

SYLLABUS
BIOS 4746 & BIOL/CHEM 6756
DISCOVERY OF SIGNALING MOLECULES

COVID-19 PANDEMIC PLANNING FOR FALL 2020:

This course is built around group discussions of literature readings, plus a small number of lectures interspersed throughout the semester as well as student presentations and exams. In fall 2020, this course will be offered using a “hybrid touch points” model. The lectures and student presentations will be delivered remotely using Canvas in a *synchronous manner* (i.e., during the regular class times). The group discussions will also occur during the regular class times, but in a mixture of in-person and remote formats. More details about in-person sessions are in the main text of the syllabus. Attendance and active participation in group discussions are required; the instructor will work with individual students to enable all students to participate regardless of location. Exams, quizzes, and assignments will be administered remotely.

Instructor information:

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Online office hours: Drop in Mondays and Thursdays, 4:00-4:30pm, on Bluejeans within Canvas

One-on-one remote meetings available by request through email or via message sent in Canvas

Course description: The diversity of chemical signals between organisms and their structural specificities will be presented along with chemical and biological approaches for identifying signaling molecules.

Pre-requisites: Undergraduate students should have previously satisfactorily completed BIOL 1510 (Biological Principles) or BIOL 1511 (Honors Biological Principles), and CHEM 2311 (Organic Chemistry 1). Graduate students should have a foundational understanding of topics covered in such courses, from their prior training.

Course goals: In this 3-credit course, I intend for students to explore the mechanisms and consequences of chemical signaling between organisms, integrating biological and chemical points of view. Using scientific articles published by experts in this field, students are encouraged to critically analyze recent research. Class meetings will involve a combination of lectures, group discussions, and student presentations to enable students to learn how to express and assess scientific hypotheses, understand research methods, and interpret findings and conclusions based upon experimental data. Students will need to regularly apply their knowledge of first- and second-year undergraduate biology and chemistry including organic chemistry; therefore this course is most appropriate for advanced undergraduates (juniors and seniors) and for graduate students in the sciences.

Learning objectives:

By the end of this course, it is my goal that students are able to:

- Explain how chemical compounds mediate interactions among organisms, using examples from predator-prey, host-parasite, competitive, mating, and cooperative interactions.
- Describe (in words and drawings) the molecular structures of some important chemical cues and justify which structural features of a molecule contribute to its solubility, volatility, reactivity, or interaction with certain biomolecules.
- Identify the structural classes to which natural product chemical cues belong.
- Predict the biosynthetic pathways and draw the reaction mechanisms by which natural products are produced by living organisms.
- Connect the various molecular mechanisms by which chemical cues function, with their behavioral and physiological effects on cells and organisms.
- Critically analyze the primary scientific literature, summarizing hypotheses and outcomes, identifying strengths and weaknesses, and proposing future directions.

The class meets on Tuesdays & Thursdays from 8:00 to 9:15 am. Most class sessions – including all of the first week – will occur remotely using Bluejeans within Canvas (www.canvas.gatech.edu). Occasional in-person class sessions will occur in CoC room 102, on dates described in the Class Calendar starting on p.6 of this syllabus (available on Canvas under “Files”). On the days in which class is held remotely, I will teach from my computer at home and won’t be in the classroom. Each class session (remote and in-person) will be video-recorded, and available thereafter in the Bluejeans section of Canvas. Lecture slides will be available by the evening before each lecture on Canvas in the Files section. There is no textbook for this course. Required readings are available on the Canvas site for our course and students are encouraged to use library databases and the scientific literature to pursue topics in more detail. Since there is no textbook and many of the sessions involve class discussion rather than formal lecture, attendance and class participation are required, whether in-person or remotely.

