures without peeking at the book or your notes? Can you explain the material to a friend who is not taking the class? These are all essential forms of active, engaged learning.

- **Additional Learning Tips** for BIO 132 are provided on Moodle in a separate document.
Lecture Capture

In an effort to assist you with managing and mastering the information covered in BIO 132, I will be video recording the lectures. These recordings will be posted online on Moodle for your review. Because the lecture slides and these recordings will be available to you for later review, I suggest you focus your note taking on the main concepts we discuss and spend time critically thinking about the material in class and participating in discussions rather than trying to transcribe every detail on the slides. Class will be more fun and interactive, less stressful, and you will get more out of the class time using this method!

Note: Some students feel that because the lectures are being recorded that they do not have to come to class. This is entirely false! Past students have indicated that the recordings are a great resource to fall back on, but do not replace the in-person experience. Similarly, sometimes there are technical problems, and the videos do not record adequately and are therefore not posted.

Biological systems operate across vast size scales, from macro-sized organisms (like ants & elephants) to the nanoscale molecules that compose biological building blocks. Figure adapted from http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2014/popular-chemistryprize2014.pdf
### Q&A

**How should I address the professor?**

Please address me as “Professor Derr”. My pronouns are he/him/his.

**What if I have a question about the material?**

Please ask your question in class or discussion section. Class time is meant to be “practice space”. Similar to athletes practicing their sport, musicians practicing their instrument, or artisans and artists practicing their craft, biologists must practice with course concepts and material. Class time is designed specifically for this task.

**What is the purpose of office hours?**

Office hours provide an opportunity to meet with me in a small group or one-on-one setting to discuss any aspect of the class. Office hours are generally conducted in small group setting, so if you have a private matter to discuss, please communicate this to Professor Derr to schedule a time to talk.

**What if I have to miss a class?**

Extenuating circumstances and illnesses happen and sometimes classes must be missed. I trust everyone to make the decisions they need to make about attendance and participation, while keeping the effect of these decisions on their classmates and the learning environment in mind.

**What is the best way to get in contact with the professor?**

Before and after class are great times for short discussions. For other questions or comments, please email nderr@smith.edu. Please include “BIO 132” in your subject. For example: “BIO 132: Question about quiz 2”. This will help me prioritize your email and get back to you quickly. If you don’t hear back within 24 hours, please re-forward your email.

**What if I need disability accommodations?**

I am happy to make adjustments as needed to facilitate documented accommodations. Please send me documentation of the requested accommodations as close to the start of there semester as possible. Please contact Laura Rauscher, Disability Services Director, for assistance and documentation guidelines.

**What if I need an extension on an assignment?**

I understand that emergencies happen. Extensions on quizzes and exams are granted for family emergency or serious illness. To receive an extension, please contact me before the quiz or exam closes. If the nature of the emergency prevents such communication, please contact me as soon as possible. (As the quizzes and exams are open for multiple days, it should usually be possible to alert me of your situation before the close of the exam or quiz.)

**What if I am unavailable to attend the office hours?**

Schedule an appointment. When you email me to ask for an appointment, please include a list of days and times you are available.