Syllabus Spring 2018 (Updated April 6, 2018)

**Biomolecular Approaches in Archaeology**

Class Meetings: Tuesdays, 4:00-6:30pm, Rhode Island Hall Room 008

Instructor: Dr. Katherine Brunson

Office Hours: Mondays, 2:00-4:00pm, Rhode Island Hall Room 102

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Canvas Website: https://canvas.brown.edu/courses/1074583

**Course Description:**

This seminar will focus on the key principles of biomolecular techniques used in archaeological research. Topics will include residue analysis, collagen fingerprinting, stable isotopes, and ancient DNA. We will discuss recent advancements in these scientific methods, best practices for collecting samples, how to build collaborations between archaeologists working in the field and in the laboratory, and new possibilities for using cutting-edge methods to address archaeological and anthropological research questions.

**Course Learning Goals:**

* Learn the ways that GC/MS, LC/MS, immunoassays, and other methods can be used to target and analyze ancient residues on ceramics and other artifacts.
* Learn how mass spectrometry is used for collagen fingerprinting and discuss its applications for identifying bone artifacts and fragmentary bone.
* Compare applications for carbon, nitrogen, oxygen, and strontium stable isotope analyses. Examine case studies that use isotopes to analyze ancient diets, animal management, transhumance, and migration.
* Learn basic principles of genome-wide ancient DNA studies and the special methods needed to extract, amplify, and analyze poorly preserved fragments of ancient DNA. Discover how cutting-edge ancient DNA research using next generation techniques is revolutionizing our understanding of admixture between humans and other extinct hominins, ancient human population migrations, paleodisease, and the domestication of plants and animals.
* Consider and discuss challenges to the democratization of scientific techniques in archaeology, best practices for collecting and storing samples during fieldwork, and how to recognize diagenetic changes to biomolecules.
* Think about anthropological and archaeological research questions that would benefit from the application of biomolecular techniques.

**Course Requirements and Grading:**

Participation and response posts 50%

Paper proposal 10%

Final paper 40%

**Participation and Response Posts:** You are expected to attend all classes, complete all readings, and participate in discussions. Each student is also responsible for posting an approximately 2 paragraph response to the readings on the course website before class each week. Response posts should raise questions to discuss in class, synthesize key concepts from the readings, or propose potential applications of biomolecular techniques to archaeological and anthropological research. Response posts are due by 11:00am before class on Tuesdays and will be graded out of 3 points (3 points for a complete and thoughtful response, 2 points for a satisfactory response, 1 point for a less than satisfactory response, and 0 points for an incomplete response).

**Research Paper:** You are required to write a 10 page research paper that expands on a topic covered in class. Each student will submit a 1-2 page proposal/outline of their paper topic for approval by the instructor. The proposal should also provide a preliminary list of at least six scholarly sources that you plan to use in your paper. **Paper topic proposals are due April 3rd.** **Students will be expected to give a 5 minute presentation on their research topic in class during the last week of class. Final papers are due on May 9th (the first day of final exams week).**

**Estimated Time Allocation:** Class meetings (28 hours); readings (6 hours per week, 66 hours total); response posts (2 hours per week, 22 hours total); research paper (65 hours).

**Accommodation for Students with Disabilities:** Any student with a documented disability is welcome to contact me as early in the semester as possible to arrange accommodations. As part of this process, please be in touch with Student and Employee Accessibility Services (SEAS).

**Readings:** All readings will be available as PDFs on the course website or through the course E-reserves.

**Course Schedule:**

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| **Date** | **Topic** |
| Jan 30 | Course introduction. Biomolecules and considerations in the field of biomolecular archaeology. |
| Feb 6 | GC/MS, immunoassays, and other techniques for residue analysis. |
| Feb 13 | LC/MS, MS/MS, and residue analysis case studies on cacao, wine, and milk. **CLASS WILL END AT 5:30.** |
| Feb 20 | **NO CLASS MEETING.** University holiday. |
| Feb 27 | Collagen fingerprinting. |
| Mar 6 | Stable isotope studies of diet. |
| Mar 13 | Isotopic studies of migration, transhumance, and environments. |
| Mar 20 | Intro to ancient DNA approaches. |
| Mar 27 | **NO CLASS MEETING.** Spring recess. |
| Apr 3 | **PAPER TOPIC PROPOSALS DUE.** Ancient DNA studies of human origins and ancient admixture. |
| Apr 10 | Ancient DNA and population migrations. |
| Apr 17 | Ancient DNA research on ancient environments and plant and animal domestication. |
| Apr 24 | New possibilities for biomolecular research. Discuss research papers and other topics based on student interests. Pizza party! |
|  | **FINAL PAPER DUE MAY 9.** |

**General references on reserve:**

Pollard, A.M. & Heron, C. (2008). *Archaeological Chemistry* (2nd Edition). Cambridge: The Royal Society of Chemistry.

