Bios 4620/6620 Syllabus

**[Aquatic Chemical Ecology, 3 Credits]**

**[Tu Th, 1530-1645h, Howey Physics N210**

**Instructor Information**

|  |  |  |
| --- | --- | --- |
| Instructor | Email | Office Hours & Location |
| [Mark Hay] | [mark.hay@biology.gatech.edu] | [EST 2102, 1300-1400h, Wed; and by appointment; it is best to just email me and set-up a mutually agreeable time] |

**General Information**

**Description**

Most organisms have neither eyes nor ears and so sense the world via chemical cues. This course focuses on understanding how chemical signals and cues (especially in aquatic systems) produce both direct and cascading effects on behavior, population regulation, community organization, and the structure and function of ecosystems. In summary, chemistry is ‘the language of life” – our goal is to learn more about ecology and evolution by better understanding that language.

## Pre- &/or Co-Requisites

BIOS 2300 or 2310 are pre-requisites, but a number of students, primarily engineering students, with strong interests in marine biology but without these pre-requisites have petitioned me to wave the pre-requisites and have done well in the course. If you are interested, discuss your interests and background and I’ll consider making an exception.

## Course Goals and Learning Outcomes

[Goals include:

* Learn to appreciate the extremely important roles of chemical cues and signals in determining how organisms select living sites, mates, avoid predators, fine prey, etc.
* Understand how complex biotic interactions are regulated by chemical cues and signals and the cascading effects of these chemically-mediated interactions on organism physiology, on population regulation, and on community structure and ecosystem function.
* Learn the fundamentals of how good science is conducted by using strong inference and multiple working hypotheses.
* Become comfortable and proficient at reading, evaluating, and challenging the primary literature (i.e., we will not use a book, but will read and evaluate the primary literature related to each lecture topic).
* Learn to appreciate how these chemically-mediated interactions give us insights into the past ecological and evolutionary forces that strongly affect populations and communities, and how these insights can be used to more wisely manage, conserve, and potentially restore the natural communities and ecosystem services upon which humans and other species depend.

**Course Requirements & Grading**

|  |  |  |
| --- | --- | --- |
| Assignment  | Date | Weight (Percentage, points, etc.) |
| Pop Quiz | Throughout the course | 5% |
| Exam 1 | 8 Feb | 20% |
| Exam 2 | 15 March | 20% |
| Exam 3 | 3 May (the final) | 20% |
| summary paper and presentation | Varies by student | 15% (5% for the write up and 10% for the presentation) |
| Research proposal | Self-scheduled, but before 2400h on 12 April | 20% |
| Class participation/ discussion |  | 3% extra credit |

**Extra Credit Opportunities**

There will be considerable class discussion about the strengths and weaknesses of the assigned papers, major issues in the field of chemical ecology, etc. At the end of the semester I’ll add 0 to 3 points to each person’s grade based on their contributions in class. Did you participate fully? Did you come with challenging questions or have insightful comments? Were you prepared by having read the paper assigned, etc.?

**Description of Graded Components**

There is no book for the class. We will read primary literature papers (i.e., real science or scientific summaries of real experiments or topics). Lectures and discussions will cover aspects of the papers, but will be broader in scope so as to better cover the general concepts and studies that the assigned papers represent one aspect of. YOU NEED TO BE IN CLASS AND TO TAKE NOTES – NOT ALL INFORMATION WILL BE IN THE READINGS OR ON THE POWERPOINTS. I’ll devote some time in each class period to discussions – some of the test material will come from these discussions – if you are not in class, you won’t know of the issues raised and discussed. I do not post powerpoints before the lecture. I will post the powerpoints before a test.

**Three tests:**

Tests will consist of a mix of multiple choice and short answer (a few sentences to a paragraph) questions mandating that you understand and be able to work with the concepts we covered. There are three exams (each covers only the material presented since the previous test). I am not reluctant to ask questions on the tests that have been addressed directly by the papers, but little, if at all, in class. I will ask questions about topics that come up in class discussions and were not in the reading or in the lecture – thus, you need to be in class. READ the assigned papers and understand them – if you don’t understand them, bring that up for discussion.

**Pop quizzes:**

I EXPECT YOU TO READ THE ASSIGNED PAPERS **BEFORE** COMING TO EACH CLASS. I will give pop quizzes designed to see if you read the papers as assigned (i.e., to punish you for not reading the papers and not being prepared to participate – there will be no make-ups for missed pop-quizzes, but you can drop ONE. Thus, don’t miss class and don’t be late). As you read the papers, make notes on what you question about them and bring that up in discussions in class. A LOT of learning occurs via these discussions. Don’t be hesitant to ask questions – If you have that question, others probably do as well.

