OEB 209: The Early Evolution of Animals

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Synopsis: In this seminar, we will explore the paleontological record of early animal evolution, evaluating fossils in the context of phylogeny and environmental history

Prerequisites: Permission of instructor.

Grading: Grades will be based on week by week participation and a 10-12 page term paper to be submitted no later than 5:00 pm on Wednesday May 3, 2017.

Week 1: Context -- AHK Overview of phylogeny and the geologic record

All:

Erwin, D.H. (2015) Early metazoan life: divergence, environment and ecology. Phil. Trans. R. Soc. B 370, 20150036.

Narbonne, G.M., S. Xiao, and G. Shields (2012) The Ediacaran Period. P. 413-435 in: Geologic Timescale, 2012, F.M. Gradstein, J.G. Ogg, M. Shcmitz, and G. Ogg (eds). doi: 10.1016/B978-0-444-59425-9.00018-4.

Week 2: Phylogeny and Comparative Biology

All:

Giribet, G. (2016) New animal phylogeny: future challenges for animal phylogeny in the age of phylogenomics. Org. Divers. Evol. 16: 419–426.

Telford, M.J., G.E. Budd, and H. Philippe (2015) Phylogenomic insights into animal evolution. Current Biology 25: R876–R887.

Volunteers:

1. Pisani, D., W. Pettc, M. Dohrmannd, R. Feudae, O. Rota-Stabellif, et al. (2015) Genomic data do not support comb jellies as the sister group to all other animals. Proc. Nat. Acad. Sci., USA 112: 15402–15407.

2. Philippe, H., R. Derelle, P. Lopez, K. Pick, C. Borchiellini et al. (2009) Phylogenomics revives traditional views on deep animal relationships. Current Biology 19: 706–712.

3. Shalchian-Tabrizi, K., M.A. Minge, M. Espelund, R. Orr, T. Ruden (2009) Multigene phylogeny of Choanozoa and the origin of animals. PlosOne 3(5), e2098.

   Richter, D.J. and N. King (2013) The genomic and cellular foundations of animal origins. Annual Rev. Genetics 47: 509–37.

4. Srivastava, M., E. Begovic, J. Chapman, N.H. Putnam, U. Hellsten, et al. (2008) The *Trichoplax* genome and the nature of placozoans. Nature 454: 955-960.

Week 3: Ediacaran Paleobiology – Key Taxa

All:

Narbonne, G.M. (2005) The Ediacara biota: Neoproterozoic origin of animals and their ecosystems. Ann. Review Earth Planet. Sci. 33: 421-442.

Droser, M.L. and J.G. Gehling (2014) The advent of animals: The view from the Ediacaran. Proc. Nat. Acad. Sci., USA 112: 4865–4870.

Volunteers:

1. *Dickinsonia*: Sperling, E.A. and J. Vinther (2010) A placozoan affinity for *Dickinsonia* and the evolution of late Proterozoic metazoan feeding modes. Evol. Develop. 12: 201–209.

   Brasier, M. and J. Antcliffe (2008) *Dickinsonia* from Ediacara: a new look at morphology and body construction. Palaeogeogr. Palaeoclimatol. Palaeoecol. 270: 311–323.

2. *Kimberella*: Fedonkin, M.A., A. Simonetta, and A.Yu. Ivantzov (2007) New data on *Kimberella*, the Vendian mollusk-like organism (White Sea region, Russia): Palaeoecological and evolutionary implications. Geol. Soc. Lond. Spec. Publ 286:157–179.

   Gehling J.G., B.N. Runnegar, and M.L. Droser (2014) Scratch traces of large Ediacara bilaterian animals. J. Paleontol. 88:284-298.

3. Fronds I: Laflamme, M. and G.M. Narbonne (2008) Ediacaran fronds. Palaeogeography, Palaeoclimatology, Palaeoecology 258: 162–179.

4. Fronds II: Cuthill, J.F. and S. Conway Morris Fractal branching organizations of Ediacaran rangeomorph fronds reveal a lost Proterozoic body plan Proc. Nat. Acad. Sci., USA 111: 13122–13126.

Antcliffe, J.B. and M.D. Braiser (2008) *Charnia* at 50: developmental models for Ediacaran fronds. Palaeontology 51: 11-26.

Weeks 4 and 5: Ediacaran Paleobiology: Key Assemblages

All:

Xiao, S. and M. Laflamme (2009) On the eve of animal radiation: Phylogeny, ecology and evolution of the Ediacara biota. Trends Ecol Evol 24(1):31–40.

Volunteers

1. Coutts, F.J., J.G. Gehling, and D.C. García-Bellido (2016) How diverse were early animal communities? An example from Ediacara Conservation Park, Flinders Ranges, South Australia. Alcheringa 40: 407-421.Coutts et al. (2016)

2. Gehling, J.G., and M.L. Droser (2012) Ediacaran stratigraphy and the Ediacara biota of the Adelaide Geosyncline, South Australia. Episodes 35: 236–246.

3. Grotzinger, J.P., S.A. Bowring, B.Z. Saylor, A.J. Kaufman, Biostratigraphic and geochronologic constraints on early animal evolution. Science 270: 598–604.

