

**HEB1480: Human Evolution Through Developmental Change
(Junior Research Seminar: Half Course)**

Course Time: Tuesday and Thursday 10:00-11:30pm
LAB: Thursday 1-2:30pm

Course Location: MCZ 541

Course Restrictions: Limited to 12 students

Course Instructors: Terence D. Capellini, Ph.D
Assistant Professor
Human Evolutionary Biology
Office: 53C/D, 5th Floor, Peabody Museum
Phone: 617-495-4710
Email: tcapellini@fas.harvard.edu
Office Hours: M 10-12, or by appointment.

Neil T. Roach, Ph.D
College Fellow
Human Evolutionary Biology
Office: 46, 4th Floor, Peabody Museum
Phone: 617-495-1870
Email: ntroach@fas.harvard.edu
Office Hours: Tu 1-2, or by appointment.

Course Website: <https://canvas.harvard.edu/courses/16746>

Prerequisite: LS1b (Genetics, Genomics, and Evolution). Introductory courses in paleoanthropology or anatomy helpful, but not required.

Course Description and Goals:

Humans and our primate relatives are incredibly variable. This variation results from natural selection operating on the developmental mechanisms that control anatomy and physiology. While these mechanisms remain mostly undiscovered, we are beginning to understand these complex processes due to major advances in technology that have pushed the fields of genetics, genomics, and developmental biology rapidly forward. This research-centered course explores these relationships in the context of the primate paleontological record. We focus on the evolution of the musculoskeleton, which includes the cranium, axial skeleton, and limbs, and present studies that cast light on the mechanisms that underlie major transitions in human evolution.

This course is divided into several different modules, each of which focuses on different anatomical regions of the body and/or evolutionary transitions in human and primate evolution. These modules are:

- Comparative primate biology, evolution, and developmental principles
- Developmental evolution of the primate vertebral column
- Developmental evolution of the primate pectoral and pelvic girdles
- Developmental evolution of the primate fore- and hindlimb
- Developmental evolution of the primate skull

Course Content:

The lecture component of the course is 3 hours meeting twice a week for 1.5 hours on Tuesday and Thursday. Each week, class time is roughly divided into a lecture on background related to primate and human evolutionary principles and developmental biology and genetic mechanisms, followed by a workshop, laboratory session, and/or discussion session on relevant readings for the week. The laboratory component of the course is 1-2 hours per week meeting on a day of the week that is determined on the first day of class. This time will be devoted to laboratory exercises, data collection for

projects, and quizzes. While this time will be blocked off for each week in the semester, in reality lab sessions will become less frequent as the semester progresses.

Course Requirements:

(1) Attendance is mandatory. Each student is permitted to miss one lecture and lab class, after which a letter grade (10% points off of final course grade) will be deducted for every additional class missed. For students missing more than one class due to extenuating circumstances (illness, death in the immediate family, etc.), proper documentation is required (e.g., doctor's note, etc.).

(2) Since this a seminar and laboratory course, it will involve considerable discussion and interrogation of current issues in paleontology, genetics, and developmental biology. Therefore, active participation is required and will be used to assess student performance.

(3) There will be four (4) quizzes counting for a total of 20% of the final grade (5% each). These will be conducted in laboratory sessions or in class at the beginning of class time (first 15-20 minutes) If you are late to the class on that day, you will not be permitted to take the quiz and you will receive a 0% grade. You are not permitted to work with another person on these quizzes. These quizzes are geared towards evaluating your understanding of material covered in the lectures just prior to the quiz date.

(4) There are two (2) mid-semester examinations counting for a total of 40% of the final grade (20% each). Both will be take home examinations. You are not permitted to work with another person on these exams; each exam will be due by the start of class-time on the date listed in the syllabus. These exams are geared towards evaluating your understanding of how developmental principles can be used to interpret evolutionary transformations in primate and human evolution. Each exam is graded on how well the student demonstrates comprehension and synthesis of the selected papers, as well as lecture and lab materials, and on how they convey this understanding in a concise, intelligible manner. Points will also be deducted for improper citation, grammar, and spelling.