Evaluation:

Exam #1	15%
Exam #2	15%
Literature assignment	20%
Student presentation	20%
Quizzes	15%
Class participation	15%

Exams will be administered remotely using Quizzes within Canvas, with a Word document of the exam made available at Canvas > Files > Exams. Each exam should take 75 minutes to complete, during a regularly scheduled class session. The exam will be made available at 7:45am on the day the exam is scheduled in order to provide students with up to 15 minutes to download the exam, prior to the expected 8:00am start. In order to account for technical difficulties that could arise, students will have until 10:00am to paste/upload and then submit their answers into Canvas Quizzes. **Exam #1** will be based on material covered in lectures, class discussions, and readings up to the date of that exam. **Exam #2** will be based on material covered since immediately after Exam #1 until Exam #2, although concepts from before Exam #1 may need to be utilized to succeed in Exam #2. Both exams will require a combination of short (single sentence) answers, longer (paragraph) answers, and drawings including molecular structures and biosynthetic reaction mechanisms. Practice exam questions will be provided a week before each exam, and an optional in-person question-and-answer session will be held during the week of the exam. Students must work independently on their exam without communicating with others during the time they take the exam. It is allowable to refer to course materials and other resources during completion of the exam but it is not acceptable to ask directly for answers to the exam questions from other people or from online tutoring services, etc.

The **literature assignment** will be a short paper written by each student (maximum 2 pages single spaced, 12 point font, not including citations), reporting on a recent article from the scientific literature (not a review) that each student chooses by conducting their own literature search. The chosen article should be one that the student found particularly interesting and important, and can focus on any area of chemical signaling between organisms. In their paper (graded out of 20 points), the student should cite the article that was selected, present a brief overview of the field with citations to additional published papers (4 points), report the important findings of the chosen article (4 points), argue why this article represents an important contribution relative to the state of the field and relative to other cited published papers (4 points), and critically evaluate its strengths and weaknesses (4 points). The remaining 4 points are awarded for clarity and organization, with deductions for failure to choose an appropriate article, observe the page limit, or appropriately cite the chosen article. For this assignment and the student presentation described below, it is not acceptable for students to re-structure an assignment from another course, nor should they base their assignments on assigned readings for this or another course.

The **student presentations** will be delivered individually, with 12-15 minutes for each student to present and 3-6 minutes to answer questions from other students and the instructor (total allowable time = 18 minutes). If students wish to deliver a joint presentation as a pair, they can use a total of 36 minutes including questions. Topics, chosen in consultation with the instructor, should be related to recent developments and/or applications of chemical signaling among organisms across several studies, rather than being solely on the contents of a single paper as for the literature assignment. It is important to present experimental data and critical interpretation of

results, and to cite the scientific literature (at least 10 citations are expected per presentation). Examples of topics from past years: Antibiotic Resistance; Secondary Metabolites as Biofuels; Natural Product-Based Chemical Weapons; Signaling Molecules in Wound Healing; Settlement Cues for Restoring Coral Reefs; Applications of Canine Olfaction in Cancer Diagnosis; Plant Volatiles as SOS Signals; Siderophore Signaling Pathways.

Quizzes will be held in Canvas > Quizzes function, associated with each class discussion in which a reading is assigned. Each quiz will consist of 2 multiple choice or fill-in-the-blank questions based on the reading, intended to ensure that students read the paper before class. Questions will be of the type that either you know the answer (because you spent at least an hour reading the paper) or you don't (because you didn't read the paper carefully). Each quiz will be made available in Canvas Quizzes starting at 1pm on the day before class, and accessible until 7:50am on the class day. Once you start the quiz, you will need to complete it within 10 minutes, so it won't help to start reading the paper at the same time you start the quiz. Since there are 15 discussion-based class sessions with readings, and 15 points for this activity, each quiz will be worth 1 point. The class sessions associated with a pre-class quiz are noted in the Class Calendar later in this syllabus.

Class participation will be judged by the degree to which each student participates in class discussions (by asking questions, answering questions, offering ideas, opinions, and critiques of readings), during student presentations (by asking questions during others' presentations, by engaging the audience during their own presentation, by connecting their presentation to previous class discussions), during lectures (by asking questions and offering opinions). During the pandemic, students (and the instructor) may need to quarantine, self-isolate, or deal with health emergencies in ways that interrupt their ability to attend in-person sessions or participate every single time. For the small number of in-class sessions, I will make every effort to involve students who need to attend remotely instead of in-person, but I expect to have students approach me ahead of time to discuss their attendance and participation plans for all but dire emergencies. I will take attendance using the chat window in Bluejeans, but attending is not enough – I expect active participation as described above. Class discussions held remotely or involving a mix of in-person and remote attendance will be challenging for all of us. I ask that you do your best to extend yourself personally, by speaking up when you don't understand something and offering your opinion even if you're not sure. When participating remotely, if technology allows, please use a camera so that we can see each other; if you cannot speak up directly, please put your comments and questions in the Bluejeans chat box. Class and online participation is the one graded element for which effort, and not outcome, is the most important thing. Students who make a strong effort to participate will be rewarded with high points.

