ARTICLE

Mad Dogs, Vampires, and Zombie Ants: A Multidisciplinary Approach to Teaching Neuroscience, Behavior, and Microbiology

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Viruses, parasites, and some bacteria use host organisms to complete their lifecycle. These infectious agents are able to hijack host processes to replicate and transmit to the next host. While we tend to think of infections as just making us sick, they are also capable of changing host behavior. In fact, many infectious agents are able to mediate host behavior in ways that can enhance transmission of the disease. In this course we explore the process of host behavior mediation by infectious agents, combining aspects of multiple fields including neurobiology, animal behavior, infectious disease microbiology, and epidemiology. The goals for this course are: 1) To explore the neurological and behavioral effects of infectious organisms on their hosts, in particular pathogen mediation of host behavior to the benefit of the pathogen, 2) to introduce students to primary literature in a multidisciplinary field, and 3) when applicable, to address cultural/historical/mythological perspectives that might alter societal norms and pressures and influence the impact of the biological processes of behavior modification by infections.

Key words: behavior manipulation hypothesis, parasite, virus, bacteria, modal action patterns, neurons, gut-brain axis, conditioning, arousal

The concept of behavior manipulation by infectious agents has received considerable attention in the popular media (Zimmer, 2012), scientific literature including an entire issue of the Journal of Experimental Biology (Adamo and Webster, 2013), and a new textbook (Hughes et al., 2012). We capitalize on this inherently multidisciplinary topic in the development of a course serving as part of the capstone experience for neuroscience students at Vassar College. A complete understanding of the behavior manipulation hypothesis requires integrating concepts in neuroscience, behavior, microbiology, ecology, and epidemiology. Drawing on our respective expertise in microbiology and behavioral neuroscience, we present a team-taught undergraduate course, “Mad Dogs, Vampires and Zombie Ants: Behavior Mediating Infections,” that has three explicit goals: 1) To explore the neurobiological and behavioral effects of infectious organisms on their hosts, in particular pathogen mediation of host behavior to the benefit of the pathogen, 2) to introduce students to primary literature in a multidisciplinary field, and 3) when applicable, to address cultural/historical/mythological perspectives that might alter societal norms and pressures and influence the impact of the biological processes of behavior modification by infections.

Senior capstone experiences allow for valuable integrative opportunities to address contemporary issues in neuroscience (Kennedy and Hassebrock, 2012; Wiertelak and Ramirez, 2008). Ramirez (2007) makes the strong case that the study of neuroscience addresses issues “ranging from the molecular to the metaphysical” (p. E7). Our capstone course draws on this liberal arts charge as it requires students to engage issues from the structure of a virus to free will.

We argue that closely related to the content goals of advanced level neuroscience courses is the aim to foster in neuroscience students good “scientific citizenship.” This includes providing opportunities for them to hone scientific presentation skills, to witness how successful laboratories engage in programmatic research, to engage in (and be rewarded for) conversations about the science outside of mandated class-time, and to develop their own research projects based on the existing literature.

Here we present how our course contributes to a neuroscience and behavior program, details of the content and conduct of this capstone seminar, assessment of meeting course objectives, student evaluations of the course, and an analysis of the strengths and continuing challenges of offering such courses.

THE NEUROSCIENCE AND BEHAVIOR PROGRAM

The Neuroscience and Behavior Program at Vassar College was established in 1985. It is a 13 course major, drawing content from and taught by professors in the Departments of Biology and Psychology. Students take both an introductory sequence in Psychology (consisting of Introduction to Psychology, Statistics and Experimental Design, and Principles of Physiological Psychology) and an introductory sequence in Biology (consisting of two semesters of coursework, one of which includes a laboratory). These courses serve as the prerequisite to the first of two neuroscience-major specific courses. This first course is laboratory based, a module for which has been described previously in this journal (Raley-Susman and Gray, 2010). At the intermediate level, students select two courses from an approved list of neuroscience related courses (one each from Psychology and Biology) and take a neuroscience laboratory based research methods course staffed by members of the Department of Psychology. The capstone requirement for the major consists of four advanced level courses. One of these courses is the second of the two neuroscience-major specific courses. This course at the advanced level is taught in a seminar format. The remaining three courses are selected from a list of neuroscience-related advanced courses in Biology and Psychology. It is to this aspect of the capstone requirement that our course contributes.

