

NEURAL CONTROL OF MOVEMENT (BIOL 4863/5863), Spring 2026

Instructor: Dr. Ari Berkowitz
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Classes: George Lynn Cross Hall 310
Tu Th 1:30-2:45 PM

Office Hours: M, Tu, Th 9:30-11:30 AM
or by appointment

Readings: Selected research articles at canvas.ou.edu (+ optional lecture videos and textbook chapter links at canvas.ou.edu and optional books: [Principles of Neurobiology](#), 2nd ed.–Luo, Garland Science 2021; [Governing Behavior](#)–Berkowitz, Harvard 2016)

Prerequisites: BIOL 3103 *or* 3113 *or* 3833 *or* 4833 *or* 5833 *or* permission of instructor

COURSE OBJECTIVES

After completing this course, you should be able to:

- 1) Summarize what is known experimentally for each of the course's 5 major questions regarding the control of movements by nervous systems.
- 2) Describe the historical development of major concepts in the field of the neural control of movements.
- 3) Provide your own answer to each of the course's 5 major questions, supported by experimental data.
- 4) Extract the main experimental findings from your reading of unfamiliar scientific research articles and explain these findings and their interpretations clearly, both orally and in writing.

GRADING

<u>Course component</u>	<u>Contribution to grade</u>
Written papers (4863: 3 papers; 5863: 4 papers).....	50%
Leading discussions of articles (2).....	30%
Pop quizzes/Online quizzes.....	10%
Class participation.....	10%

Pop quizzes will include material from readings assigned for that day or before. There will be no make-up quizzes.

Grading Errors: If you believe there was an error in a quiz or other mistake in grading, you must give the instructor a *written* description of the apparent mistake and your reasoning within one week of receiving the grade. The instructor will decide on the complaint and inform the student *at a later time*.

IMPORTANT DATES

No class (Spring Break): March 17 & 19

Due dates: paper 1: 2/26 (draft) & 3/12 (final); paper 2: 4/2 (draft) & 4/16 (final); paper 3-4: 5/11
“Final exam” time: Monday, 5/11, 1:30-3:30 PM, GLCH 310

NOTES

- 1) **Attendance and class participation are expected.** This is a discussion-based course. **But please do not attend class if you are sick.** Instead, contact the instructor promptly and if possible attend class virtually. Some important announcements may also occur during class.
- 2) **Required readings** will be available on Canvas (canvas.ou.edu). Students are expected to access and download readings as assigned.
- 3) Some course communications may be via e-mail. Students are expected to access their OU e-mail account (or set e-mail forwarding appropriately) and check for course-related messages **daily**.
- 4) At least for the first time, it is strongly recommended that you meet with the instructor to discuss the article before you lead a class discussion. Please read the article carefully before this meeting.
- 5) **Plagiarism:** Regulations and responsibilities stated in the *Student Code* and *Faculty Handbook* will be followed in the event of academic dishonesty. (See <http://integrity.ou.edu/>.) **Papers must be written entirely by the student alone; plagiarism will not be tolerated. Student papers should not copy phrases from publications or quote authors or make use of artificial intelligence software. Student papers will be submitted electronically to Turnitin.com to check for plagiarism. Cases of academic misconduct have been and will be pursued.**
- 6) If a grade of W or I is requested, University policy will be followed.
- 7) **Mental health support services:** Support is available for any student experiencing mental health issues that are impacting their academic success. Students can either be seen at the University Counseling Center (UCC) located on the second floor of Goddard Health Center or receive 24/7/365 crisis support from a licensed mental health provider through [TimelyCare](#). To schedule an appointment or receive more information about mental health resources at OU please call the UCC at 405-325-2911 or visit [University Counseling Center](#). The UCC is located at 620 Elm Ave., Room 201, Norman, OK 73019.
- 8) **Title IX resources and reporting requirement:** The University of Oklahoma faculty are committed to creating a safe learning environment for all members of our community, free from sex-based discrimination, including sexual harassment, domestic and dating violence, sexual assault, and stalking, in accordance with Title IX. There are resources available to those impacted, including: speaking with someone confidentially about your options, medical attention, counseling, reporting, academic support, and safety plans. If you have (or someone you know has) experienced any form of sex-based discrimination or violence and wish to speak with someone confidentially, please contact [OU Advocates](#) (available 24/7 at 405-615-0013) or [University Counseling Center](#) (M-F 8 a.m. to 5 p.m. at 405-325-2911). Because the University of Oklahoma is committed to the safety of you and other students, and because of our Title IX obligations, I, as well as other faculty, Graduate Assistants, and Teaching Assistants, are mandatory reporters. This means that we are obligated to report sex-based violence that has been disclosed to us to the Institutional Equity Office. This means that we are obligated to report sex-based violence that has been disclosed to us to the Institutional Equity Office. This includes disclosures that occur in: class discussion, writing assignments, discussion boards, emails and during Student/Office Hours. You may also choose to report directly to the Institutional Equity Office. After a report is filed, the Title IX Coordinator will reach out to provide resources, support, and information and the reported information will remain private. For more information regarding the University's Title IX Grievance procedures, reporting, or support measures, please visit [Institutional Equity Office](#) at 405-325-3546.
- 9) **Reasonable accommodation policy:** The University of Oklahoma (OU) is committed to the goal of achieving equal educational opportunity and full educational participation for students with disabilities. If