Grading scale: Your final grade will be assigned as a letter grade according to the following scale:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Additional course expectations and guidelines:

If you get sick or have been exposed to the coronavirus: If you answer yes to any of the daily health self-screening questions at <http://health.gatech.edu/coronavirus/daily-checklist>, please do not come to class or otherwise expose yourself to others, and follow directions at <http://health.gatech.edu/coronavirus/prevention-wellbeing>. If you are able, please communicate with me by email or via message in Canvas to let me know of your planned absence or intention to attend any in-class sessions remotely. I will work with you to keep you connected with the course. If I get sick or have been exposed, I will let the class know how we will continue to learn remotely. If I'm too sick to teach, I'll do my best to keep you informed through Canvas announcements and to launch a plan for substitute instruction. The course is designed so that if we receive a stay-at-home order after the start of the semester, we will continue to learn remotely.

Face covering and other classroom safety measures: During this pandemic, there is substantial scientific evidence that properly covering our faces protects each other from infection. Consistent with requirements of the University System of Georgia (USG), students and instructors must wear a face covering (cloth or equivalent) at all times in classrooms, hallways, offices, and restrooms of the buildings in which classes are held. That means

that drinking and eating in class cannot be allowed during the pandemic. Six feet separation between individuals must also be maintained, in addition to mask wearing, so we'll be using a strict seating plan when we hold in-person class sessions. If you don't have a mask, I'll give you one. I carry extras in case some people forget. If you have an approved accommodation to not wear a mask, I expect you to let me know via email or message in Canvas prior to any in-person class sessions so we can make alternate arrangements for you to learn during these sessions, since mask wearing is obligatory in the classroom for the safety of others. If you refuse to wear a mask inside the classroom, I will adjourn class for the day and send everyone home. Please consider the health of your community (<http://health.gatech.edu/coronavirus/jackets-protect-jackets>).

Academic integrity: Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit <http://www.catalog.gatech.edu/policies/honor-code/> or <http://www.catalog.gatech.edu/rules/18/>. Any student suspected of cheating or plagiarizing an exam or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Collaboration and group work: Students are encouraged to work together to facilitate learning on analysis of the readings, studying for exams, and preparation for presentations. In contrast, exams, literature assignments, and the final content of student presentations should reflect each individual student's understanding and effort.

Extensions, late assignments, and rescheduled or missed exams: If you know that you will miss an exam or a deadline, you must discuss with the instructor prior to that date to try to reach an agreeable solution. If an unanticipated event prevents you from meeting a deadline without prior notification, please communicate with me via email or message in Canvas as soon as possible (preferably that same day). Missed exams or assignments that are not brought to the instructor for discussion by the student will result in zero points for that graded item. Of course, the pandemic may result in unforeseen health emergencies and interruptions to students' ability to perform work. I will aim to work with you in such cases to help come to a mutually agreeable solution.

Accommodations for students with disabilities: If you are a student with learning needs who requires accommodation, contact the Office of Disability Services at (404)894-2563 or <http://disabilityservices.gatech.edu/>, as soon as possible, to make an appointment to discuss your needs and to obtain an accommodations letter. I would also like to do my best to meet your learning needs, so please contact me by email as soon as possible to set up a time to discuss.

Student-faculty expectations agreement: It is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty and students. See <http://www.catalog.gatech.edu/rules/22/> for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Campus resources for students:

In your time at Georgia Tech, you may find yourself in need of support. Below you will find some resources to support you both as a student and as a person.