In addition to its place in the neuroscience and behavior program, the course fulfills one of the senior-level requirements for Biology and Psychology majors.

OVERVIEW OF COURSE CONTENT

The catalogue description for this course is presented in Table 1. The host-pathogen relationship is a complicated one in which the pathogen uses host resources and machinery for replication, and ultimately, transmission to the next host. While the details of the process vary tremendously, from a virus entirely dependent on host cellular processes to replicate to a multicellular parasitic worm dependent on more than one host species to complete its lifecycle, each agent of disease is only successful if it manages to transmit to the next host. There is an expanding body of research demonstrating that many parasites, broadly defined, are capable of altering host behavior, likely to the benefit of the parasite by enhancing transmission. The course is structured around readings of the primary literature, which is highly multidisciplinary. The list of assigned readings for each topic is given in Table 2.

We begin the course with a presentation of concepts from neuroscience and behavior that serve as foundations upon which subsequent topics build. For example, students are introduced to taxes and kineses that are co-opted by infectious agents during behavior manipulation. Further, known neural pathways and related neurotransmitters, especially those in insects and those related to sensory systems, are detailed for the students to further their understanding of how seemingly small perturbations of existing behavior mechanisms allow pathogens and parasites to alter behavior.

From this starting point we introduce viruses. The Rabies virus infects through a bite wound and travels via retrograde transport from neurons innervating the wound site to the brain, and eventually, to the salivary gland. By an unknown mechanism, infection of the brain frequently leads to aggressive behavior driving the animal to bite with its mouth full of virus-laden saliva. We explore viral replication cycles, the structure of neurons, and modal action patterns. We also discuss the proposal of rabies virus infections in humans as the origin of vampire legends. Dengue virus is used to illustrate manipulation at the sensory level, through its alteration of olfaction in infected mosquitoes.

We then move on to the parasite *Toxoplasma gondii.* Here students are exposed to the first cellular parasite covered in the course, and the complexities of the asexual and sexual stages of its life-cycle, including dependence on both rodent and feline hosts. Completion of the sexual stage of the *T. gondii* life-cycle requires transmission from the rodent host to the gastrointestinal tract of the cat. To achieve this, the parasite overcomes the aversion of the rodent host for its predator through activation of neuronal pathways involved in sexual arousal, rather than fear, in response to cat odors. Here we begin to explore in greater depth experimental design for the investigation of animal behavior, neuronal signaling in response to stimuli, conditioning, arousal, and the limbic system. We then evaluate the evidence linking *T. gondii* in humans with schizophrenia.

PSY 385 - Mad Dogs, Vampires and Zombie Ants: Behavior Mediating Infections

1 unit

(Same as BIOL 385) Viruses, bacteria and parasites use host organisms to complete their lifecycle. These infectious agents are masters of host manipulation, able to hijack host processes to replicate and transmit to the next host. While we tend to think of infections as just making us sick, they are also capable of changing our behavior. In fact, many infectious agents are able to mediate host behavior in ways that can enhance transmission of the disease. In this inquiry driven course we explore the process of host behavior mediation by infectious agents combining aspects of multiple fields including infectious disease microbiology, neurobiology, epidemiology, and animal behavior. Mathematical models and computer simulations are used to address questions that arise from class discussion. Mr. Esteban and Mr. Holloway.

Prerequisites: two 200-level biology courses, or Psychology Research Methods Course and either PSYC 241 or PSYC 243, or one 200-level biology course and either NEUR 201 or PSYC 241, or CMPU 250 and one of the previously listed courses.