**Short summary paper and presentation:**

You are to find, read, and summarize **in no more than one page** (12 pt font, single spaced, 1 inch margins all round) a primary research paper about a topic on our schedule - or one that covers chemical ecology but that we don't address on the schedule. This assures that we cover a variety of topics in the class and that you get to cover something that you choose and find interesting. YOU CANNOT SELECT AND REPORT ON A PAPER I'VE ASSIGNED LATER IN OUR READING ASSIGNMENTS - SO LOOK AHEAD AND BE SURE NOT TO START SUMMARIZING ONE OF THOSE. A good way to look for good papers to consider is to look at the papers cited [in recent papers] or at papers that have cited the paper I assign [for older papers]). Find something that interests you. If there are special topics that interest you and that we are not covering, ask me if you can do a summary on a paper on that topic. I often OK these requests. Sources for good papers are *Science, Nature, PNAS, Ecology Letters, Ecology, Marine Ecology Progress Series, Oecologia, Ecological Applications, Trends in Ecology and Evolution*….). **Include the following in each summary:**

1) the reference for the paper,

2) a quick summary of the hypotheses, methods, and findings,

3) strengths of the study (what makes it interesting, novel, substantial and rigorous, etc.),

4) limitations of the study (are the methods suitable for the questions addressed? Do the author’s conclusions exceed the foundations of their data? etc. Explain your conclusions about these issues), and

5) a short statement on the overall value of the paper given its relative strengths and limitations.

SUBMIT THESE VIA EMAIL – PUT YOUR NAME ON THEM… somehow the need for this repeatedly escapes some.

**After turning this in and getting feedback from me, prepare a 10 minute powerpoint on this paper.** You will then present that powerpoint to the class at the end of one of the classes starting on 25 January (i.e., I’ll give you a couple of weeks to get prepared – **TURN IN YOUR SUMMARY SEVERAL DAYS BEFORE YOUR PRESENTATION SO YOU HAVE TIME TO GET FEEDBACK ON IT.**

**I’ll “volunteer” some of the graduate students to go first on this effort, so they will be the initial guinea pigs**). **I WILL SCHEDULE THIS FIRST COME FIRST SERVED VIA EMAIL SO DETERMINE A 1ST, 2ND, AND 3RD CHOICE OF DATES ASAP AND ACT FAST WHEN YOU GET THE EMAIL ON THIS. AVAILABLE DATES ARE FEB 1, 3, 8, 15, 17, 22, 24, MAR 1, 3, 8, 10, 17, 29, APR 5, 7, 12, 14, 19 (missing dates are test days, days when I have to be gone, etc.).**

**Larger research paper:**

During the course, we will repeatedly discuss issues of experimental design, rigor, confounding factors in experiments, ways to control for, or lessen the influence of these, etc. By mid-way through the course, I expect you to have a good idea of how to pose and answer a novel question, how to conduct an experiment, how to be sure of appropriate controls, etc. **Thus, this final assignment is for you to write a short research proposal proposing an experiment in aquatic chemical ecology.** You need to include: a title, a short abstract of the question, an introduction providing background and justifying the importance of the question, and finally, a detailed experimental design on how you will address the question posed. The paper can be no more than 5 pages (10 pages for graduate students) single spaced (12 point font, 1 inch margins, - literature cited does not count in the 5 [or 10] pages). You will be graded on the depth and understanding you show of the topic, of experimental design, and on the novelty and importance of the question you ask. As you progress through the semester reading papers, be on the look-out for what you see as unanswered questions you have after reading some of your favorite papers – these make good topics for a proposal. In numerous cases, students have used this proposal as a first draft for their M.S. or Ph.D. research. For those of you considering grad school, view this as an opportunity that may provide more than simply a grade in this class. YOU CAN SELF-SCHEDULE THIS AND TURN IT IN ANY TIME BEFORE MIDNIGHT ON APRIL 12.

**Job Opportunities, Summer courses, etc.** - Some of you will be interested in summer jobs involving chemical ecology, marine ecology, summer classes, going on to grad-school, etc. Information I get regarding these will be sent to you via email, or possibly announced in class. Doing well, preferably very well, in this class enhances my ability to promote you for such opportunities. I also may hire assistants for the summer, and I work in French Polynesia (Tahiti, Moorea, Tetiaroa), Palmyra, etc. so…..