Brown, T. & Brown, K. (2011). *Biomolecular Archaeology: An Introduction*. Malden: Wiley-Blackwell.

**\*\*\*PLEASE NOTE THAT ALL ASSIGNED READINGS ARE SUBJECT TO CHANGE\*\*\***

**JANUARY 30 (WEEK 1). Introduction to biomolecules and considerations in the field of biomolecular archaeology**

Required Readings:

1. Nigra, B.T., Faull, K.F., & Barnard, H. (2014). Analytical chemistry in archaeological research. *Analytical Chemistry* 87(1): 3-18.
2. Killick, D. (2015). The awkward adolescence of archaeological science. *Journal of Archaeological Science* 56: 242-247.
3. Horsburgh, K.A. (2015). [Molecular anthropology: The judicial use of genetic data in archaeology](http://www.smu.edu/-/media/Site/Dedman/Departments/Anthropology/pdf/Horsburgh/Horsburgh-2015.ashx?la=en). *Journal of Archaeological Science* 56:141-145.

**FEBRUARY 6 (WEEK 2). GC/MS, immunoassays, and other techniques for residue analysis**

Required Readings:

1. Dallongeville, S., Garnier, N., Rolando, C., & Tokarski, C. (2015). Proteins in art, archaeology, and paleontology: From detection to identification. *Chemical Reviews* 116(1): 2-79.
2. McGovern, P.E., Zhang, J., Tang, J., Zhang, Z., Hall, G.R., Moreau, R.A., ... & Cheng, G. (2004). Fermented beverages of pre-and proto-historic China. *Proceedings of the National Academy of Sciences* 101(51): 17593-17598.
3. Pavelka, J., Smejda, L., Hynek, R., & Kuckova, S.H. (2016). Immunological detection of denatured proteins as a method for rapid identification of food residues on archaeological pottery. *Journal of Archaeological Science* 73: 25-35.
4. Barnard, H., Ambrose, S.H., Beehr, D.E., Forster, M.D., Lanehart, R.E., Malainey, M.E., ... & Yohe, R.M. (2007). Mixed results of seven methods for organic residue analysis applied to one vessel with the residue of a known foodstuff. *Journal of Archaeological Science* 34(1): 28-37.
5. Roffet-Salque, M., Dunne, J., Altoft, D.T., Casanova, E., Cramp, L.J., Smyth, J., ... & Evershed, R.P. (2016). From the inside out: Upscaling organic residue analyses of archaeological ceramics. *Journal of Archaeological Science: Reports*. http://dx.doi.org/10.1016/j.jasrep.2016.04.005

Supplemental Readings:

1. Cartechini, L., Palmieri, M., Vagnini, M., & Pitzurra, L. (2016). Immunochemical methods applied to art-historical materials: Identification and localization of proteins by ELISA and IFM. *Topics in Current Chemistry* *374*(1): 5.
2. Dal Sasso, G., Lebon, M., Angelini, I., Maritan, L., Usai, D., & Artioli, G. (2016). Bone diagenesis variability among multiple burial phases at Al Khiday (Sudan) investigated by ATR-FTIR spectroscopy. *Palaeogeography, Palaeoclimatology, Palaeoecology* 463: 168-179.
3. Colonese, A.C., Lucquin, A., Guedes, E.P., Thomas, R., Best, J., Fothergill, B.T., ... & Maltby, M. (2017). The identification of poultry processing in archaeological ceramic vessels using in-situ isotope references for organic residue analysis. *Journal of Archaeological Science* 78: 179-192.

**FEBRUARY 13 (WEEK 3). LC/MS, MS/MS, and residue analysis case studies on cacao, wine, and milk**

Required Readings:

1. Hurst, W.J. (2011). The Determination of Cacao in Samples of Archaeological Interest. In C. McNeil (Ed.) *Chocolate in Mesoamerica: A Cultural History of Cacao* (pp. 105-113). Gainesville: University of Florida Press.
2. McNeil, C., Hurst, W.J., & Sharer, R.J. (2011). The use and representation of cacao during the Classic period at Copan, Honduras. In C. McNeil (Ed.) *Chocolate in Mesoamerica: A Cultural History of Cacao* (pp. 224-252). Gainesville: University of Florida Press.
3. Washburn, D.K., Washburn, W.N., Shipkova, P.A., & Pelleymounter, M.A. (2014). Chemical analysis of cacao residues in archaeological ceramics from North America: Considerations of contamination, sample size and systematic controls. *Journal of Archaeological Science* 50: 191-207.
4. Barnard, H., Dooley, A.N., Areshian, G., Gasparyan, B., & Faull, K.F. (2011). Chemical evidence for wine production around 4000 BCE in the Late Chalcolithic Near Eastern highlands. *Journal of Archaeological Science* 38(5): 977-984.