(5) There is one "Evo-Devo" assignment that will be worked on during the course of the semester. It will involve working as a team to integrate data from genetic, developmental biology, morphometric, and primate evolution. All students will learn toolsets important to this assignment during specific lab exercises/training sessions that have been placed in the early part of the semester. While these exercises will not be graded, they will significantly impact your Team's final Evo-Devo project, which will be graded, and so it is encouraged not to miss these sessions. The Evo-Devo assignment will be worth 40% of the final grade and will involve both a Team Presentation (10%) and a final Team Paper (30%). Details of this assignment will be covered in-class and outlined in a detailed handout entitled "HEB1480 Final Evo-Devo Project".

Thus, the evaluation criteria for the final course grade are as follows:

Quiz (5% each)	20%
Take Home (20% each)	40%
Final Presentation	10%
Final Paper	30%
Total	100%
Attendance: 10% off final grade per missed class.	

Grading Statement:

All assignments are graded on a sliding curve. Extra credit is not available for this course. Thus, it is imperative that the student stays on top of the reading and exercises, and that office hours are attended when necessary.

Grades will be assigned as follows:

A = 90-100%; B = 80-89%; C = 70-79%; D = 60-69%; F < 60%
(with minus and plus grades assigned at appropriate cutoffs).

Required Readings:

While there is no required textbook for the course, there are required journal articles and textbook readings for each week. These articles are listed in the calendar portion of this syllabus and pdfs of each are downloadable from the course website. If there are issues with downloading these articles, it must be brought to either Dr. Capellini's or Dr. Roach's attention, as they are in charge of running the course website. Readings should be completed before arriving to class on the day they are listed, as they will be the subject of lecture and discussion.

Classroom and Laboratory Etiquette:

Help make this an intellectually friendly and productive environment by respecting others in the class.

Along these lines, please:

- (1) Arrive to class on time and read all assigned materials before the start of each class.
- (2) Before class begins turn off your cell phones.
- (3) Never text, instant message, or surf the web during class. In addition to being disrespectful and distracting to others, it will cost you your participation credit for the day.
- (4) Never interrupt someone speaking in class.
- (5) Never record any part of the lectures or discussions unless allowed by the instructor.

Disabilities:

Students needing academic adjustments or accommodations because of a documented disability must present their Faculty Letter from the Accessible Education Office and speak with the instructor by the end of the second week of the term. Failure to do so may result in the instructor's inability to respond in a timely manner.

Academic Integrity:

All Harvard University policies regarding ethics and honorable behavior apply to this course. Regarding the take-home mid-semester examination, any material or ideas obtained from other sources (e.g., information acquired from the web) must be supported by a legitimate source reference (i.e., from a peer reviewed article or book). Plagiarism will not be tolerated; that is, the student must not appropriate the writing of others and present it without citation to a refereed academic source. With that in mind, the student also cannot simply regurgitate ideas espoused by others, but must generate theses that are innovative, novel, and reflect the synthesis of ideas generated through learning from multiple sources. For more information on plagiarism follow the rules and guidelines found in the Student Handbook at <http://handbook.fas.harvard.edu/icb/icb.do>. If deemed necessary, student material can be checked for plagiarism on www.turnitin.com. Furthermore, students are not permitted to work with others on any of the written assignments. Students violating these simple policies will receive a failing course grade, and the issue will be pursued further under the University's regulations concerning academic integrity.

Computer Resources:

During the course, there are training sessions involving the use genomic databases/browsers and the Geneious software. It will be helpful for each student to bring a laptop to class. For students desiring to perform their own genomic level analyses, access and server space will be provided. Each student will be instructed on setting up a UCSC session during the genome browser tutorial portion of this course.