**Grading Scale**

I grade rigorously and expect you to do well. Your final grade will be assigned as a letter grade according to **roughly** the following scale. However, given that I’m a rigorous grader, it is not uncommon for there to be few students with 90%+ grades. **I commonly curve the grades and it is not unusual for 86%+ to be in the A group.** As we progress through the tests, I’ll show you the class distribution on each test and you can see your placement within the class distribution

A 90-100%

B 80-89%

C 70-79%

D 60-69%

F 0-59%

**Course Materials**

**Course Text**

We will read the primary literature (i.e., real scientific papers) for each lecture. There is no textbook. Papers for each lecture are listed below and will be available on Canvas or the equivalent (Tech periodically changes this, but you will know by the time class starts).

## Additional Materials/Resources

## If you are interested in specific topics within chemical ecology and want additional information, come discuss this with me and I can lead you to specific texts or suggests searches focused on especially impactful researchers, etc.

## Course Website and Other Classroom Management Tools

Readings, schedules, etc. will be posted on Canvas

**Course Expectations & Guidelines**

## 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 on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

## Accommodations for Students with Disabilities

If you are a student with learning needs that require special 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 special needs and to obtain an accommodations letter. See me or e-mail me to discuss your learning needs and we will find a way that is fair and works.

## Attendance and/or Participation

## Lectures and discussions will cover aspects of the papers but will be broader in scope so as to better cover the general concepts and studies that the assigned papers represent one aspect of. YOU NEED TO BE IN CLASS AND TO TAKE NOTES – NOT ALL INFORMATION WILL BE IN THE READINGS OR ON THE POWERPOINTS. I’ll devote some time in each class period to discussions – some of the test material will come from these discussions – if you are not in class, you won’t know of the issues raised and discussed.

## Collaboration & Group Work

## Science is often a collaborative, interactive effort. During discussions in and out of class it is fine to share ideas, build and learn based on group discussions and interactions, etc. but for your presentation, research proposal, tests, etc. I expect all work to be your independent effort.

## Extensions, Late Assignments, & Re-Scheduled/Missed Exams

If you have an excused absence for missing an exam, I’ll give you a make-up exam, but it may be oral instead of written or a long summary paper to write instead of a standard test. Your proposal and presentation can be self-scheduled (but I’ll “help” with this if I don’t see you doing so). I expect all of these to be done on time. If you are late with assignments, come discuss this with me. If you have a very good reason (you were hospitalized, etc.), we will work out a way to give you additional time. If your reason for being late is less persuasive, I’ll deduct 5% of that grade’s value/day for each day it continues to be late.

## Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. 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.

## Student Use of Mobile Devices in the Classroom

No mobile phone use. You can use your computer for notes, for looking at the specifics of the papers we are discussing, etc, but usage needs to be for academic activities.

**Campus Resources for Students**

Georgia Tech has a range of services to help support your mental, emotional, and physical well-being. Click [here](http://ctl.gatech.edu/sites/default/files/documents/campus_resources_students.pdf) for a list of these relevant campus resources.

**Course Schedule**

**Schedule of Topics and Readings**

**(Readings are to be completed BEFORE class)**

**A GENERAL OVERVIEW OF AQUATIC CHEMICAL ECOLOGY**

**January:**

**11** - **Introduction to the course – This is about chemical ecology, but also about SCIENCE** –Read the one-page essay handed out in class and get comfortable with asking “stupid” questions. If we don’t ask these questions, we stay stupid – so speak up; doing so also will help those around you, and the “stupid” questions are often some of the most critical ones….

 **What is “Science”?**

**Why CHEMICAL Ecology**?

**The value of discussion instead of just lectures**: (real science is questioning/discussion/testing hypotheses – not defending them. *Science* is not listening, remembering, and taking tests; it is erecting novel questions and designing ways to answer them rigorously.)

READINGS – If you have not read these for other classes, read 1) Schwartz MA (2008) the importance of stupidity in scientific research. J Cell Sci 121:1771 (**IT IS ONLY ONE PAGE – READ IT)** and2) Chamberlin TC (1965 – **but really 1890. It is to my knowledge the only paper that has been published twice in Science**) The method of multiple working hypotheses. Science 148:754-759

**13 - Guest Lecture – Prof. Steve Diggle; Bacteria communicate chemically.**

 READ – Azimi et al. 2020. Bacterial quarum sensing during infection. Annu Rev Microbiol 74: 201-219.