Table 1. Catalog Description.

We introduce more complex parasites, and further discussion of experimental approaches to the study of animal behavior and species typical behavior, with *Paragordius*, a hairworm shown to induce suicidal behavior in host crickets, and *Ophiochordyceps*, the "zombie ant" fungus. Thanks in part to students interested in ecology, we found the discussion of these topics infused new ideas into the course by considering the challenges of studying animal behavior in the field, and the greater role of parasites and behavior mediation on entire ecosystems.

With the parasitoid wasp *Ampulex,* we begin to explore beyond host-parasite and into predator-prey relationships. *Ampulex* precisely injects neurotoxins into the sub-esophogeal ganglion of a cockroach resulting in decreased initiation of movement, recalling the symptoms of Parkinson's disease in humans. The parasitoid wasp lays its eggs inside the cockroach, using it as a live but subdued food source for developing larvae.

Placement of bacteria at the end of the course provides an opportunity to challenge strict definitions of parasitism

Fear	Epstein JM, et al. (2008) Coupled contagion dynamics of fear and disease: Mathematical and computational explorations. PLoS ONE 3:1-11.
Rabies virus	Gómez-Alonso J (1998) Rabies: a possible explanation for the vampire legend. Neurology 51:856–859. Fu ZF, Jackson AC (2005) Neuronal dysfunction and death in rabies virus infection. J Neurovirol 11:101–106. Dietzschold B, et al. (2008) Pathogenesis of rabies. Curr Top Microbiol Immunol 292:45–56. Wang X, et al (2010) Aggression and rabid coyotes, Massachusetts, USA. Emerging Infect Dis 16:357–359.
Kakugo virus	Fujiyuki T, et al (2009) Distribution of Kakugo virus and its effects on the gene expression profile in the brain of the worker honeybee Apis mellifera L. J Virol 83:11560–11568. Fujiyuki T, et al (2004) Novel insect picorna-like virus identified in the brains of aggressive worker honeybees. J Virol 78:1093-1100.
Dengue virus	Lima-Camara TN, et al. (2011) Dengue infection increases the locomotor activity of Aedes aegypti females. PLoS ONE 6:1-5. Sim S, et al. (2012) Dengue virus infection of the Aedes aegypti salivary gland and chemosensory apparatus induces genes that modulate infection and blood-feeding behavior. PLoS Pathog 8:1-15.
Toxoplasma (rodents)	House PK, et al (2011) Predator cat odors activate sexual arousal pathways in brains of Toxoplasma gondii infected rats. PLoS ONE 6:1-4. Vyas A, et al (2007) The effects of toxoplasma infection on rodent behavior are dependent on dose of the stimulus. Neuroscience 148:342–348.
Toxoplasma (humans)	McAuliffe K (2012) How your cat is making you crazy. The Atlantic Monthly 309: 36-40, 42-44. Flegr J (2007) Effects of Toxoplasma on human behavior. Schizophrenia Bull 33:757–760. Okusaga O, et al. (2011) Toxoplasma gondii antibody titers and history of suicide attempts in patients with schizophrenia. Schizophrenia Res 133:150–155. YOlken RH, et al. (2009) Toxoplasma and schizophrenia. Parasite Immunol 31:706–715.
Ophiocordyceps	Andersen SB, et al. (2009) The life of a dead ant: The expression of an adaptive extended phenotype. Am Nat 174:424–433. Hughes DP, et al. (2011) Behavioral mechanisms and morphological symptoms of zombie ants dying from fungal infection. BMC Ecol 11:13. Pontoppidan M-B, et al. (2009) Graveyards on the move: The spatio-temporal distribution of dead Ophiocordyceps-infected ants. PLoS ONE 4:1-10.
Paragordius	Ponton F, et al. (2011) Water-seeking behavior in worm-infected crickets and reversibility of parasitic manipulation. Behav Ecol 22:392–400. Sanchez MI, et al. (2008) Two steps to suicide in crickets harbouring hairworms. Anim Behav 76:1621–1624. Thomas F, et al. (2002) Do hairworms (Nematomorpha) manipulate the water seeking behaviour of their terrestrial hosts? J Evol Biol 15:356–361. Thomas F, et al (2003) Biochemical and histological changes in the brain of the cricket Nemobius sylvestris infected by the manipulative parasite Paragordius tricuspidatus (Nematomorpha). Int J Parasitol 33:435–443.
Ampulex	Gal R, Libersat F (2008) A parasitoid wasp manipulates the drive for walking of its cockroach prey. Curr Biol 18:877–882. Gal R, Libersat F (2010) A wasp manipulates neuronal activity in the sub-esophageal ganglion to decrease the drive for walking in Its cockroach prey. PLoS ONE 5:1-10. Libersat F, et al. (2009) Manipulation of host behavior by parasitic insects and insect parasites. Annu Rev Entomol 54:189–207.
Wolbachia	Hiroki M, et al. (2002) Feminization of genetic males by a symbiotic bacterium in a butterfly, Eurema hecabe (Lepidoptera: Pieridae). Naturwissenschaften 89:167–170. Huigens ME, et al. (2000) Infectious parthenogenesis. Nature 405:178–179. Weeks AR, et al. (2002) Wolbachia dynamics and host effects: what has (and has not) been demonstrated? Trends Ecol Evol 17:257–262.
Gut bacteria	Leland, KN et al. (2010) Niche construction, ecological inheritance, and cycles of contingency in evolution. In: Cycles of contingency: Developmental systems and evolution (Oyama S, Oding-Smee FJ, and Feldman MW, ed), pp 117-126. Cambrige, MIT Press. Bravo JA, et al. (2011) Ingestion of Lactobacillus strain regulates emotional behavior and central GABA receptor expression in a mouse via the vagus nerve. Proc Natl Acad Sci USA 108:16050–16055. Diaz Heijtz R, et al. (2011) Normal gut microbiota modulates brain development and behavior. Proc Natl Acad Sci USA 108:3047–3052. Dinan TG, Cryan JF (2012) Regulation of the stress response by the gut microbiota: Implications for psychoneuroendocrinology. Psychoneuroendocrinology 37:1369–1378.
Final	Luong LT, et al. (2011) Parasite-induced changes in the anti-predator behavior of a cricket intermediate host. FEMS Microbiol Ecol 117:1019–1026.