Please download a copy of the Geneious Software by following these steps:

- (1) The software is actually downloaded directly from Geneious (www.geneious.com)
- (2) After installation is complete, select "use license server"
- (3) Specify server name as: rcllc1.rc.fas.harvard.edu
- (4) Specify port: 27004

This software can be run from within the sciences, if using this from off campus, a VPN connection would be necessary. Please let me know if you are having difficulty downloading this software.

Course Schedule Calendar

Date	Topic	Readings	PPT	Assignments
9/1/16 Week 1	Course introduction & Central questions in evolutionary developmental biology	Willmore, 2012	TC1	
9/6/16 Week 2	Developmental Biology & Embryology; Bone Development	Gilbert, Pp. 5-29	TC2	
9/8/16 AM Week 2	Lab#1: Project Introduction; Bone biology	None		
9/8/16 PM Week 2	Cartilage/Bone Biology/Function/biomechanics	Shipman et al. ch 2-4 (pgs. 18-49)	NR1	
9/13/16 Week 3	Introduction to the Primates	Fleagle (ch. 2; 11-45) Anatomy Primer	ZM1	
9/15/16 AM Week 3	Lab#2: Quiz#1 and MCZ Tour	None		Quiz#1 (covering 9/1-9/13)
9/15/16 PM Week 3	Human biology and evolution	Wood (ch. 5-7; pgs. 58-99) (browse)	NR2	
9/20/16 Week 4	Developmental Genetics 1	Carroll et al., 2008 Kingsley, 2009	TC3, part1	
9/22/16 AM Week 4	Lab#3: UCSC Browser Tutorial	None	TC-Supp.	
9/22/16 PM Week 4	Developmental Genetics 2	Arthur, Chapter 3. Pp 34-53 Arthur, Chapter 14. Pp 218-233	TC3, part2	Take Home Examination #1 Handed Out (covering 9/1-9/22)
9/27/16 Week 5	Vertebral Column Morphology	Langdon (ch.6; 77-87)	NR3	Take Home Examination #1 Due
9/29/16 AM Week 5	Lab#4: Vertebral Column in Primates	None		
9/29/16 PM Week 5	Vertebral Column Development	Pilbeam, 2004 Gilbert, Pp. 309-314 415-436	TC4	
10/4/16 Week 6	Girdle Morphology	Young et al, 2015/2016 Young 2004	NR4	
10/6/16 AM Week 6	Lab#5: Girdle Morphology and Project Work	None		
10/6/16 PM Week 6	Girdle Development	Lovejoy, 1988 Gilbert, Pp. 415-436 Capellini et al 2010/11	TC5	
10/11/16 Week 7	Quiz#2 and Discussion on Evo-Devo of Human Evolution	Pilbeam 2004 Roilan, 2014		Quiz#2 (covering 9/27-10/6)
10/13/16 AM Week 7	Lab#6: Final Projects: Bioinformatics and Morphometrics help	None		
10/13/16 PM Week 7	Final Projects: Final Project Discussion	None		
10/18/16 Week 8	Limb Morphology	Langdon (ch 7-8; 88-115)	NR5	Final Project Summary Due
10/20/16 AM Week 8	Lab#7: Comparative Limb Morphology	None		
10/20/16 PM Week 8	Limb Development	Gilbert, Pp. 489-518	TC6	
10/25/16 Week 9	Quiz#3 and Discussion on Evo-Devo of human evolution	Young et al. 2010 Reno, 2014		Quiz#3 (covering 10/11-10/20)
10/27/16 AM Week 9	Lab#8: Final Projects: Bioinformatics and Morphometrics help	None		
10/27/16 PM Week 9	Skull Morphology	TBD	NR6	Take Home Examination #2 Handed Out (covering 9/27-10/25)
11/1/16 Week 10	Lab#9: Skull Morphology	None		Take Home Examination #2 Due
11/3/16 AM Week 10	Skull Development	Gilbert, Pp.379-391	TC7	
11/3/16 PM Week 10	Quiz#4 and Discussion on Evo-Devo of human evolution	None		Quiz#4 (covering 10/27-11/3)