you have already established reasonable accommodations with the Accessibility and Disability Resource Center (ADRC), please log into iAdvise to request your semester accommodations as soon as possible and contact me privately, so that we have adequate time to arrange your approved academic accommodations. If you have not yet established services through ADRC, but have a documented disability and require accommodations, please complete [ADRC's pre-registration form](#) to begin the registration process. ADRC facilitates the interactive process that establishes reasonable accommodations for students at OU. For more information on ADRC registration procedures, please review their [website](#). You may also contact them at (405)325-3852 or adrc@ou.edu, or visit www.ou.edu/adrc for more information. Note: disabilities may include, but are not limited to, mental health, chronic health, physical, vision, hearing, learning and attention disabilities, pregnancy-related. ADRC can also support students experiencing temporary medical conditions.

- 10) **Religious observances:** It is the policy of the University to excuse the absences of students that result from religious observances and to reschedule examinations and additional required classwork that may fall on religious holidays, without penalty. [\[See Faculty Handbook 3.15.2\]](#)
- 11) **Adjustments for pregnancy/childbirth related issues**
Should you need modifications or adjustments to your course requirements because of pregnancy or a pregnancy-related condition, please request modifications via the [Institutional Equity Office website](#) or call the Institutional Equity Office at 405/325-3546 as soon as possible. Also, see the Institutional Equity Office [FAQ on Pregnant and Parenting Students' Rights](#) for answers to commonly asked questions.
- 12) **Final exam preparation period:** Pre-finals week will be defined as the seven calendar days before the first day of finals. Faculty may cover new course material throughout this week. For specific provisions of the policy please refer to OU's [Final Exam Preparation Period policy](#).
- 13) **Emergency protocol:** During an emergency, there are official university [procedures](#) that will maximize your safety.

Severe Weather: If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather.

1. Look for severe weather refuge location maps located inside most OU buildings near the entrances.
2. Seek refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building.
3. Go to the building's severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows.
4. Get in, Get Down, Cover Up
5. Wait for official notice to resume normal activities.

Additional [Weather Safety Information](#) is available through the Department of Campus Safety.

- 14) **Active threat guidance:** The University of Oklahoma embraces a Run, Hide, Fight strategy for active threats on campus. This strategy is well known, widely accepted, and proven to save lives. To receive emergency campus alerts, be sure to update your contact information and preferences in the account settings section at one.ou.edu.

RUN: Running away from the threat is usually the best option. If it is safe to run, run as far away from the threat as possible. Call 911 when you are in a safe location and let them know from which OU campus you're calling from and location of active threat.

HIDE: If running is not practical, the next best option is to hide. Lock and barricade all doors; turn off all lights; turn down your phone's volume; search for improvised weapons; hide behind solid objects and walls; and hide yourself completely and stay quiet. Remain in place until law enforcement arrives. Be patient and remain hidden.

FIGHT: If you are unable to run or hide, the last best option is to fight. Have one or more improvised weapons with you and be prepared to attack. Attack them when they are least expecting it and hit them where it hurts most: the face (specifically eyes, nose, and ears), the throat, the diaphragm (solar plexus), and the groin.

Please save OUPD's contact information in your phone.

NORMAN campus: *For non-emergencies call (405) 325-1717. For emergencies call (405) 325-1911 or dial 911.*

15) **Fire alarm/general emergency:** If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates:

1. *LEAVE* the building. Do not use the elevators.
2. *KNOW* at least two building exits
3. *ASSIST* those that may need help
4. *PROCEED* to the emergency assembly area
5. *ONCE safely outside, NOTIFY first responders of anyone that may still be inside building due to mobility issues.*
6. *WAIT* for official notice before attempting to re-enter the building.

[OU Fire Safety on Campus](#)

16) **Office of access and opportunity's belonging statement:** Why You Belong at the University of Oklahoma: The University of Oklahoma fosters an inclusive culture of respect and civility, belonging, and access, which are essential to our collective pursuit of excellence and our determination to change lives. The unique talents, perspectives, and experiences of our community enrich the learning, and working environment at OU, inspiring us to harness our innovation, creativity, and collaboration for the advancement of people everywhere.

TIPS FOR READING & PRESENTING RESEARCH ARTICLES

When you read, focus on the Introduction, Summary or Abstract, and Discussion or Conclusions (probably read in that order). Try not to get hung up on methodological details or unfamiliar vocabulary. As you read, ask yourself the following questions: What did the author(s) basically do in the key experiment(s)? Why did they choose to do this particular experiment(s)? What was the major finding(s) of this experiment(s)? How did the authors interpret this finding(s) (i.e., what did it tell them about how nervous systems mediate natural behaviors)? Do you think this interpretation of the finding(s) is reasonable? Try to identify the key 3-4 data figures in the article (or data descriptions, for some older articles) and evaluate whether they really support the authors' conclusions.