Table 2. Topics and assigned readings.

and mutualism. The endosymbiotic bacterium *Wolbachia* induces a wide range of behavioral and developmental effects, including feminization of males. We finish the course with new research on the role of commensal gut bacteria on neurological development and anxiety. We explore the gut-brain axis, and again challenge student's perceptions of agency.

Several themes recur throughout, providing numerous opportunities to relate concepts back to previous host-pathogen pairs covered in class and allowing students to make connections among topics. These include central concepts in neuroscience and behavior, microbiology, general biology, and cognitive science. Students consider the behavioral manipulation hypothesis, whether behaviors, symptoms, and other signs of disease are the result of parasite action (such as production of a toxin), host response (such as tissue damage due to inflammation), or a combination. Further, students evaluate the host-pathogen relationship from an evolutionary perspective. Richard Dawkins' concept of the extended phenotype, in which the parasite's genes influence its environment (the host), is frequently raised (Dawkins, 1982).

Students also have the opportunity to critically evaluate the evidence supporting the behavior mediation hypothesis, and can see how the research in an entire discipline evolves. For example, behavior mediation by the newly identified Kakugo virus is only speculated from correlative studies, as are the effects of *Toxoplasma* on humans, while the research into the parasitoid wasp *Ampulex* and *Toxoplasma* infections in mice are supported with mechanistic explanations of the observed behavioral changes.