Supplemental Readings:

1. Henderson, J.S., Joyce, R.A., Hall, G.R., Hurst, W.J., & McGovern, P.E. (2007). Chemical and archaeological evidence for the earliest cacao beverages. *Proceedings of the National Academy of Sciences* 104(48): 18937-18940.
2. Buckley, M., Melton, N.D., & Montgomery, J. (2013). Proteomics analysis of ancient food vessel stitching reveals> 4000‐year‐old milk protein. *Rapid Communications in Mass Spectrometry* 27(4): 531-538.
3. Roffet-Salque, M., Lee, M. R., Timpson, A., & Evershed, R. P. (2016). Impact of modern cattle feeding practices on milk fatty acid stable carbon isotope compositions emphasize the need for caution in selecting reference animal tissues and products for archaeological investigations. *Archaeological and Anthropological Sciences*: 1-6. doi:10.1007/s12520-016-0357-5
4. Yang, Y.M., Shevchenko, A., Knaust, A., Abuduresule, I., Li, W.Y., Hu, X.J., Wang, C.S., Shevchenko, A. (2014). Proteomics evidence for kefir dairy in Early Bronze Age China. *Journal of Archaeological Science* 45: 178-186.
5. Warinner, C., Hendy, J., Speller, C., Cappellini, E., Fischer, R., Trachsel, C., ... & Fotakis, A. (2014). Direct evidence of milk consumption from ancient human dental calculus. *Scientific Reports* 4: 7104.

**FEBRUARY 20. NO CLASS MEETING**

**FEBRUARY 27 (WEEK 4). Collagen fingerprinting**

Required Readings:

1. Kendall, C., et al. (2018). Diagenesis of archaeological bone and tooth. *Paleogeography, Paleoclimatology, Palaeoecology* 491: 21-37
2. Buckley, M. (2018). Zooarchaeology by Mass Spectrometry (ZooMS) Collagen Fingerprinting for the Species Identification of Archaeological Bone Fragments. In: Giovas C., LeFebvre M. (eds.) *Zooarchaeology in Practice* (pp. 227-247). Springer, Cham.
3. Kirby, D.P., Buckley, M., Promise, E., Trauger, S.A., & Holdcraft, T.R. (2013). Identification of collagen-based materials in cultural heritage. *Analyst* 138(17): 4849-4858.
4. Harvey, V.L., Egerton, V.M., Chamberlain, A.T., Manning, P.L., & Buckley, M. (2016). Collagen fingerprinting: A new screening technique for radiocarbon dating ancient bone. *PLOS ONE* 11(3): e0150650.
5. Welker, F., Hajdinjak, M., Talamo, S., Jaouen, K., Dannemann, M., David, F., ... & Brace, S. (2016). Palaeoproteomic evidence identifies archaic hominins associated with the Châtelperronian at the Grotte du Renne. *Proceedings of the National Academy of Sciences* 113(40): 11162-11167.

Supplemental Readings:

1. Buckley, M., & Kansa, S.W. (2011). Collagen fingerprinting of archaeological bone and teeth remains from Domuztepe, South Eastern Turkey. *Archaeological and Anthropological Sciences* 3(3): 271-280.
2. Von Holstein, I.C., Ashby, S.P., van Doorn, N.L., Sachs, S.M., Buckley, M., Meiri, M., ... & Collins, M.J. (2014). Searching for Scandinavians in pre-Viking Scotland: Molecular fingerprinting of Early Medieval combs. *Journal of Archaeological Science* 41: 1-6.
3. Buckley, M., Fraser, S., Herman, J., Melton, N.D., Mulville, J., & Pálsdóttir, A.H. (2014). Species identification of archaeological marine mammals using collagen fingerprinting. *Journal of Archaeological Science* 41: 631-641.
4. Brown, S., Higham, T., Slon, V., Pääbo, S., Meyer, M., Douka, K., ... & Derevianko, A. (2016). Identification of a new hominin bone from Denisova Cave, Siberia using collagen fingerprinting and mitochondrial DNA analysis. *Scientific Reports* 6: 23559.
5. van Doorn, N.L., Hollund, H., & Collins, M.J. (2011). A novel and non-destructive approach for ZooMS analysis: Ammonium bicarbonate buffer extraction. *Archaeological and Anthropological Sciences* 3(3): 281-289.
6. Welker, F., Soressi, M., Rendu, W., Hublin, J.J., & Collins, M. (2015). Using ZooMS to identify fragmentary bone from the late Middle/Early Upper Palaeolithic sequence of Les Cottes, France. *Journal of Archaeological Science* 54: 279-286.