Academic support:

- Center for Academic Success <http://success.gatech.edu>
 - 1-to-1 tutoring <http://success.gatech.edu/1-1-tutoring>
 - Peer-Led Undergraduate Study (PLUS) <http://success.gatech.edu/tutoring/plus>
- OMED: Educational Services (<http://omed.gatech.edu/programs/academic-support>)
 - Group study sessions and tutoring programs
- Communication Center (<http://www.communicationcenter.gatech.edu>)
 - Individualized help with writing and multimedia projects
- Advising and Transition (<https://advising.gatech.edu>)
 - Study Strategies Seminar course <https://advising.gatech.edu/gt2801-study-strategies-seminar>
 - Academic coaching <https://advising.gatech.edu/academic-coaching>

- Advising in your major <http://advising.gatech.edu/>

Personal Support: Georgia Tech Resources:

- The Office of the Dean of Students: <https://studentlife.gatech.edu/content/get-help-now>; 404-894-6367; Smithgall Student Services Building 2nd floor
 - You also may request assistance at https://gatech-advocate.symphlicity.com/care_report/index.php/pid383662?
- Center for Assessment, Referral and Education (CARE) 404-894-3498; <https://care.gatech.edu/>
 - Smithgall Student Services Building 1st floor
 - Students seeking assistance from the Counseling Center or Stamps Psychiatry need to visit CARE first for a primary assessment and referral to on and off campus mental health and well-being resources.
 - *Students in crisis may walk in during business hours (8am-4pm, Monday through Friday) or contact the counselor on call after hours at 404-894-2575 or 404-894-3498. Other crisis resources: <https://counseling.gatech.edu/content/students-crisis>*
- Students' Temporary Assistance and Resources (STAR): <https://studentlife.gatech.edu/content/star-services>
 - Can assist with interview clothing, food, and housing needs.
- Stamps Health Services: <https://health.gatech.edu/>; 404-894-1420
 - Primary care, pharmacy, women's health, psychiatry, immunization and allergy, health promotion, and nutrition
- OMED: Educational Services: <http://www.omed.gatech.edu>
- Women's Resource Center: <http://www.womenscenter.gatech.edu>; 404-385-0230
- LGBTQIA Resource Center: <http://lgbtqia.gatech.edu/>; 404-385-2679
- Veteran's Resource Center: <http://veterans.gatech.edu/>; 404-385-2067
- Georgia Tech Police: 404-894-2500; <http://www.police.gatech.edu>

National Resources:

- The [National Suicide Prevention Lifeline](#) | 1-800-273-8255
 - Free and confidential support 24/7 to those in suicidal or emotional distress
- The [Trevor Project](#)
 - Crisis intervention and suicide prevention support to members of the LGBTQ+ community and their friends
 - Telephone | 1-866-488-7386 | 24 hours a day, 7 days a week
 - [Online chat](#) | 24 hours a day, 7 days a week
 - Text message | Text "START" to 687687 | 24hrs day, 7 days a week

Statement of intent for inclusivity: As a member of the Georgia Tech community, I am committed to creating a learning environment in which all of my students feel safe and included. Because we are individuals with varying needs, I am reliant on your feedback to achieve this goal. To that end, I invite you to enter into dialogue with me about the things I can stop, start, and continue doing to make my classroom an environment in which every student feels valued and can engage actively in our learning community.

Class calendar – subject to change as pandemic conditions require:

Week	Date	Topic	Reading assignment (read BEFORE class)
1	Aug 18	Course objectives and expectations; Introduction to molecules as information in nature (remote, synchronous lecture with question & answer opportunity)	None, but before class please download lecture slides for this and every lecture, available by the evening before class, at Canvas under “Files”
	Aug 20	Overview of classes of natural products and their biological origins (remote, synchronous lecture with Q&A)	Meinwald et al (2018); plus, if rusty on organic chemistry: Wyatt (2014) [no quiz]
<i>Aug 21: Last day to register, make schedule changes, and/or drop courses without a "W" grade for Fall</i>			
2	Aug 25	Human sex pheromones (part 1): what Swiss university students have to say about the smells of their peers (remote, synchronous discussion)	Wedekind et al (1995) [pre-class quiz on Canvas]
	Aug 27	Pheromones in mammals: regulation of female reproductive readiness by volatile molecules from males (remote, synchronous discussion)	Murata et al (2014) [pre-class quiz on Canvas]
3	Sept 1	Human sex pheromones (part 2): how smelling others drives behavior, feelings, and physiology (remote, synchronous discussion)	Bensafi et al (2004) [pre-class quiz on Canvas]
	Sept 3	Biosynthesis of signaling molecules (part 1): polyketide and fatty acid metabolism in plants, microbes, and animals (remote, synchronous lecture with Q&A)	
4	Sept 8	Fatty acid-derived pheromone guides homing behavior in an ancestral fish (remote, synchronous discussion)	Li et al (2018) [pre-class quiz on Canvas]
	Sept 10	Bacterial quorum sensing in cholera disease, focusing on identifying a new fatty acid-derived signaling molecule (remote, synchronous discussion) <i>Literature assignment due 8am through Canvas</i>	Higgins et al (2007) [pre-class quiz on Canvas]
5	Sept 15	Fatty acid-derived metabolites from algae create hot spots of oceanic bacteria (in-person class discussion – CoC room 102 with remote option)	Edwards et al (2015) [pre-class quiz on Canvas]
	Sept 17	The importance of blends of molecules as chemical cues: Fatty acid-derived pheromones in the nematode worm <i>C. elegans</i> (in-person class discussion – CoC room 102 with remote option)	Srinivasan et al (2008) [pre-class quiz on Canvas]
6	Sept 22	Chemoreception and neuronal signaling of <i>C.</i> <i>elegans</i> pheromones (remote, synchronous discussion)	Kim et al (2009) [pre-class quiz on Canvas]
	Sept 24	Exam #1 (remote using Canvas Gradescope. Expected duration: 8:00-9:15 but exam becomes available at 7:30am and answers must be uploaded by students by 10:00am)	
7	Sept 29	Biosynthesis of signaling molecules (part 2): isoprenoid metabolism in plants, microbes, and animals (remote, synchronous lecture with Q&A)	
	Oct 1	Marine algae use isoprenoid-derived chemical weapons to harm corals (remote, synchronous discussion)	Rasher et al (2011) [pre-class quiz on Canvas]

8	Oct 6	Surface-associated role of marine algal isoprenoid-derived defenses against fungi (remote, synchronous discussion)	Lane et al (2009) [pre-class quiz on Canvas]
	Oct 8	Learning to avoid toxic food: isoprenoid chemical defenses taste bad to some animals but not others (remote, synchronous discussion)	Long & Hay (2006) [pre-class quiz on Canvas]
9	Oct 13	Biosynthesis of signaling molecules (part 3): shikimate and peptide metabolism in plants, microbes, and animals (remote, synchronous lecture with Q&A)	
	Oct 15	Why chili peppers taste hot to mammals but not to birds: chemoreception of shikimate-derived capsaicin (in-person class discussion – CoC room 102 with remote option)	Jordt & Julius (2002) [pre-class quiz on Canvas]
10	Oct 20	Identification of peptide-derived molecule as ant-associated chemical weapon (remote, synchronous discussion)	Oh et al (2009) [pre-class quiz on Canvas]
	Oct 22	Microbiomes shaped by host peptides (remote, synchronous discussion)	Franzenburg et al (2013) [pre-class quiz on Canvas]
<i>Oct 24: Deadline to change grade mode from letter grade to pass/fail (and vice versa). Last day to withdraw from a single course or from school with "W" grades for Fall.</i>			
11	Oct 27	Symbiotic bacteria offer defensive peptides in return for safe home inside algal cells (in-person class discussion – CoC room 102 with remote option)	Zan et al (2019) [pre-class quiz on Canvas]
	Oct 29	Exam #2 (remote using Canvas Gradescope. Expected duration: 8:00-9:15 but exam becomes available at 7:30am and answers must be uploaded by students by 10:00am)	
12	Nov 3	Student presentations (remote, synchronous)	
	Nov 5	Student presentations (remote, synchronous)	
13	Nov 10	Student presentations (remote, synchronous)	
	Nov 12	Student presentations (remote, synchronous)	
14	Nov 17	Student presentations (remote, synchronous)	
	Nov 19	Student presentations (remote, synchronous)	
15	Nov 24	Student presentations (remote, synchronous)	