Due to the emphasis on primary literature, students are exposed to experimental techniques in diverse fields. They see experiments in animal behavior using a variety of species from mice to cockroaches and mosquitos, and are exposed to the structure and function of the brain and nervous system of insects and mammals. This diversity is beneficial in demonstrating the use of simple and complex organisms in neuroscience and behavioral studies.

COURSE FORMAT AND CONDUCT

Target students

This course is designed for advanced students of neuroscience, biology, and psychology. It is cross-listed in the course catalog in both psychology and biology to reach the greatest number of interested students. As prerequisites, students meet either the requirements for an advanced level psychology course, or an advanced level biology course. Meeting these requirements necessarily satisfies the requirements for neuroscience.

At Vassar, capstone courses typically cap at approximately 15 students. We allow 21 students to enroll in this course, in part due to demand, and in part to ensure that students of various science backgrounds have the opportunity to enroll. During a preregistration phase, 16 students are permitted to enroll, eight from each cross-listed department. From a lengthy waitlist, we select five additional students in a manner to balance the student background preparation. We are able to have approximately equal number of neuroscience and biology/biochemistry students with this strategy. We also are able to admit a small number of well-prepared students from other majors, and have interest from students in Vassar's Cognitive Science program and Department of Religion as the course necessarily addresses issues of agency and intentionality.

Assignments

Students are required to make two in-class presentations, write one primary on-line discussion entry on the class blog, participate regularly in the on-line blog discussions based on other's discussion entries, participate in classroom discussions, and write a response to a take-home final exam question.

Presentations. Groups of 4-5 students prepare approximately 1-hour presentations of the topic to be discussed the next class. Each student contributes to two presentations over the course of the semester, with group composition varying. As part of our goal to foster oral presentation skills, each student is expected to contribute about 15 min of material to the presentation. For grading purposes, the first presentation is weighted substantially less than the second for any given student. This allows us to shape presentation skills and reward improvement. Well in advance of their presentations, students are provided with the readings assigned to the class as a whole, and with a few additional background "seed" articles to help prepare for the topic. We also expect that each student will contribute material from 8-10 more articles in their presentations. Further expectations for the presentations are included on the syllabus. Students are informed that their grade will be determined by 1) comprehensive coverage of the assigned readings, 2) thorough presentation of background readings not assigned to the class as a whole, 3) clarity, 4) integration of the individual talks, and 5) the ability to engage the class in the material. To ensure that student groups (and individuals) are prepared for their talks, we meet with the groups twice before their assigned time, once approximately one week before their delivery, once 48-24 h before they make their presentations. At this second meeting, groups are required to demonstrate their readiness for the presentation.

On-line writing and discussion. Within 24 hours of class discussion of each topic, two students not in the group presenting on that topic write on-line posts of 600-700 words on the class blog site. The bloggers task is to write on an additional related paper with the intent of stimulating continued discussion of the topic outside the classroom. On weeks when students are not making presentations, they are expected to contribute to the blog by posting comments and questions to other students. These comments count towards the overall participation grade.

Participation. In addition to the on-line conversation, class discussion is a crucial component of the success of the course, so students are expected to contribute substantially every class. They are informed on the syllabus that at a minimum they must come to every class session prepared with notes on the readings assigned for that day and a willingness to share their ideas. To emphasize this expectation, participation as a whole accounts for 30% of the course grade.

Final exam. The final assignment is a take-home, open book exercise in which the students write a research proposal. Students are provided with a recent research paper on a host-parasite pair that they have not encountered in class. Based on this, they are asked to propose the "next" experiment to contribute to this line of research. We are careful to select an un-cited, current article to prevent students from gaining hints from on-line sources. This assignment allows them to integrate the concepts and techniques learned throughout the course and apply what they have learned in a new context. Examples of programmatic research were provided in the assigned readings at several points in the semester to model the flow of research ideas (for example, see *Ophiochordyceps, Paragordius, and Ampulex* readings from Table 2). The assignment details are provided on the last day of class, and although they may prepare as they see necessary, the actual writing of the exam is limited to 2 hours. In this way our take-home final mirrors other final exams they may have.