11/8/16 Week 11	Final Projects: Bioinformatics and Morphometrics help	None		
11/10/16 AM Week 11	Lab#10: Extra Project Time	None		
11/10/16 PM Week 11	Final Projects: Bioinformatics and Morphometrics help	None		Final Project Outline Due
11/15/16 Week 12	Final Projects: Bioinformatics and Morphometrics help	None		
11/17/16 AM Week 12	Lab#11: Extra Project Time	None		
11/17/16 PM Week 12	Final Projects: Bioinformatics and Morphometrics help	None		
11/22/16 Week 13	Final Projects: Bioinformatics and Morphometrics help	None		
11/24/16 Week 13	NO CLASS: Thanksgiving	None		
11/29/16 Week 14	Class Presentations			In class presentation
12/1/16 AM Week 14	Class Presentations	None		In class presentation
12/1/16 PM Week 14	Class Presentations (if needed)	None		In class presentation
Finals	Final Paper Due	None		Final Paper Due

Resource Websites and Browsers:

Keeping track of genomes:

<http://genomesonline.org/cgi-bin/GOLD/index.cgi>

1000 genomes project website: <http://www.1000genomes.org/>

Blast: <http://blast.ncbi.nlm.nih.gov/Blast.cgi>

[http://blast.ncbi.nlm.nih.gov/Blast.cgi?](http://blast.ncbi.nlm.nih.gov/Blast.cgi?PROGRAM=blastn&BLAST_SPEC=TraceArchive&PAGE_TYPE=BlastSearch&PROGRAM_DEFAULTS=on)

[PROGRAM=blastn&BLAST_SPEC=TraceArchive&PAGE_TYPE=BlastSearch&PROGRAM_DEFAULTS=on](http://blast.ncbi.nlm.nih.gov/Blast.cgi?PROGRAM=blastn&BLAST_SPEC=TraceArchive&PAGE_TYPE=BlastSearch&PROGRAM_DEFAULTS=on)

CMS browser (selection): <http://www.broadinstitute.org/mpg/cmsviewer/>

ENCODE: <https://genome.ucsc.edu/ENCODE/>

<http://www.genome.gov/10005107>

<http://www.encodeproject.org/ENCODE>

Mouse ENCODE: <http://www.mouseencode.org>

Ensembl: <http://www.ensembl.org/index.html>

Epigenomics Roadmap: <http://www.roadmapepigenomics.org/data>

HGP website: http://www.ornl.gov/sci/techresources/Human_Genome/home.shtml

HGDP Selection Browser: <http://hgdp.uchicago.edu/cgi-bin/gbrowse/HGDP/>

HAPMAP: <http://hapmap.ncbi.nlm.nih.gov/>

HaploReg: <http://www.broadinstitute.org/mammals/haploreg/haploreg.php>

Haplotter: <http://haplotter.uchicago.edu/>

UCSC Genome Browsers:

Main - <https://genome.ucsc.edu/>

Test - <http://genome-test.cse.ucsc.edu/>

UNIPROBE (TF predictions): http://the_brain.bwh.harvard.edu/uniprobe/

Vista Alignment: <http://genome.lbl.gov/vista/index.shtml>

Vista Enhancer Browser: <http://enhancer.lbl.gov/>

Additional software resources from lab/company pages:

<http://pritchardlab.stanford.edu/software.html>

http://kingsley.stanford.edu/Lab_Protocols.html

<http://bejerano.stanford.edu/resources.html>

<http://web.mit.edu/manoli/>

<http://bustamantelab.stanford.edu/software.html>

<http://giladlab.uchicago.edu/Data.html>

<http://132.239.197.19/bli/mouse/hi-c/index.html>

<http://www.sanger.ac.uk/resources/software/genevar/>

<http://www.hsph.harvard.edu/liming-liang/software/eqtl/>

<http://www.ncbi.nlm.nih.gov/pubmed/22693428>