Chapter 6

Paper:

Feild, Taylor S., Timothy J. Brodribb, Ari Iglesias, David S. Chatelet, Andres Baresch, Garland R. Upchurch, Bernard Gomez et al. "Fossil evidence for Cretaceous escalation in angiosperm leaf vein evolution." *Proceedings of the National Academy of Sciences* 108, no. 20 (2011): 8363-8366.

Questions:

1. **This paper focuses on the evolution of vein density in angiosperms compared with gymnosperms. How is leaf vein density measured in fossil plants and what are the typical ranges of vein densities observed in living angiosperms and gymnosperms?** ANSWER: Vein density is the length of veins per unit leaf area in mm mm^{-2}. It is measured in fossil leaves by taking high quality photographs of well-preserved fossils specimens and tracing the length of veins per 5 to 12 mm^2 area using freely available software. Typical vein density ranges in living angiosperms are ~ 4 to 19 mm mm^{-2} (based on data presented in Fig 1). Typical vein density ranges in Gymnosperms are below 6 mm mm^{-2}.

2. **What are the advantages of high vein density to a species? How have these advantages been demonstrated?** ANSWER: Based on previous research the authors argue that high vein density is advantageous because it enables higher maximum transpiration rates (e.g. higher rate of water loss from the leaf) and higher rates of maximum photosynthesis because higher rates of C uptake is possible.

3. **What is the primary aim of the paper and why is it important?** ANSWER: The main aim of the paper is to firmly establish the timing of acquisition of high vein densities in angiosperms compared with gymnosperms by assessing temporal trends in vein densities from fossil plants representative of both groups. This is important because previous research has shown that high vein density confers modern angiosperms with a significant advantage in terms of their maximum photosynthetic rate and their capacity to exchange water via transpiration for CO_2 uptake for photosynthesis. Establishing the timing of these events would enable the authors to investigate the role of long-term environmental change for the evolution of uniquely angiosperm traits and to explore the importance of trait evolution in the ecological success of angiosperms.

4. **Describe the pattern of vein density change observed in the fossil leaf record.** ANSWER: The oldest Angiosperm leaf fossils analysed were found to have vein densities of ~ 3.31 mm mm^{-2} which was similar to coeval gymnosperms. Angiosperm vein density was then found to increase above the average gymnosperm vein density in the late Albian and again in the Maastrichtian, reaching average values of 9.76 mm mm^{-2} by this time.

5. **How were the fossil leaves used in this study dated and what is the typical range of error associated with the assigned dates?** ANSWER: All of the fossil leaf material used to estimate

vein density have been previously published. A supplementary information file, which is downloadable with the paper, lists the primary references associated with each fossil and provides a stratigraphic age assigned to each fossil. Most of the fossil material is relatively dated using biostratigraphy. The age error bars shown usually refer to the minimum and maximum ages of the geological stage age of the formation in which the fossil leaves were found.

6. **The timing of the rise in fossil angiosperm leaf vein density is compared with that inferred from time-calibrated phylogenies of living angiosperms. What does this comparison show and why is it significant?** ANSWER. The temporal trends in leaf vein density change demonstrated by fossil leaves is more or less the same as that inferred for an analysis of vein density of living plants each with an estimated date of origin in the geological past. The fact that both the fossil data set and time-calibrated living data set are similar is significant because (1) it demonstrates that the estimated age of origin of major angiosperm lineages based on a molecular clock approach is relatively accurate, and (2) it implies that the assumption that a vein density observed today in living plants is a good approximation of the vein density that was present in its ancestors when the lineage diverged. Put more simply, this is an example where the present can be a key to the past (using time-calibrated phylogenies).

7. **What are the likely costs associated with higher leaf vein densities?** ANSWER: Veins are lignified. Lignin is a nitrogen-rich complex molecule which in terms of energetics is costly to produce. Therefore high vein density would incur a higher energetic cost to the plant.