**MARCH 6 (WEEK 5). Stable isotope studies of diet**

Required Readings:

1. Makarewicz, C.A., & Sealy, J. (2015). Dietary reconstruction, mobility, and the analysis of ancient skeletal tissues: Expanding the prospects of stable isotope research in archaeology. *Journal of Archaeological Science* 56: 146-158.
2. Warinner, C., Garcia, N. R., & Tuross, N. (2013). Maize, beans and the floral isotopic diversity of highland Oaxaca, Mexico. *Journal of Archaeological Science* 40(2): 868-873.
3. Sugiyama, N., Somerville, A.D., & Schoeninger, M.J. (2015). Stable isotopes and zooarchaeology at Teotihuacan, Mexico reveal earliest evidence of wild carnivore management in Mesoamerica. *PloS One* 10(9): e0135635.
4. Barton, L., Newsome, S. D., Chen, F. H., Wang, H., Guilderson, T. P., & Bettinger, R. L. (2009). Agricultural origins and the isotopic identity of domestication in northern China. *Proceedings of the National Academy of Sciences* 106(14): 5523-5528.
5. Balasse, M., & Tresset, A. (2002). Early weaning of Neolithic domestic cattle (Bercy, France) revealed by intra-tooth variation in nitrogen isotope ratios. *Journal of Archaeological Science* 29(8): 853-859.
6. Watch Christina Warinner’s 20 minute TED talk that critiques the “Paleodiet” trend: <https://www.youtube.com/watch?v=BMOjVYgYaG8>

Supplemental Readings:

1. Britton, K. (2017). A stable relationship: Isotopes and bioarchaeology are in it for the long haul. *Antiquity* 91 (358): 853-864.
2. Reynard, L.M. & Tuross, N. (2015). The known, the unknown and the unknowable: Weaning times from archaeological bones using nitrogen isotope ratios. *Journal of Archaeological Science* 53: 618-625.
3. Spiteri, C.D., Gillis, R.E., Roffet-Salque, M., Navarro, L.C., Guilaine, J., Manen, C., ... & Craig, O.E. (2016). Regional asynchronicity in dairy production and processing in early farming communities of the northern Mediterranean. *Proceedings of the National Academy of Sciences* 113(48): 13594-13599.
4. Hedges, R. E. M., Stevens, R. E., and Koch, P. L., 2005. Isotopes in Bones and Teeth. In: M.J. Leng (Ed.), *Isotopes in Palaeoenvironmental Research* (pp. 117-145) Springer Netherlands.
5. Koch, P.L., Behrensmeyer, A., Stott, A., Tuross, N., Evershed, R., and Fogel, M. L. (2001). The

effects of weathering on the stable isotope composition of bones. *Ancient Biomolecules* 3:

117–134.

1. Warinner, C., & Tuross, N. (2009). Alkaline cooking and stable isotope tissue-diet spacing in swine: Archaeological implications. *Journal of Archaeological Science* 36(8): 1690-1697.
2. Casar, I., Morales, P., Manzanilla, L.R., Cienfuegos, E., & Otero, F. (2016). Dietary differences in individuals buried in a multiethnic neighborhood in Teotihuacan: Stable dental isotopes from Teopancazco. *Archaeological and Anthropological Sciences* 9(1): 99-115.

**MARCH 13 (WEEK 6). Isotopic studies of migration, transhumance, and environments**

Required Readings:

1. Lightfoot, E., O’Connell, T.C. (2016). On the Use of Biomineral Oxygen Isotope Data to Identify Human Migrants in the Archaeological Record: Intra-Sample Variation, Statistical Methods and Geographical Considerations. *PLoS ONE* 11(4): e0153850.
2. Tuross, N. et al. (2017). Human skeletal development and feeding behavior: the impact on oxygen isotopes. *Archaeological and Anthropological Sciences* 9(7): 1453-1459.
3. Bentley, R.A. (2006). Strontium isotopes from the earth to the archaeological skeleton: A review. *Journal of Archaeological Method and Theory* 13(3): 135-187.
4. Choose one of the following:
   1. Price, T.D., Burton, J.H., Fullagar, P.D., Wright, L.E., Buikstra, J.E., & Tiesler, V. (2015). Strontium isotopes and the study of human mobility among the ancient Maya. In A. Cucina (Ed.), *Archaeology and bioarchaeology of population movement among the Prehispanic Maya* (pp. 119-132). Springer International Publishing.
   2. Scherer, A.K., de Carteret, A., & Newman, S. (2015). Local water resource variability and oxygen isotopic reconstructions of mobility: A case study from the Maya area. *Journal of Archaeological Science: Reports* 2: 666-676.
5. And choose one of the following:
   1. Cheung, C., Jing, Z., Tang, J., Weston, D.A., & Richards, M.P. (2017). Diets, social roles, and geographical origins of sacrificial victims at the royal cemetery at Yinxu, Shang China: New evidence from stable carbon, nitrogen, and sulpher isotope analysis. *Journal of Anthropological Archaeology* 48: 28-45.
   2. Makarewicz, C.A. (2017). Sequential δ 13 C and δ 18 O analyses of early Holocene bovid tooth enamel: Resolving vertical transhumance in Neolithic domesticated sheep and goats. *Palaeogeography, Palaeoclimatology, Palaeoecology*.