When you lead a discussion of an article, first describe the background and motivation for doing the study. Describe the key experiment(s) in as simple terms as possible. Show the key data figures and explain how to read them and what each demonstrates. Summarize the author's conclusions and give your own critique of whether or not the experimental data support those conclusions.

Tentative Reading List—Neural Control of Movement—BIOL 4863/5863—Spring 2026

1: Are movements of individual body parts controlled by distinct regions of the brain?

- “Investigations of the properties and functions of the various parts which compose the cerebral mass,” by Marie-Jean-Pierre Flourens (1824)
- * “Remarks on the seat of the faculty of articulate language, followed by an observation of aphemia,” by Paul Broca (1861)
- * “A study of convulsions,” by John Hughlings Jackson (1870)
- * “On the electrical excitability of the cerebrum,” by Gustav Fritsch and Eduard Hitzig (1870)
- “Experiments on the brain of monkeys.—No. 1,” by David Ferrier (1874-1875)
- “Observations on the physiology of the cerebral cortex of some of the higher apes (preliminary communication),” by A.S. F. Grunbaum and Charles S. Sherrington (1902)
- * “Basic neural mechanisms in behavior,” by Karl S. Lashley (1930)
- * “Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation,” by Wilder Penfield and Edwin Boldrey (1937)
- * “How somatotopic is the motor cortex hand area?” by Marc H. Schieber and Lyndon S. Hibbard (1993)
- * “Complex movements evoked by microstimulation of precentral cortex,” by Michael S.A. Graziano et al. (2002)
- * “Neuroethology of natural actions in freely moving monkeys,” by Francesca Lanza et al. (2025)

2: To what extent are individual neurons responsible for the generation of a single type of movement or a single behavior?

- “The command neuron concept,” by Irving Kupfermann and Klaudiusz R. Weiss (1978)
- * “Alternative neural pathways initiate fast-start responses following lesions of the Mauthner neuron in goldfish,” by Robert C. Eaton et al. (1982)
- “Size and distribution of movement fields in the monkey superior colliculus,” by David L. Sparks et al. (1976)
- * “Population coding of saccadic eye movements by neurons in the superior colliculus,” by Choongkil Lee et al. (1988)
- “Neuronal population coding of movement direction,” by Apostolos P. Georgopoulos et al. (1986)
- * “A single pair of interneurons commands the *Drosophila* feeding motor program,” by Thomas F. Flood et al. (2013)

3: How is sensory feedback integrated with the central nervous system (CNS) control of movements?

- “Treatise on Physiological Optics,” by Herman Ludwig von Helmholtz (1866) [excerpt]
- * “Neural basis of the spontaneous optokinetic response produced by visual inversion,” by Roger W. Sperry (1950)
- * “The reafference principle,” by Erich von Holst and Horst Mittelstaedt (1950)
- * “A pathway in primate brain for internal monitoring of movements,” by Marc A. Sommer and Robert H. Wurtz (2002)
- * “Motor commands contribute to human position sense,” by Simon C. Gandevia et al. (2006)

4: How do central pattern generators control movements and how is their function modified?

“Observations on the scratch-reflex in the spinal dog,” by Charles S. Sherrington (1906) [excerpt] and “Notes on the scratch-reflex on the cat,” by Charles S. Sherrington (1910)

- * “The intrinsic factors in the act of progression in the mammal,” by T. Graham Brown (1911)
- * “Neuropeptide fusion of two motor-pattern generator circuits,” by Patsy S. Dickinson et al. (1990)
- * “Substance P modulates NMDA responses and causes long-term protein synthesis-dependent modulation of the lamprey locomotor network,” by David Parker et al. (1998)
- * “Activity-independent homeostasis in rhythmically active neurons,” by Jason N. MacLean et al. (2003)
- * “Membrane voltage is a direct feedback signal that influences correlated ion channel expression in neurons,” by Joseph M. Santin and David J. Schulz (2019)

5: To what extent can an adult brain reorganize its control of movements over the long term?

“Adaptation of disarranged hand-eye coordination contingent upon re-afferent stimulation,” by Richard Held and Alan V. Hein (1958) and “Plasticity in sensory-motor systems,” by Richard Held (1965)

- * “Use-dependent alterations of movement representations in primary motor cortex of adult squirrel monkeys,” by R. J. Nudo et al. (1996)
- * “Direct control of paralysed muscles by cortical neurons,” by Chet Moritz et al. (2008)
- * “Task-specific modulation of corticospinal neuron activity during motor learning in mice,” by Najet Serradj et al. (2023)
- * “Synaesthesia in phantom limbs induced with mirrors,” by V.S. Ramachandran and D. Rogers-Ramachandran (1996)

* Students may choose any of these articles for leading class discussions.