Welcome to the PSY397H Biological Rhythms, Winter, 2023.
Tuesdays 11am-2 pm.

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D ATE	TOPIC	READINGS
Jan. 10	Biological and psychological representations of time; Temporal biology and the organization of living things; Adaptive significance; "hierarchy" of circadian clocks; Temporal programs.	**A**
Jan. 17	Properties and synchronization of biological clocks. Resetting by light and nonphotic mechanisms including *social zeitgebers* and metabolism.	**B**
Jan. 24	Molecular mechanisms of rhythm production and regulation – Molecular clocks throughout the living world. Discovery of clock genes. First models – Fruit flies, fungus.	**C**
Jan. 31	The structure of circadian systems. Comparative anatomy and physiology across the 5 taxonomic groups.	**D**
Feb. 07	**TEST 1** (25%) covers everything including Oct 4. Followed by: Sleep, and circadian rhythms in human beings and other organisms. *Chronotype*, jet lag, temporal isolation.	**E**
Feb. 14	The "other" circadian systems? Food entrainable oscillators; amphetamine sensitive oscillators; metabolic clocks, circadian disorganization in chronic mental disorders.	**F**
Feb. 21	Reading week (20 – 24)	
Feb. 28	Non-circadian biological clocks: tidal, lunar, annual, ultradian Time memory, time-place learning and the perception of time	**G**
Mar. 07	**TEST 2** (30%) Covers up to and including Feb 28. Followed by: Seasonality,	
Mar. 14	Photoperiodic time measurement,Sleep, hibernation and memory	**H**
Mar 21	Migration orientation and the sun compasses	**I**
Mar. 28	Circadian disorganization, chronic disease, and longevity	**J**
Apr. 4	The different conceptualizations of Time in biology. Integration of timing mechanisms; and adaptive significance for living beings	**K**

PSY397 Biological Rhythms

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Course description

Biological rhythmicity is found throughout Nature, from bacteria to humans. While all living systems display various cycles, specific types of rhythms have evolved which provide temporal organization to the physiology and behavior of organisms and the ability to anticipate regular, cyclic changes in their environments. These are what we call "biological clocks". Some mechanisms have become adapted for use in complex behaviors such as migration, seasonality, and coordinated reproduction. In addition, organisms gain an adaptive advantage from being able to predict the possible recurrence of conditioned that they have experienced. This is time memory, an aspect of circadian biology that is used in concert with the biological clock to predict the likelihood that significant events are going to recur at the same time as the initial experience. In this course, we will examine both mechanisms, the highly conserved systems that predict the regular changes in the environment, as well as the systems that underlie the memory of events that are not regular, nor linked to specific times of day. We will review current findings at all levels of organization from molecular genetic, to anatomical, to behavioral, always coming back to the question of how these rhythmic systems are able to function to predict demand, thereby operating as biological clocks, and we will examine the consequences of disordered timing systems.

Marking scheme

Term test 1: 25%; Term test 2: 30%; Final 2 hour exam: 45%

Tests will be a combination of multiple choice, short answer, matching, and fill-in-the-blanks. Some minor arithmetic calculations are required for some questions. No aids are allowed on tests.

Missed tests may be made up only with University of Toronto approved documentation, and must be taken before marked tests are returned to the class (~1 week). Students who are unable to make up test must show evidence for why this was not possible, again with U. of Toronto approved documentation.

Asking questions, office hours and reviews

Within reason, you are encouraged to ask questions during the lectures. Bear in mind that although the instructor may be responsive in this way, your fellow students may not appreciate too many interruptions. The instructor will reserve some lecture time at the end of each class to answer questions. Official office hours: 11-12 am Fridays. Other hours by appointment.

Recommended resources

Circadian Rhythms: A Very Short Introduction (Very Short Introductions) 1st Edition, Kindle Edition by Russell Foster and Leon Kreitzman

Rhythms of Life: The Biological Clocks that Control the Daily Lives of Every Living Thing by Russell G. Foster and Leon Kreitzman | Oct 10 2005.
Seasons of Life: The Biological Rhythms That Enable Living Things to Thrive and Survive by Russell G. Foster and Leon Kreitzman | Jun 30 2009

TEXTBOOK (recommended)
Introducing Biological Rhythms: A primer on the Temporal Organization of Life… **(2006)** Willard L. **Koukkari** & Robert B. **Sothern**, authors.

The BioClock Studio, UCSD: https://ccb.ucsd.edu/the-bioclock-studio/index.html

Reading list (articles)

A. Week 1; January 10

1. Pittendrigh, CS (1993) Temporal organization: reflections of a Darwinian clock-watcher. Annu Rev Physiol. 1993;55:16-54.
2. Vitaterna, M. H., Takahashi, J. S., & Turek, F. W. (2001). Overview of circadian rhythms. *Alcohol Research & Health*, *25*(2), 85-93.
3. Roenneberg T, Merrow M. (2005) Circadian clocks - the fall and rise of physiology. Nat Rev Mol Cell Biol. 2005 Dec;6(12):965-71.

B. Week 2; January 17

4 Pittendrigh, C. S., & Daan, S. (1976). A Functional Analysis of Circadian Pacemakers in Nocturnal Rodents. IV. Entrainment: Pacemaker as Clock. *Journal of Comparative Physiology A*, *106*(3), 291-331. https://doi.org/10.1007/BF01417856.
5 Golombek, DA and Rosenstein, R (2010) The physiology of entrainment. *Physiol Rev* 90: 1063–1102 doi:10.1152/physrev.00009.2009.
6 Mrosovsky N, Salmon PA, Menaker M, Ralph MR. (1992) Nonphotic phase shifting in hamster clock mutants. *J Biol Rhythms*. 7(1):41-49.