4. Clapham, M., G.M. Narbonne, and J.G. Gehling (2003) Paleoecology of the oldest known animal communities: Ediacaran assemblages at Mistaken Point, Newfoundland. Paleobiology, 29:5 27-544.

5. Hofmann, H.J., S.J. O'Brien, and A.F. King (2008) Ediacaran Biota on Bonavista Peninsula, Newfoundland, Canada. J. Paleontol. 82: 1-36.

6. Grazhdankin, D. (2014) Patterns of evolution of the Ediacaran soft-bodied biota. J. Paleontol. 88: 269-283.

7. Cai, Y., H. Hua, S. Xiao, J.D. Schiffbauer, and P. Li (2010) Biostratinomy of the late Ediacaran pyritized Gaojiashan Lagerstätte from southern Shaanxi, South China: Importance of event deposits. Palaios 25: 487-506.

8. Boag, T.H., S.A.F. Darroch, and M. Laflamme (2016) Ediacaran distributions in space and time: testing assemblage concepts of earliest macroscopic body fossils. Paleobiology 42: 574-594.

Weeks 6 and 7: Ediacaran Paleobiology III

1. Trace fossils:

   Jensen, S. (2003) The Proterozoic and earliest Cambrian trace fossil record: patterns, problems and perspectives. Integrative and Comparative Biology 43, 219–228.

   Liu, A.G., D. Mcllroy, and M.D. Brasier (2010) First evidence for locomotion in the Ediacara biota from the 565 Ma Mistaken Point Formation, Newfoundland. Geology 38: 123-126.

   Chen, Z., C. Zhou, M. Meyer, Ke Xiang, J.D. Schiffbauer, et al. (2013) Trace fossil evidence for Ediacaran bilaterian animals with complex behaviors. Precambrian Research 224: 690– 701.

2. Carbonate skeletons:

   Grotzinger, J.P., W. Watters, and A.H. Knoll (2000) Calcareous metazoans in thrombolytic bioherms of the terminal Proterozoic Nama Group, Namibia. Paleobiology 26: 334-359.

   Wood, R.A. (2011) Paleoecology of the earliest skeletal metazoan communities: Implications for early biomineralization. Earth Sci. Rev. 106: 184-190.

   Cai, Y., H. Hua, J.D. Schiffbauer, B. Sun, X. Yuan (2014) Tube growth patterns and microbial mat-related lifestyles in the Ediacaran fossil *Cloudina*, Gaojiashan Lagerstätte, South China. Gondwana Res. 25: 1008-1018.

3. Corumbella

   Pacheco, M.L.A. et al. (2015) Insights into the skeletonization, lifestyle, and affinity of the unusual Ediacaran fossil *Corumbella*. PlosOne 10(3): e0114219.

4. Embryos?

   Xiao, S. and A.H. Knoll (2000) Phosphatized animal embryos from the Neoproterozoic Doushantuo Formation at Weng'an, Guizhou Province, South China. J. Paleontol. 74: 767-788.

   Huldtgren, T., J. A. Cunningham, C. Yin, M. Stampanoni, F. Marone, P.C.J. Donoghue, and S. Bengtson. 2011. Fossilized nuclei and germination structures identify Ediacaran “animal embryos” as encysting protists. Science 334: 1696–1699.

   Chen, L., S. Xiao, K. Pang, C. Zhou, an X Yuan (2014) Cell differentiation and germ-soma separation in Ediacaran animal embryo-like fossils. Nature 516: 238-241.

Yin, Z., M. Zhu, D.J. Bottjer, F. Zhao, and P. Tafforeau (2016) Meroblastic cleavage identifies some Ediacaran Doushantuo (China) embryo-like fossils as metazoans. Geology 44: 735-738.

5. Cysts:

   Xiao, S., C. Zhou, P. Liu, D. Wang, and X. Yuan (2014) Phosphatized acanthomorphic acritarchs and related microfossils from the Ediacaran Doushantuo Formation at Weng'an (South China) and theirimplications for biostratigraphic correlation. J. Paleontol. 88: 1-67.

   Cohen. P.A., R. Kodner, and A.H. Knoll (2009) Large spinose acritarchs in Ediacaran rocks as animal resting cysts. Proceedings of the National Academy of Sciences, USA 106: 6519-6524.

6. Carbonaceous compressions:

   Xiao, S., X. Yuan, M. Steiner, and A.H. Knoll (2002) Carbonaceous macrofossils in a terminal Proterozoic shale: a systematic reassessment of the Miaohe biota, South China. J. Paleontol. 76: 347-376.

   Cohen, P.A., A.H. Knoll and ten others (2009) Tubular compression fossils from the Ediacaran Nama Group, Namibia. Journal of Paleontology 83:110-122.

7. Biomarkers:

   Love, G.D., et al. (2009) Fossil steroids record the appearance of Demospongiae during the Cryogenian period. Nature 457:718–721.