Supplemental Readings:

1. Frémondeau, D., Cucchi, T., Casabianca, F., Ughetto-Monfrin, J., Horard-Herbin, M.P., & Balasse, M. (2012). Seasonality of birth and diet of pigs from stable isotope analyses of tooth enamel (δ 18 O, δ 13 C): A modern reference data set from Corsica, France. *Journal of Archaeological Science* 39(7): 2023-2035.
2. Henton, E., Martin, L., Garrard, A., Jourdan, A.L., Thirlwall, M., & Boles, O. (2017). Gazelle seasonal mobility in the Jordanian steppe: The use of dental isotopes and microwear as environmental markers, applied to Epipalaeolithic Kharaneh IV. *Journal of Archaeological Science: Reports* 11: 147-158.

**MARCH 20 (WEEK 7). Introduction to ancient DNA approaches**

Note: Please try to attend Linda Raynard’s Brown Bag talk in the Joukowsky Institute on Thursday, March 22 at 12:00pm.

Required Readings:

1. Linderholm, A. (2016). Ancient DNA: The next generation–chapter and verse. *Biological Journal of the Linnean Society* 117(1): 150-160.
2. Hofreiter, M., Paijmans, J.L., Goodchild, H., Speller, C.F., Barlow, A., Fortes, G.G., ... & Collins, M.J. (2015). The future of ancient DNA: Technical advances and conceptual shifts. *BioEssays* 37(3): 284-293.
3. Llamas, B., Valverde, G., Fehren-Schmitz, L., Weyrich, L. S., Cooper, A., & Haak, W. (2017). From the field to the laboratory: Controlling DNA contamination in human ancient DNA research in the high-throughput sequencing era. *STAR: Science & Technology of Archaeological Research* 3(1): 1-14.
4. TallBear, K. (2013). *Native American DNA: Tribal Belonging and the False Promise of Genetic Science*. Minneapolis: University of Minnesota Press. Chapter 4 and Conclusion.
5. Select at least one of the following:
   1. Meltzer, D.J. (2015). Kennewick Man: Coming to closure. *Antiquity* 89(348): 1485–1493.
   2. <https://www.sapiens.org/archaeology/chaco-canyon-nagpra/>
   3. <https://www.theatlantic.com/science/archive/2018/03/ancient-dna-history/554798/>
   4. <https://www.nytimes.com/2016/05/17/science/eske-willerslev-ancient-dna-scientist.html>
   5. <https://www.nytimes.com/2018/03/23/opinion/sunday/genetics-race.html>

Supplemental Readings:

1. Matisoo-Smith, E., & Horsburgh, K.A. (2012). *DNA for Archaeologists*. Walnut Creek: Left Coast Press. Chapter 2 and 3.
2. Gamba, C., Hanghoj, K., Gaunitz, C., Alfarhan, A.H., Alquiraishi, S.A., Al-Rasheid, K.A.S., Bradley, D.G., & Orlando, L. (2017). Comparing the performance of three ancient DNA extraction methods for high-throughput sequencing. *Molecular Ecology Resources* 16 (2): 459-469.
3. Hansen, H.B., Damgaard, P.B., Margaryan, A., Stenderup, J., Lynnerup, N., Willerslev, E., & Allentoft, M.E. (2017). Comparing Ancient DNA Preservation in Petrous Bone and Tooth Cementum. *PLoS One* 12(1): e0170940.
4. Hollund, H. I., Teasdale, M. D., Mattiangeli, V., Sverrisdóttir, O. Ó., Bradley, D. G., & O'Connor, T. (2016). Pick the Right Pocket. Sub‐sampling of Bone Sections to Investigate Diagenesis and DNA Preservation. *International Journal of Osteoarchaeology*. DOI: 10.1002/oa.2544
5. Damgaard, P.B., Margaryan, A., Schroeder, H., Orlando, L., Willerslev, E., & Allentoft, M.E. (2015). Improving access to endogenous DNA in ancient bones and teeth. *Scientific Reports* 5: 11184.