Weekly meetings

The class meets once per week, for at least 2 hours. We teach the first two and half sessions in a lecture/discussion format. This serves the dual purpose of allowing us to review concepts from neuroscience, behavior, and the microbiology of infectious agents and to model for the students (and reinforce) our expectations of their participation.

Subsequent to our introduction, the class sessions run as follows. In the second half of class sessions, groups of 4-5 students deliver presentations, described previously, of the readings for the following week. Their classmates are thus able to address the often-difficult readings having already been exposed to the material, presented with background for the material, and prompted with discussion questions to be addressed in the next class meeting. The first hour of each class session is therefore dedicated to discussion of the readings for that day, which as just described, were presented by a peer-group the previous week. We are careful to instruct the student groups to introduce the readings, not obviate their peers' readings of them. So, for example, the student presentation on rabies may cover the basic biology of the virus, its effects on the host, and some aspects of the class readings. The following week, the class discusses the assigned rabies literature during the first hour of class. This first hour of class time, and second hour on a topic, also allows us to elucidate complicated concepts and to present materials that may have been not as fully covered in the student presentations without making the student presentations superfluous.

Supplemental Material

On several occasions we use the two hours immediately following class time to present additional material. We secure this time during registration to avoid student schedule conflicts. Most typically, this time is used to further our goal of exploring cultural/historical/mythological perspectives that might alter societal norms and pressures and influence the impact of the biological processes of behavior modification by infections. For example, we screen the movie *Contagion* during this time at the beginning of the semester. This is followed by a discussion of Epstein et al (2008) the next class session. This serves to introduce the students to basic concepts in disease transmission, virology, and the effect of changing behavior on the spread of disease. In a subsequent session we screen *28 Days Later* followed by a discussion of the rabies virus and a general review of how behavior mediating pathogens usually hijack existing behaviors rather than cause entirely new, non-species-typical behaviors to emerge.

COURSE ASSESSMENT

Encompassing and expanding the goals set forth in the introduction, we have five specific objectives for this course. These are to foster oral presentation skills, to develop skills in reading primary literature, to increase student interest in the sub-disciplines contributing to the course, to increase an appreciation for the multidisciplinary approach in science, and to increase understanding of the techniques used to investigate behavior mediating infections. We build into the course several mechanisms to assess our success at meeting these goals. The most prominent is the two-presentation strategy described previously. Following the first presentation, we provide extensive feedback on the thoroughness of students' use of primary literature, on their attention to multidisciplinary approaches to the presentation topic, on their ability to elucidate the experimental procedures presented, and on their overall presentation skills. We provide identical feedback following the second presentation allowing us, and the students, to evaluate improvement in these areas over the duration of the course. In the majority of cases, we saw improvement in all of these feedback topics directly related to our course objectives, and in no case did we see no improvement.

Our final exam format also allows us to evaluate success at meeting course objectives. As described before, we require that students apply knowledge gained in the course to a novel research question. In this way, we test the use of primary literature, use of multi-disciplinary approaches, and understanding of experimental techniques. In all cases we witnessed very good to excellent achievement of these objectives.

Finally, as detailed in the following section, we poll the students directly about their assessment of whether course objectives were met. Two factors are important in this poll. First, it provides the only mechanism to assess whether we achieve our objective of increasing student interest in the sub-disciplines contributing to the course. Second, this poll provides convergent evidence that we do meet our course objectives.