   D.A. Gold, J. Grabenstatter, A. de Mendoza, A. Riesgo, I. Ruiz-Trillo, and R.E. Summons (2016) Sterol and genomic analyses validate the sponge biomarker hypothesis. Proc. Nat. Acad. Sci., USA 113: 2684–2689.

Week 8: Environmental context: Ice ages and oxygen

All:

Sperling, E.A. A.H. Knoll and P.R. Girguis (2015) The ecological physiology of Earth’s second oxygen revolution. Annual Review of Ecology, Evolution and Systematics 46: 215-235.

Hoffman, P.F. (2009) Neoproterozoic glaciation. Geology Today 25: 107-114.

Volunteers:

1. Sperling, E.A., C.A. Frieder, P.R. Girguis, A.V. Raman, L.A. Levin, and A.H. Knoll (2013) Oxygen, ecology, and the Cambrian radiation of animals. Proc. Nat. Acad. Sci., USA 110: 13446-13451.

2. Johnston, D.T., T. Goldberg, S.W. Poulton, V.N. Sergeev, V. Podkovyrov, N.G. Vorob'eva, A. Bekker, and A.H. Knoll (2012) Late Ediacaran redox stability and metazoan diversification. Earth and Planetary Science Letters 335–336: 25–35.

3. Sahoo, S.K., N.J. Planavsky, G. Jiang, B. Kendall, J.D. Owens, X. Wang, X. Shi, A.D. Anbar, and T.W. Lyons (2016) Oceanic oxygenation events in the anoxic Ediacaran ocean. Geobiology 14: 457–468.

4. Mills, D.B., L.M. Ward, C. Jones, B. Sweeten, M. Forth, et al. (2014) The oxygen requirements of sponges: modern analogues for the earliest animals. Proc. Nat. Acad. Sci. 111: 9073—9078.

Week 9: A bottom-up ecological hypothesis (Knoll's week)

A break from reading!

Week 10: What if anything happened at the PC-C boundary?

All:

Narbonne, G.M., P.M. Myrow, E. Landing, and M.M. Anderson (1994) A candidate stratotype for the Precambrian- Cambrian boundary, Fortune Head, Burin Peninsula, southeastern Newfoundland. Can. J. Earth Sci. 24: 1277- 1293.

Volunteers:

1. Darroch, S.A.F. et al. (2015) Biotic replacement and mass extinction of the Ediacara biota. Proc. R. Soc. B 282: 20151003.

2. Amthor, J.E. et al. (2003) Extinction of *Cloudina* and *Namacalathus* at the Precambrian-Cambrian boundary in Oman. Geology 31: 431–434.

3. Kouchinksy, A. et al. (2010) Carbon isotope stratigraphy of the Precambrian–Cambrian Sukharikha River section, northwestern Siberian platform. Geol. Mag. 144:609-618.

Wille, M. et al. (2003) Hydrogen sulphide release to surface waters at the Precambrian/Cambrian boundary. Nature 453: 767-769.

4. Yang, B. et al. (2016) Transitional Ediacaran–Cambrian small skeletal fossilassemblages from South China and Kazakhstan: Implications for chronostratigraphy and metazoan evolution. Precambrian Res. 285: 202-215.

Week 11: The Cambrian explosion

All:

Marshall, C.R., 2006, Explaining the Cambrian "explosion" of animals: Ann. Review Earth Planet. Sci. 34: 355–384.

Erwin, D.H., M. Laflamme, S.M. Tweedt, E.A. Sperling, D. Pisani, and K.J. Peterson (2011) The Cambrian conundrum: Early divergence and later ecological success in the early history of animals. Science 334:1091-1097.

Volunteers:

1. Edgecombe, G.D. and D.A. Legg (2014) Origins and early evolution of arthropods. Palaeontology 57: 457–468.

2. Antcliffe, J.B., R.H.T. Callow, and M.D. Brasier (2014) Giving the early fossil record of sponges a squeeze. Biol. Rev. 89: 972–1004.

3. Van Iten, H. et al. (2014) Origin and early diversification of the phylum Cnidaria Verrill: major developments in the analysis of the taxon's Proterozoic–Cambrian history. Palaeontology 57: 677–690.

4. Vinther, J. (2015) The origins of molluscs. Palaeontology 58: 19-34.

Week 12: Cambrian radiation II

All:

Maloof, A.C., S.M. Porter, J.L. Moore, F.O. Dudas, S.A. Bowring, et al. (2010) The earliest Cambrian record of animals and ocean geochemical change. Geol. Soc. Am. Bull. 122: 1731—1774.

Volunteers:

1. Budd, G.E., and I.S.C. Jackson (2016) Ecological innovations in the Cambrian and

the origins of the crown group phyla. Phil. Trans. R. Soc. B 371: 20150287.

2. Dove, P.M. (2010) The rise of skeletal biominerals. Elements 6: 37-42.
3. Pruss, S., S. Finnegan, W.W. Fischer, and A.H. Knoll (2010) Carbonates in skeleton-poor seas: New insights from Cambrian and Ordovician strata of Laurentia. Palaios 25: 73-84.

4. Porter, S.M. (2010) Calcite and aragonite seas and the de novo acquisition of carbonate skeletons. Geobiology 8: 256–277.