**MARCH 27. NO CLASS MEETING. SPRING BREAK.**

**APRIL 3 (WEEK 8). Ancient DNA studies of human origins and ancient admixture**

**PAPER TOPIC PROPOSALS DUE.**

NOTE: Please also skim the supplemental information sections for the assigned articles.

Required Readings:

1. Nielsen, R., Akey, J.M., Jakobsson, M., Pritchard, J.K., Tishkoff, S., & Willerslev, E. (2017). Tracing the peopling of the world through genomics. *Nature* 541(7637): 302-310.
2. [Prufer, K., et al. (2014). The complete genome sequence of a Neanderthal from the Altai Mountains. *Nature*505: 43-49.](https://canvas.harvard.edu/courses/7085/files/1074967/download?wrap=1)
3. [Huerta-Sanchez, E., et al. (2014). Altitude adaptation in Tibetans caused by introgression of Denisovan-like DNA. *Nature* 512: 194-7.](https://canvas.harvard.edu/courses/7085/files/1075987/download?wrap=1)
4. Lipson, M. and Reich, D. (2017). A working model of the deep relationships of diverse modern human genetic lineages outside of Africa*. Molecular Biology and Evolution* 34(4): 889-902.
5. Yang, M.A. & Fu, Q. (2018). Insights into modern human prehistory using ancient genomes. *Trends in Genetics* 34(3): 184-196.

Supplemental Readings:

1. Meyer, M., Kircher, M., ,Gansauge, M.,…Paabo, S. (2012). A High-Coverage Genome Sequence from an Archaic Denisovan Individual. *Science* 338 (6401): 222-226.
2. <http://www.archaeology.org/issues/268-1709/features/5816-tibet-high-altitude-adaptation> (and watch the associated video)
3. Yang, M.A. et al. (2017). 40,000-year-old individual from Asia provides insight into early population structure in Eurasia. *Current Biology* 27(20): 3202-3208.e9
4. Meyer, M., Arsuaga, J. L., de Filippo, C., Nagel, S., Aximu-Petri, A., Nickel, B., ... & Viola, B. (2016). Nuclear DNA sequences from the Middle Pleistocene Sima de los Huesos hominins. *Nature* 531(7595): 504-507.
5. [Fu, Q., et al. (2013). DNA analysis of an early modern human from Tianyuan Cave, China. *PNAS* 110, 2223-7.](https://canvas.harvard.edu/courses/7085/files/1251780/download?wrap=1)
6. [Fu Q., et al. (2015). An early modern human from Romania with a recent Neanderthal ancestor. *Nature* 524: 216-9.](https://canvas.harvard.edu/courses/7085/files/1075356/download?wrap=1)
7. [Sankararaman, S., et al. (2014). The genomic landscape of Neanderthal ancestry in present-day humans. *Nature* 507: 354-7.](https://canvas.harvard.edu/courses/7085/files/1075335/download?wrap=1)
8. Meyer, M., et al. (2014). A mitochondrial genome sequence of a hominin from Sima de los Huesos. *Nature* 505(7483): 403-406.
9. [Meyer, M., et al. (2012). A high-coverage genome sequence from an archaic Denisovan individual. Science 338, 222-6.](https://canvas.harvard.edu/courses/7085/files/1075959/download?wrap=1)
10. [Fu, Q., et al. (2014). Genome sequence of a 45,000-year-old modern human from western Siberia. *Nature* 514: 445-9.](https://canvas.harvard.edu/courses/7085/files/1075775/download?wrap=1)
11. Jeong, C., Alkorta-Aranburu, G., Basnyat, B., Neupane, M., Witonsky, D. B., Pritchard, J. K., ... & Di Rienzo, A. (2014). Admixture facilitates genetic adaptations to high altitude in Tibet. *Nature Communications* 5.
12. [Reich, D., et al. (2011). Denisova Admixture and the First Modern Human Dispersals into Southeast Asia and Oceania. *American Journal of Human Genetics* 89: 516-28.](https://canvas.harvard.edu/courses/7085/files/1075951/download?wrap=1)
13. Schaefer, N. K., Shapiro, B., & Green, R. E. (2016). Detecting hybridization using ancient DNA. *Molecular Ecology* 25: 2398-2412.