**18 - Chemical ecology: Setting the stage -from molecules to ecosystems (part 1)**

 READ – Hay ME (2009) Marine chemical ecology: chemical signals and cues structure marine populations, communities, and ecosystems. Annu Rev Mar Sci 1:193-212

**20 - Chemical ecology: Setting the stage -from molecules to ecosystems (part 2)**

 READ - Seymour JR, Amin SA, Jean-Baptiste Raina J-B, Stocker R. 2017. Zooming in on the phycosphere: the ecological interface for phytoplankton-bacteria relationships. Nature Microbiology, Vol 2: Article 17065

**CHEMICALLY- MEDIATED FORAGING AND CONSUMER-PREY INTERACTIONS**

**25 - Chemically-mediated foraging (large-scale tracking) + (small-scale tracking and prey responses).**

 READ - Savoca MS, Nevitt GA (2014) Evidence that dimethyl sulfide facilitates a tritrophic mutualism between marine primary producers and top predators. Proc. Nat. Acad. Sci. 111: 4157-4161.

**27 - Micro-scale responses**

 READ - Seymour JR, Simo R, Ahmed T, Stocker R (2010) Chemoattraction to dimethylsulfoniopropionate throughout the marine microbial food web. Science 329: 342-345.

**February:**

**1 - Defense: Getting lunch w/o becoming lunch – chemical warfare in the sea**

READ - Rasher DB, Stout EP, Engel S, Shearer TL, Kubanek J, Hay ME. (2015) Marine and terrestrial herbivores display convergent chemical ecology despite 400 million years of independent evolution. Proceedings of the National Academy of Sciences 112: 12110-12115

 Student presentation by:

**3**  **- Chemical ecology and specialization in the sea: Why small herbivores eat toxic plants**

READ – Hay, M. E. 1992. The role of seaweed chemical defenses in the evolution of feeding specialization and in the mediation of complex interactions. pages 93-118 in V. J. Paul (ed.), *Ecological Roles for Marine Natural Products*. Comstock Press, Ithaca, NY, USA.

Student presentation by:

**8 - Chemical mimicry?**

READ – Torres JP et al. (2021) Small-molecule mimicry hunting strategy in the imperial cone snail, *Conus imperialis*. Sci. Adv. 7, eabf2704.

Student presentation by:

**February:**

**10**  **- TEST #1 (covering 11 January – 8 February)**

**15 - Associational defense and shared doom**

READ – Stachowicz JJ, Hay ME. 1999. Reducing predation through chemically-mediated camouflage: indirect effects of plant defenses on herbivores. **Ecology** 80:495-509.

 Student presentation by:

**17**  **The geography of chemical defense**

 READ – Pennings SC, Ho IC, Salgado CS, Wieski K, Nilam D, Kunza AE, Wason E (2009) Latitudinal variation in herbivore pressure in Atlantic Coast salt marshes. Ecology 90:183-195.

Student presentation by:

**22**  - **The counter argument: Is the geography of defense a "zombie hypothesis"?**

 READ - Moles AT, Bonser SP, Poore AGB, Wallis IR, Foley WJ (2011) Assessing the evidence for latitudinal gradients in plant defense and herbivory. Functional Ecology 25, 380–388

 Student presentation by: Andrew Sharkey

**24 - The smell of fear and its cascading effects on populations, communities, and ecosystems**

READ -Turssell GC, Ewanchuk PJ, Matassa CM (2006) Habitat effects on the relative importance of trait and density-mediated indirect interactions. Ecology Letters 9: 1245–1252

 Student presentation by: Shannon Salter

March

**1**  **- Induction, activation, & costs of defenses**

 READ – Baldwin, IT. 1998. Jasmonate-induced responses are costly but benefit plants under attack in native populations. Proc. Nat. Acad. Sci. USA 95 (14): 8113-8118

 **AND**

 Selander E, Kubanek J, Hambergd M, Anderssona MX, Cervinc G, Pavia H. (2015) Predator lipids induce paralytic shellfish toxins in bloom-forming algae. Proc. Nat Acad Sci. 112: 6395-6400

 Student presentation by: Erica Strope

**THE CHEMICAL ECOLOGY OF COMPETITION**

**3**  **- Killing your neighbor - Allelopathy (costs and benefits)**

 READ - Rasher DB, ME Hay. 2014. Competition induces allelopathy but suppresses growth and anti-herbivore defence in a chemically rich seaweed. Proceedings of the Royal Society B 281: 1-9

 Student presentation by: Yiping Zuo

**8 - Offense and defense via chemically-mediated mutualists**

 READ - Dixson DL and ME Hay. 2012. Corals chemically cue mutualistic fishes to remove competing seaweeds Science 338: 804-807

 AND

Lopanik NB. 2014. Chemical defensive symbioses in the marine environment. Functional Ecology 28:328-340