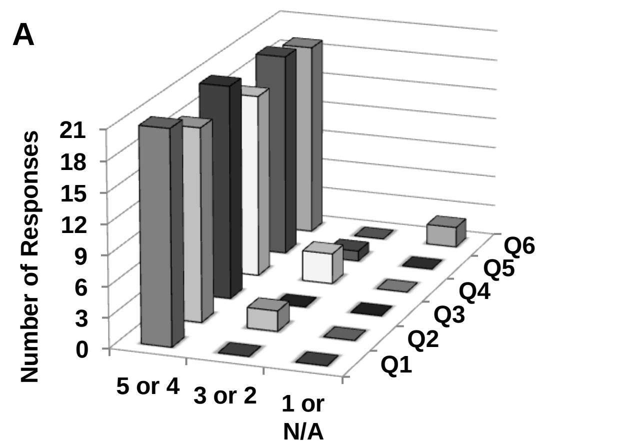
STUDENT COURSE EVALUATIONS

Within the final two weeks of a course, students at Vassar are expected to provide free-form written and rating scale evaluations of the course. Distribution by the faculty of the common forms necessary for this student feedback is mandated by College governance, and time is set aside for completion of the evaluations, typically during a final class session. The rating scale evaluations consist of 18 questions, eight of which are specific to instructor performance (e.g., organization, ability to illuminate difficult material, openness to students' point of view), six of which address course content (readings, written assignments, meeting course objectives, effort given to the course, increased knowledge, and effectiveness of team teaching), and four that are idiosyncratic to address laboratory and studio courses, etc. The ratings questionnaires contribute to professors' teaching portfolios for developmental and evaluative purposes. Additionally, we provide students the opportunity to evaluate the course with five supplemental questions addressing course objectives. Participation in the evaluations for our course was 100%.

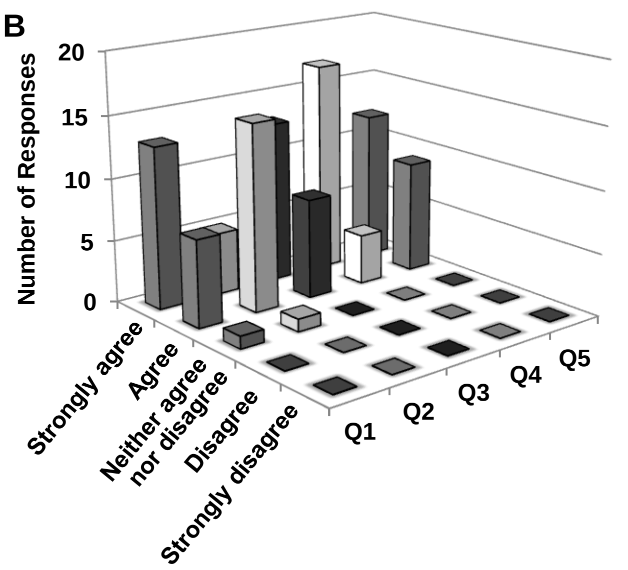
Students' evaluations of the course were very favorable. Expectations at Vassar are that on a five-point scale, with 5 being best, a minimum of 80% of the responses for each question on the common form should be 4s or 5s as a demonstration of excellence in teaching. We received at or near 100% 4s and 5s for all relevant questions. The common rating scale evaluations specific to the course are summarized in Figure 1A.

Written comments on the common form were also quite supportive of the course. One student wrote, "as a bio-chem major the neuroscience was incredible and actually I have now applied to a few neurovirology focused Ph.D. programs." Another wrote, "as a bio major, I really appreciated hearing your neuro/psych point of view on things." Highlighting aspects of our specific, unique questions one student wrote, "I really enjoyed this course and the integration of topics including biology/virology, neuroscience, and psychology," while another wrote, "I love the presentation/discussion format. I legitimately feel my presentation skills improved." Where there were common criticisms of the course, they tended to be complaints about there not being enough course hours. One student suggested increasing the number of meeting times to twice per week, another wrote, "even if the course was (sic) a little longer to accommodate more discussion, I'm sure students would still be attentive."