C. Week 3; January 24

7 Lundkvist, GB, Block, GD. (2005) Role of Neuronal Membrane Events in Circadian Rhythm Generation *METHODS IN ENZYMOLOGY*, VOL. 393:623-642.
8 Underwood, H, Steele, CT, Zivkovic, B (2001) Circadian Organization and the Role of the Pineal in Birds. *MICROSCOPY RESEARCH AND TECHNIQUE* 53:48–62.
9 Antle, MC, Silver, R (2005) Orchestrating time: arrangements of the brain circadian clock*TRENDS IN NEUROSCIENCES* Vol.28.

10 Reppert, SM, Weaver, DR (2002) Coordination of circadian timing in mammals *NATURE* 418:935-941.
11 Page, TL (1982) Transplantation of the Cockroach Circadian Pacemaker. *Science* 216, 73-75.

D. Week 4; January 31

12 Haraszti RÁ, Ella K, Gyöngyösi N, Roenneberg T, Káldi K. (2014) Social jetlag negatively correlates with academic performance in undergraduates. Chronobiol Int. 2014 Jun;31(5):603-12. doi: 10.3109/07420528.2013.879164.
13 Roenneberg, T. (2015) Having trouble typing? What on earth is chronotype? *J.Biol. Rhythms* Dec;30(6):487-91. doi: 10.1177/0748730415603835.
14 Hahn C1, Cowell JM, Wiprzycka UJ, Goldstein D, Ralph M, Hasher L, Zelazo PD. (2012) Circadian rhythms in executive function during the transition to adolescence: the effect of synchrony between chronotype and time of day. Dev Sci. 2012 May;15(3):408-16. doi:10.1111/j.1467-7687.2012.01137.x. Epub 2012 Feb 23.
15 Castillo-Ruiz A, Paul MJ, Schwartz WJ (2012) In search of a temporal niche: Social interactions. *In.* A. Kalsbeek, M. Merrow, T. Roenneberg and R. G. Foster (Eds.) *Progress in Brain Research*, Vol. 199 pp 267-280. Elsevier.
16 Chouvet, G et al. (1974) *Periodicite bicircadienne du cycle veille-sommeil dans des conditions hors du temps. Etude polygraphique*. *Electroenceph Clin Neurophysiol* **37**:367-380.

E. Week 5; February 7

17 Reppert, SM, Weaver, DR (2001) MOLECULAR ANALYSIS OFMAMMALIAN CIRCADIAN RHYTHMS *Annu. Rev. Physiol*. 2001. 63:647–76
18 Williams, JA, Sehgal, A (2001) MOLECULAR COMPONENTS OF THE CIRCADIAN SYSTEM IN DROSOPHILA. *Annu. Rev. Physiol*.. 63:729–55
19 Tauber, E, Last, KS, Olive, PJW, Kyriacou, CP. (2004) Clock Gene Evolution and Functional Divergence. *J Biol Rhythms*, 19 445-458.
20 OUYANG, Y, ANDERSSON, CR, KONDO, T, GOLDEN, SS, JOHNSON, H (1998) Resonating circadian clocks enhance fitness in cyanobacteria *Proc. Natl. Acad. Sci. USA* **95**, 8660–8664.
21 Green CB, Takahashi JS, Bass J. The meter of metabolism. Cell. 2008 Sep 5;134(5):728-42. doi: 10.1016/j.cell.2008.08.022.

F. Week 6; February 14

22 Stephan FK. (2002) The "other" circadian system: food as a Zeitgeber. *J Biol Rhythms*. Aug;17(4):284-92.
23 Honma K1, Honma S. (2009) The SCN-independent clocks, methamphetamine and food restriction. Eur J Neurosci. Nov;30(9):1707-17. doi: 10.1111/j.1460-9568.2009.06976.x. Epub 2009 Oct 28.
24 Coward, D., Cain, S. and Ralph, M. R. (2001) A circadian rhythm in mice that is unaffected by the period mutation at *clock*. *Biol. Rhythm Res.* **32**: 233-242.

Week 7; February 21 READING WEEK

G. Week 8; February 28

25. Mulder CK, Gerkema MP & Van der Zee1 EA. (2013) Circadian clocks and memory: time-place learning. *Front. Mol. Neurosci*. https://doi.org/10.3389/fnmol.2013.00008.
26. Ralph MR, Ko CH, Antoniadis EA, Seco P, Irani F, Presta C, McDonald RJ. (2002) The significance of circadian phase for performance on a reward-based learning task in hamsters. *Behav Brain Res*. Oct 17;136(1):179-84.
27. Cain SW, Yoon J, Shrestha TC, Ralph MR (2014) Retention of a 24-hour time memory in Syrian hamsters carrying the 20-hour short circadian period mutation in casein kinase-1ε (ck1εtau/tau). *Neurobiol Learn Mem*. 114C:171-177. doi: 10.1016/j.nlm.2014.06.004.
28. Cain, SW, Rawashdeh, OA, Siu, M, Kim, SC & Ralph, MR. (2017) Dopamine dependent setting of a circadian oscillator underlying the memory for time of day. *Neurobiol Learn Mem*. 141:78–83.27.