**APRIL 10 (WEEK 9). Ancient DNA and population migrations**

Required Readings:

1. [Pickrell, J.K., Reich, D. (2014). Toward a new history and geography of human genes informed by ancient DNA. *Trends in Genetics* 30: 377-89.](https://canvas.harvard.edu/courses/7085/files/1066928/download?wrap=1)
2. Haak, W., et al. (2015). Massive migration from the steppe was a source of Indo-European languages in Europe. *Nature* 522: 207-211.
3. <https://www.nature.com/articles/d41586-018-03773-6>
4. <https://www.lrb.co.uk/blog/2017/08/10/yannis-hamilakis/who-are-you-calling-mycenaean/>
5. <http://nautil.us/issue/58/self/social-inequality-leaves-a-genetic-mark?utm_source=Nautilus&utm_campaign=98440292f1-EMAIL_CAMPAIGN_2018_03_28&utm_medium=email&utm_term=0_dc96ec7a9d-98440292f1-50625661>
6. <https://www.nytimes.com/2018/03/23/opinion/sunday/genetics-race.html>
7. <https://www.nytimes.com/2018/03/30/opinion/race-genetics.html>
8. <https://www.buzzfeed.com/bfopinion/race-genetics-david-reich?utm_term=.ivRQja0R8#.cwz5lPx1E>

Supplemental Readings:

1. Matisoo-Smith, E. (2015). Ancient DNA and the human settlement of the Pacific: A review. *Journal of Human Evolution* 79: 93-104.
2. Skoglund, P., & Reich, D. (2016). A genomic view of the peopling of the Americas. *Current Opinion in Genetics & Development* 41: 27-35.
3. Moreno-Mayar, J.V., et al. (2018). Terminal Pleistocene Alaskan genome reveals first founding population of Native Americans. *Nature* 553: 203-207.
4. [Rasmussen, ­­M., et al. (2015). The ancestry and affiliations of Kennewick Man. *Nature* 523: 455-8.](https://canvas.harvard.edu/courses/7085/files/1111122/download?wrap=1)
5. [Raghavan, M., et al. (2014). Upper Palaeolithic Siberian genome reveals dual ancestry of Native Americans.*Nature* 505: 87-91.](https://canvas.harvard.edu/courses/7085/files/1110897/download?wrap=1)
6. Rasmussen, M. et al. (2014). The genome of a late Pleistocene human from a Clovis burial site in western Montana. *Nature* 506:225-229.
7. Raghavan, M., DeGiorgio, M., Albrechtsen, A., Moltke, I., Skoglund, P., Korneliussen, T. S., ... & Fitzhugh, W. (2014). The genetic prehistory of the New World Arctic. *Science* 345(6200): 1255832.
8. Skoglund, P., et al. (2015). Genetic evidence for two founding populations of the Americas. *Nature* 525: 104-8.
9. [Raghavan. M., et al. (2015). Genomic evidence for the Pleistocene and recent population history of Native Americans. *Science* 349: 841/aab3884](https://canvas.harvard.edu/courses/7085/files/1199550/download?wrap=1)

**APRIL 17 (WEEK 10). Ancient DNA from floral and faunal remains**

Required Readings:

1. Hofman, C.A., Rick, T.C., Fleischer, R.C., & Maldonado, J.E. (2015). Conservation archaeogenomics: Ancient DNA and biodiversity in the Anthropocene. *Trends in Ecology & Evolution* 30(9): 540-549.
2. Explore the Revive and Restore website: <http://reviverestore.org/>
3. MacHugh, D.E., Larson, G., & Orlando, L. (2016). Taming the past: Ancient DNA and the study of animal domestication. *Annual Review of Animal Biosciences* 5: 329-351.
4. Choose one of the following:
   1. Ottoni, C. et al. (2013). Pig Domestication and Human-mediated Dispersal in Western Eurasia Revealed through Ancient DNA and Geometric Morphometrics. *Molecular Biology and Evolution* 30(4): 824-832.
   2. Flink, L.G., Allen, R., Barnett, R., Malmström, H., Peters, J., Eriksson, J., ... & Larson, G. (2014). Establishing the validity of domestication genes using DNA from ancient chickens. *Proceedings of the National Academy of Sciences* 111(17): 6184-6189.
   3. Gaunitz, C. et al. (2018). Ancient genomes revisit the ancestry of domestic and Przewalski’s horses. Science 22 Feb 2018: eaao3297.

Supplemental Readings:

1. <https://www.statnews.com/2018/02/27/moa-extinct-bird-genome/>
2. Witt, K. E., Judd, K., Kitchen, A., Grier, C., Kohler, T. A., Ortman, S. G., ... & Malhi, R. S. (2015). DNA analysis of ancient dogs of the Americas: Identifying possible founding haplotypes and reconstructing population histories. *Journal of Human Evolution* 79: 105-118.
3. Skoglund, P. et al. (2015). Ancient wolf genome reveals an early divergence of domestic dog ancestors and admixture into high-latitude breeds. Current Biology 25(11): 1515-1519.
4. Heintzman, P., et al. (2016). Bison phylogeography constrains dispersal and viability of the Ice Free Corridor in Western Canada. *Proceedings of the National Academy of Sciences* 113 (29): 8057-8063.
5. Jaenicke-Després, V.R., & Smith, B.D. (2006). Ancient DNA and the integration of archaeological and genetic approaches to the study of maize domestication. In J.E. Staller, R.H. Tykot, & B.F. Benz (Eds.), *Histories of Maize in Mesoamerica: Multidisciplinary Approaches* (pp. 32-44). London and New York: Routledge.
6. Ramos-Madrigal, J. et al. (2016). Genome Sequence of a 5,310-Year-Old Maize Cob Provides Insights into the Early Stages of Maize Domestication. *Current Biology* 26: 3195-3201.
7. Shapiro, B., & Hofreiter, M. (2014). A paleogenomic perspective on evolution and gene function: New insights from ancient DNA. *Science* 343(6169): 1236573.
8. Sinding, M.H., & Gilbert, M.T. (2016). The draft genome of extinct European aurochs and its implications for de-extinction. *Open Quaternary* 2: 7. DOI: 10.5334/oq.25
9. Speller, C., van den Hurk, Y., Charpentier, A., Rodrigues, A., Gardeisen, A., Wilkens, B., ... & Hofreiter, M. (2016). Barcoding the largest animals on Earth: Ongoing challenges and molecular solutions in the taxonomic identification of ancient cetaceans. *Phil. Trans. R. Soc. B* 371(1702): 20150332.
10. Gutaker, R. M., & Burbano, H. A. (2017). Reinforcing plant evolutionary genomics using ancient DNA. *Current Opinion in Plant Biology* 36: 38-45.

**APRIL 24 (WEEK 11). New possibilities for biomolecular research**

Required Readings:

1. Thomsen, P.F., & Willerslev, E. (2015). Environmental DNA – An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation* 183: 4-18.
2. Watch Christina Warinner’s talk on the oral microbiome: <https://www.youtube.com/watch?v=h3FawTt1sXg>
3. Revisit articles from the first week of class and think about the “guiding questions” posted on the course website.
4. Choose one of the following:
   1. Weyrich, L.S., et al. (2017). Neanderthal Behaviour, Diet, and Disease Inferred from Ancient DNA in Dental Calculus. *Nature* 544: 357-361.
   2. McCoy, R.C. et al. (2017). Impacts of Neanderthal-Introgressed Sequences on the Landscape of Human Gene Expression. *Cell* 168 (5): 916-927.
   3. [Rasmussen, S., et al. (2015). Early divergent strains of *Yersinia pestis* in Eurasia 5,000 years ago. *Cell* 163: 571-582.](https://canvas.harvard.edu/courses/7085/files/1381323/download?wrap=1)
   4. Amorim, C.E.G., et al. (2018). Understanding 6th-Century Barbarian social organization and migration through paleogenomics. BioRxiv. doi.org/10.1101/268250
   5. Schroeder, H., et al. (2015). Genome-wide ancestry of 17th-century enslaved Africans from the Caribbean. *PNAS* 112(12): 3669-3673.

Supplemental Readings:

1. Weyrich, L.S., Dobney, K.M., Cooper, A. (2015). Ancient DNA analysis of dental calculus. *Journal of Human Evolution* 79: 119-124.
2. Warinner, C., Speller, C., & Collins, M.J. (2015). A new era in palaeomicrobiology: Prospects for ancient dental calculus as a long-term record of the human oral microbiome. *Phil. Trans. R. Soc. B* 370(1660): 20130376.
3. Warinner, C. (2016). Dental calculus and the evolution of the human oral microbiome. *Journal of the Canadian Dental Association*, *44*(7), 411-420.
4. Slon, V., et al. (2017). Neandertal and Denisovan DNA from Pleistocene sediments. *Science* 356 (6338): 605-608.
5. Ávila-Arcos, M. C., Ho, S. Y., Ishida, Y., Nikolaidis, N., Tsangaras, K., Hönig, K., ... & Willerslev, E. (2013). One hundred twenty years of koala retrovirus evolution determined from museum skins. *Molecular Biology and Evolution* 30(2): 299-304.
6. Campana, M. G., García, N. R., Rühli, F. J., & Tuross, N. (2014). False positives complicate ancient pathogen identifications using high-throughput shotgun sequencing. *BMC research notes* 7(1): 111.
7. Gokhman, D. et al. (2016). Epigenetics: It’s getting Old. Past meets future in paleoepigenetics. Trends in Ecology and Evolution 31(4): 290-300.
8. [Leslie, S., et al. (2015). The fine-scale genetic structure of the British population. *Nature* 519: 309-14.](https://canvas.harvard.edu/courses/7085/files/1252054/download?wrap=1)