 Student presentation by: Christine McDonald

**10 - Microbes as competitors: Why fish stink**

READ **-** Burkepile, DE, JD Parker, CB Woodson, HJ Mills, J Kubanek, PA Sobecky, and ME Hay. 2006. Chemically-mediated competition between microbes and animals: microbes

as consumers in food webs. Ecology 87:2821-2831

 Student presentation by: Hannah Strudwick

**15 - TEST #2 (covering 15 Feb - 10 March)**

**17 - Chemical defense against disease.**

 READ – Rebecca J. Case, Sharon R. Longford, Alexandra H. Campbell, Adrian Low, Niina Tujula, Peter D. Steinberg, Staffan Kjelleberg. 2011. Temperature induced bacterial virulence and bleaching disease in a chemically defended marine macroalga. Environmental Microbiology 13(2), 529–537

 AND

 Gil-Turnes, M. S., M. E. Hay, and W. Fenical. 1989. Symbiotic marine bacteria chemically defend crustacean embryos from a pathogenic fungus. Science 246:116-118.:

 Student presentation by: Harry Tuazon

**22 - SPRING BREAK**

**24 - SPRING BREAK**

**SOCIAL INTERACTIONS/ RECRUITMENT**

**29 Outside discussion session**

**31 - Chemical cues and dominance**

 READ – Bergman DA, Moore PA (2005) Prolonged exposure to social odours alters subsequent social interactions in crayfish (*Orconectes rusticus*). Animal Behaviour 70:311-318

 Student presentation by:

**April:**

**5 - Sex (Pheromones)**

 **READ -** Bagoien E, Kiorboe T (2005) Blind dating – mate finding in planktonic copepods. I. Tracking the pheromone trail of *Centropages typicus*. Mar Ecol Prog Ser 300:105-115

 AND

 Gelstein S, Y Yeshurun, L Rozenkrantz, S Shushan, I Frumin, Y Roth, N Sobel. 2011. Human tears contain chemosignal. Science 331: 226-230

Student presentation by: Tyler Houts

**YOUR RESEARCH PROPOSAL NEEDS TO BE TURNED IN BY MIDNIGHT ON 12 APRIL - SEND IT EMAIL (YOU CAN DO IT EARLIER, TO GET IT OUT OF YOUR WAY - AND I SUGGEST DOING SO)**

**7 - Kin and competitor recognition**

 READ - Karban R, Shiojiri K, Ishizaki S, Wetzel WC, Evans RY. 2013 Kin recognition affects plant communication and defence. Proc R Soc B 280: 20123062. http://dx.doi.org/10.1098/rspb.2012.3062

 AND

 Grosberg RK (1981) Competitive ability influences habitat choice in marine invertebrates. Nature 290: 700-702

 Student presentation by: Andrew Sharkey

**12 - Settlement/recruitment cues**

 READ – Dixson DL, D Abrego, ME Hay. 2014. Chemically-mediated behavior of recruiting corals and fishes: a tipping point that may limit reef recovery. Science 345:892-897

Student presentation by:

**14 - Global change and impacts on chemical cuing behavior.**

 READ – Munday PL, AJ Cheal, DL Dixson, JL Rummer, KE Fabricius. 2014. Behavioral impairment in reef fishes caused by ocean acidification at CO2 seeps. Nature Climate Change 4: 487-492.

 Student presentation by:

**19 - Do anthropogenic compounds disrupt chemical communication?**

 READ - Heidi S. Fisher, Bob B. M. Wong, Gil G. Rosenthal. 2006. Alteration of the chemical environment disrupts communication in a freshwater fish. Proc. R. Soc. B 273: 1187–1193

 AND

 Ashley J. W. Ward, Alison J. Duff, Jennifer S. Horsfall, Suzanne Currie. 2008. Scents and scents-ability: pollution disrupts chemical social recognition and shoaling in fish. Proc. R. Soc. B (2008) 274, 101–105

Student presentation by: Sara Pierson

**21 - go to the ecology seminar 3:00-4:00 in** Dalney 180

(In non-covid times, 1-2 researchers with expertise in chemical ecology would generally “drop-by” during the semester for a visit. When this happens, I get them to give a guest lecture on their research, and you get to interact with them. In “covid-times” this is less likely, but I’m ever hopeful, so I’m holding one slot open just-in-case. If we get such an opportunity, we will slot them in when possible and bump lectures down by a period.)

**28 - FINAL EXAM (1440-1615 h – the final is NOT cumulative. It will cover topics addressed between 17 March and 21 April. Testing will start at 1440h, but will take only ~1h)**