Although they do not contribute to official development or review processes, our particular interest was in the responses to the five supplemental questions addressing our five specific course objectives. The responses to these questions are summarized in Figure 1B. On all but one of the five questions, students rated the achievement of our goals as "strongly agree" more often than "agree." We were not surprised that the goal of "developing skills in reading primary literature" was rated slightly less high than the others. Vassar holds as a central tenet that students should "Go to the source," a quotation attributed to Lucy Maynard Salmon (1887) who founded Vassar's history



Q1: Rate the course on: Readings and other required material
Q2: Rate the course on: Written and other assignments
Q3: Rate the course on: How well the course met the objectives, as stated by the instructor
Q4: How much time, attention, and effort did you give to this course?
Q5: As a result of this course, how much have your knowledge and understanding of the subject matter increased?
Q6: How effective was the team-teaching aspect of the course?



As a result of taking this class I have:
Q1: Developed oral presentation skills
Q2: Developed skills in reading primary literature
Q3: Enhanced my interest in one or more of sub-disciplines encountered
Q4: Gained an appreciation of the importance of using a multidisciplinary approach to addressing questions
Q5: Gained an understanding of the techniques used to investigate behavior mediation infections

Figure 1. Student course evaluations. A) Results of ratings questionnaire (scale 1-5, with 5 being the highest). B) Course objective assessment.

department. We expect from introductory through advanced classes that students engage primary literature across disciplines. By the time they reach their capstone experiences, students are well versed in the literature of their majors, so we were pleased to find that even with this background, students saw us as furthering their abilities to read the literature.

DISCUSSION

By the metrics of meeting the course objectives and the student course evaluations, this course was very successful. Further, there has been substantial demand for subsequent iterations of the course suggesting that we were able to spark sustained student interest in the course material. Beyond these measures of success there were several features of this course that we found particularly positive with regard to neuroscience and behavior programs.

The issues in staffing neuroscience courses have been noted in this journal (e.g., Wiertelak and Ramirez, 2008). Our course is an example of how faculty from outside the field of neuroscience can be encouraged to participate in the instruction of neuroscience courses. One (DJE) of our backgrounds is in the biochemistry of viruses, an area of limited intersection with neuroscience. Rather than viewing this as a limiting factor in the instruction of this course, we capitalized on the differing areas of expertise.

We were able to model for the students how two professors of disparate training could work together to address a common topic. Our course is only one of many possibilities for such collaborations. Based on our experience with this course, we envision that neuroscience curriculums could be similarly enriched by joint efforts among neuroscience professors and chemists (e.g., in courses on neurotransmitters, pharmacology, chemical stimuli in the environment), physicists (e.g., in courses on the neurobiology of audition and auditory stimuli, vision and electromagnetic radiation), and computer scientists (courses in the modeling of many various questions in neuroscience).

We were very fortunate to have funding to support a team taught effort for this course. This funding was not, however, a limiting factor. Planning for the course took place before funding was secured, and had it not materialized, we would have greatly benefited from the interactions between us even if the instruction of the course were done by only one of us. The collaboration provided an in-house faculty enrichment opportunity that allowed us to extend the materials we teach in other courses.

Ramirez's (2007) statement that, "Challenging disciplinary boundaries will provide an interdisciplinary crucible from which the next generation of our Nation's leaders, problem solvers, and visionaries will emerge," (p. E7) motivated our thinking about this course from inception to instruction. If we had one disappointment with the course, it would be that we were unsuccessful in drawing students from even more disciplines. We had hoped, for example, to attract students with interests in epidemiological modeling from our Computer Science Department. We were also surprised that no student not already affiliated with the neuroscience major from the psychology program enrolled. Our hope as we prepare for the next presentation of the course is that the success we report here will expand student interest from these areas.

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Course development was funded by a grant from the Howard Hughes Medical Institute (HHMI) administered by the Vassar College Center for Collaborative Approaches to Science (CCAS).

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