Reading list – articles available at www.canvas.gatech.edu in Readings folder (click on Files tab)

- Bensafi M, Brown WM, Khan R, Levenson B, Sobel N (2004) Sniffing human sex-steroid derived compounds modulates mood, memory and autonomic nervous system function in specific behavioral contexts. *Behavioural Brain Research* 152:11-22
- Edwards BR, Bidle KD, Van Mooy BAS (2015) Dose-dependent regulation of microbial activity on sinking particles by polyunsaturated aldehydes: implications for the carbon cycle. *Proceedings of the National Academy of Sciences* 112:5909-5914
- Franzenburg S, Walter J, Kunzel S, Wang J, Baines JF, Bosch TCG, Fraune S (2013) Distinct antimicrobial peptide expression determines host species-specific bacterial associations. *Proceedings of the National Academy of Sciences* E3730-E3738
- Higgins DA, Pomianek ME, Kraml CM, Taylor RK, Semmelhack MF, Bassler BF (2007) The major *Vibrio cholerae* autoinducer and its role in virulence factor production. *Nature* 450:883-886
- Jordt SE, Julius D (2002) Molecular basis for species-specific sensitivity to “hot” chili peppers. *Cell* 108:421-430
- Kim K, Sato K, Shibuya M, Zeiger DM, Butcher RA, Ragains JR, Clardy J, Touhara K, Sengupta P (2009) Two chemoreceptors mediate developmental effects of dauer pheromone in *C. elegans*. *Science* 326:994-998
- Lane AL, Nyadong L, Galhena A, Shearer TL, Stout EP, Parry RM, Kwasnik M, Wang MD, Hay ME, Fernandez F, Kubanek J (2009) Desorption electrospray ionization mass spectrometry reveals surface-mediated antifungal chemical defense of a tropical seaweed. *Proceedings of the National Academy of Sciences* 106:7314-7319
- Li K, Brant CO, Huertas M, Hessler EJ, Mezei G, Scott AM, Hoye TR, Li W (2018) A fatty acid derivative acts as a sea lamprey migratory pheromone. *Proceedings of the National Academy of Sciences* 115:8603-8608
- Long JD, Hay ME (2006) Fishes learn aversions to a nudibranch’s chemical defense. *Marine Ecology Progress Series* 307:199-208
- Meinwald J, Leal WS, Kubanek J (2018) Molecules as biotic messengers. *ACS Omega* 3:4048-4053.
- Murata K, Tamogami S, Itou M, Ohkubo Y, Wakabayashi Y, Watanabe H, Okamura H, Takeuchi Y, Mori Y (2014) Identification of an olfactory signal molecule that activates the central regulator of reproduction in goats. *Current Biology* 24:681-686
- Oh DC, Poulson M, Currie CR, Clardy J (2009) Dentigerumycin: a bacterial mediator of an ant-fungus symbiosis. *Nature Chemical Biology* 5:391-393
- Rasher DB, Stout EP, Engel S, Kubanek J, Hay ME (2011) Macroalgal terpenes function as allelopathic agents against reef corals. *Proceedings of the National Academy of Sciences* 108:17726-17731
- Srinivasan J, Kaplan F, Ajredini R, Zachariah C, Alborn HT, Teal PEA, Malik RU, Edison AS, Sternberg PW, Schroeder FC (2008) A blend of small molecules regulates both mating and development in *Caenorhabditis elegans*. *Nature* 454:1115-1119
- Wedekind C, Seebeck T, Bettens F, Paepke AJ (1995) MHC-dependent mate preferences in human. *Proceedings of the Royal Society B* 260:245-249
- Wyatt TD (2014) An introduction to chemical terms for non-chemists. From: *Pheromones and Animal Behavior*, 2nd edition. Cambridge University Press.
- Zan J, Li Z, Tianero MD, Davis J, Hill RT, Donia MS (2019) A microbial factory for defensive kahalalides in a tripartite marine symbiosis. *Science* 364:eaaw6732.