Chapter 9

Paper:

Willis, K. J., A. Feurdean, H. J. B. Birks, A. E. Bjune, E. Breman, R. Broekman, J-A. Grytnes, M. New, J. S. Singarayer, and J. Rozema. "Quantification of UV-B flux through time using UV-B-absorbing compounds contained in fossil Pinus sporopollenin." *New Phytologist* 192, no. 2 (2011): 553-560.

Questions:

1. **What effect does UV-B radiation have on plants?** ANSWER: UV-B radiation has been shown to reduce plant biomass, to induce DNA damage and cause mutations, and generally reduce plant fitness.

2. **What factors influence the amount of UV-B radiation reaching the Earth's surface?** ANSWER: Many factors can influence the % of UV-B in solar radiation. For example, stratospheric ozone loss increases UV-B radiation, volcanic event can decrease (via ash loading) or increase (via destruction of stratospheric ozone layer by organohalogens) UV-B, Milankovitch orbital variations will increase or decrease UV-B by decreasing or increasing the distance between Earth and Sun respectively. Finally the proportion of cloud cover is inversely related to the amount of UV-B reaching the Earth's surface.

3. **Why is it interesting or important to reconstruct UV-B radiation through geological time?** ANSWER: UV-B radiation has the potential to influence both the timing and rate of speciation and extinction. This implies that UV-B radiation may influence the time and course of evolution. The role of UV-B as an evolutionary driver can only be examined if records of how it has changed during the time course of Earth history are available to compare with records of speciation and extinction events.

4. **What 'proxy' or indicator method can be used to infer past levels of UV-B radiation?** ANSWER: Plants naturally use phenolic compounds, such as para-coumaric acid, to protect their cells and proteins (DNA, RNA etc.) from UV-B induced damage. The compounds are UV-B absorbing and increase with increasing dosage of UV-B radiation. They are particularly important in the exines of pollen (which protect the male sex cells), the plant cuticle (which protects all aerial parts of the plants) and wood. These compounds are also well preserved in the fossil record. The UV-B proxy is therefore based on quantification of the amount of phenolics such as para-coumaric acid found in fossil pollen gains, wood or cuticle through time.

5. **What are the limitations associated with this proxy method?** ANSWER: (1) the amount of phenolic compounds found in plants is species specific. This means that in order to track UV-B through time it is advisable to do so using the same species or genus through time; (2) the methods used to extract fossil cuticles and pollen grains from rock sediments (acid maceration) can alter the quantity of phenolics preserved within the fossilized tissue; (3) it is

difficult to find fossil plant species with long- time series that are easily extractable using non-conventional methods that do not involve acid maceration.

6. **What are the two main objectives of the paper:** ANSWER: To investigate whether there is a quantifiable relationship between *Pinus* pollen grain para-coumaric acid content and UV-B radiation and to examine the feasibility of extracting sufficient para-coumaric acid from fossil pine pollen to reconstruct palaeo-UV-B dosage through time.

7. **How did the authors ensure that the procedures used to extract fossil pine pollen did not alter the original para-coumaric acid content of the pollen grain?** ANSWER: The authors did not extract the fossilized pollen using acid maceration. Instead they sub-sampled small quantities of sediment core and washed it in distilled water. The pine pollen was then individually extracted using a micromanipulator guided under a microscope.

8. **What are the key findings in relation to UV-B and para-coumaric acid abundance across modern latitudinal gradients?** ANSWER: The authors found a significant increase in the average abundance of para-coumaric acid in Pine pollen grains with decreasing latitude and a positive correlation between the abundance of para-coumaic acid and modelled UV-B dose in Joules m^{-2}. According to figure 1 the dose of UV-B accounts for ~70% of the variability in the para-coumaric acid abundance (R^2= 0.7044). Based on these results it appears that para-coumaric acid in pollen grains is a good proxy for the amount of UV-B radiation reaching the ground.

9. **What are the key findings in relation to Holocene UV-B?** ANSWER: The smoothed record of para-coumaric acid abundance found in fossil pollen grains shows a similar trend of change through the Holocene as that of modelled UV-B radiation based on the Hadley-Centre Climate model. These results suggest that there is great potential to use fossil pollen phenolic acid content as a qualitative and perhaps also quantitative proxy of palaeo UV-B.

10. **What interesting features of Holocene UV-B history does the fossil pollen para-coumaric acid record show?** ANSWER: One of the most intriguing observations from the record is that it shows that during the mid-Holocene climatic optimum, when climate is generally believed to have been warmed than today, the UV-B loading in Norway was similar to that observed today in Crete.