Appropriate environmental conditions for parchment

The Structure of Parchment

Parchment is manufactured from animal hides, most commonly sheep, goat and calf. The process of manufacture removes the epidermis and hyperdermis layers, fats and hair from the skin to leave the dermis layer (Poole and Reed, 1962). The dermis layer is predominantly made of type I and type III collagen (Kennedy and Wess, 2003). Collagen is a hierarchical protein where specific sequences of amino acids form polypeptide chains and three polypeptide chains are twisted to form a collagen helix. The collagen helices are then arranged in a quarter stagger to form strands that bundle together to form a fibril (Hodge and Petruska, 1963). Collagen fibril bundles further form fibres, and fibres form tissues. The molecular and fibrillar arrangement of collagen in parchment is well documented (Maxwell et al., 2006). See Figure 1.

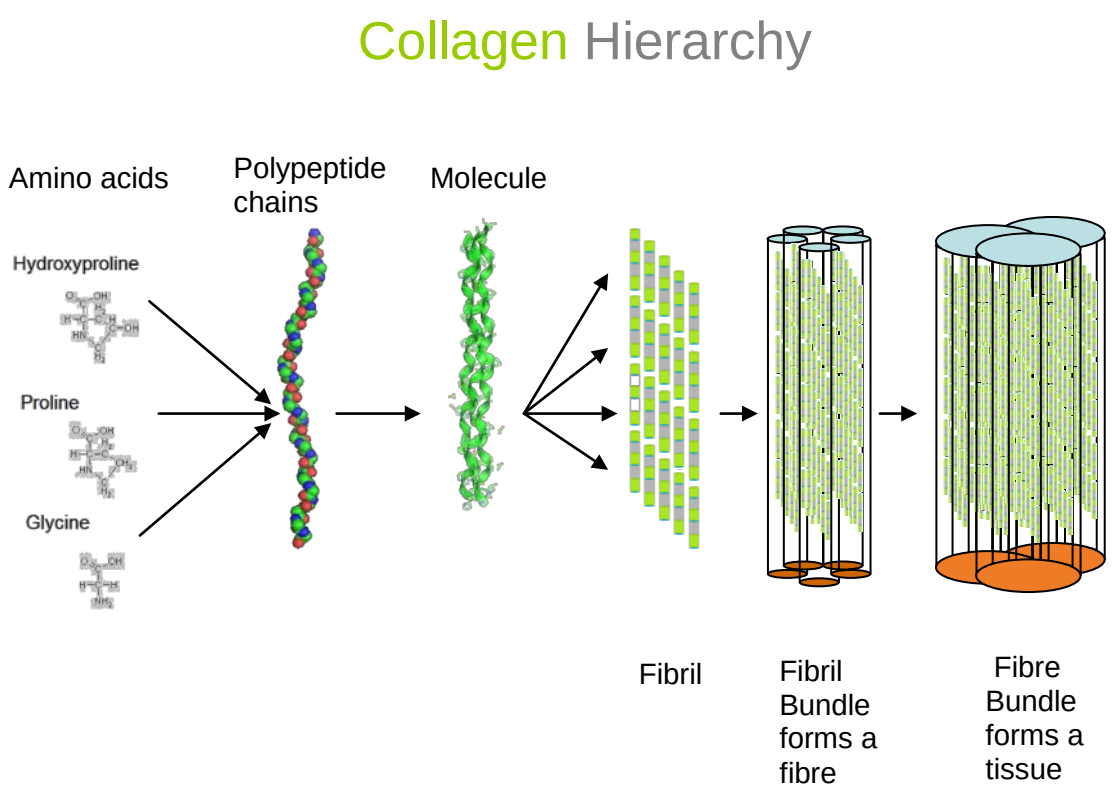

Figure 1. Schematic showing the hierarchical structure of collagen

During the manufacture of parchment, surface collagen is exposed to harsh chemical treatments. This consequently denatures the collagen and it forms its degraded product, gelatine. Although gelatine has the same polypeptide sequences as collagen, these are no longer arranged in the triple helix motif, and the fibril and fibre structures are lost (Zhou et al., 2006). Kennedy et al. (2004) found using microfocus X-ray diffraction that parchments have a structural stratigraphy, where collagen is found in centre/core of parchments and gelatine is found on the surface. (See Figure 2)

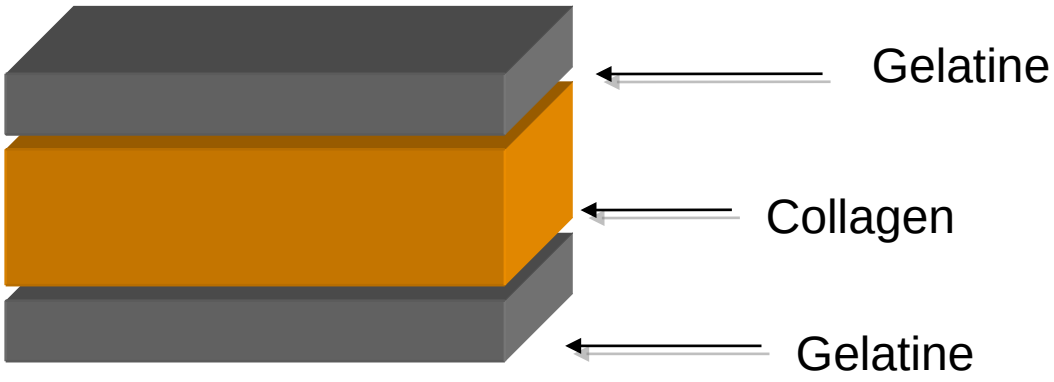

Figure 2: Schematic showing a model of stratigraphy of parchment

How can we measure changes in parchment due to relative humidity?
There are several techniques available to investigate changes in parchment caused by relative humidity and the relationship between the nanoscopic and macroscopic properties. We have selected three in this project: X-ray diffraction, Fourier Transform Infrared Spectroscopy and mechanical testing.

X-ray diffraction
When X-rays are exposed to an object, individual atoms will scatter the X-rays at an angle from the incident/original X-ray beam. When atoms are arranged in a lattice, where many atoms are of an equal distance apart, thousands of X-rays will scatter at the same angle: this is known as diffraction. The scattering angle can be calculated from the diffraction pattern, see Figure 3. When there are changes in the atomic lattice, for example due to the effects of relative humidity, then we can measure that change. We can also measure when there is a loss of diffraction, and therefore determine whether collagen has degraded into gelatine. Adjustments to relative humidity will cause the water content in parchment to change and changes in the collagen packing features which can also be measured (Wess et al., 2001, Wess and Nielsen, 2002).

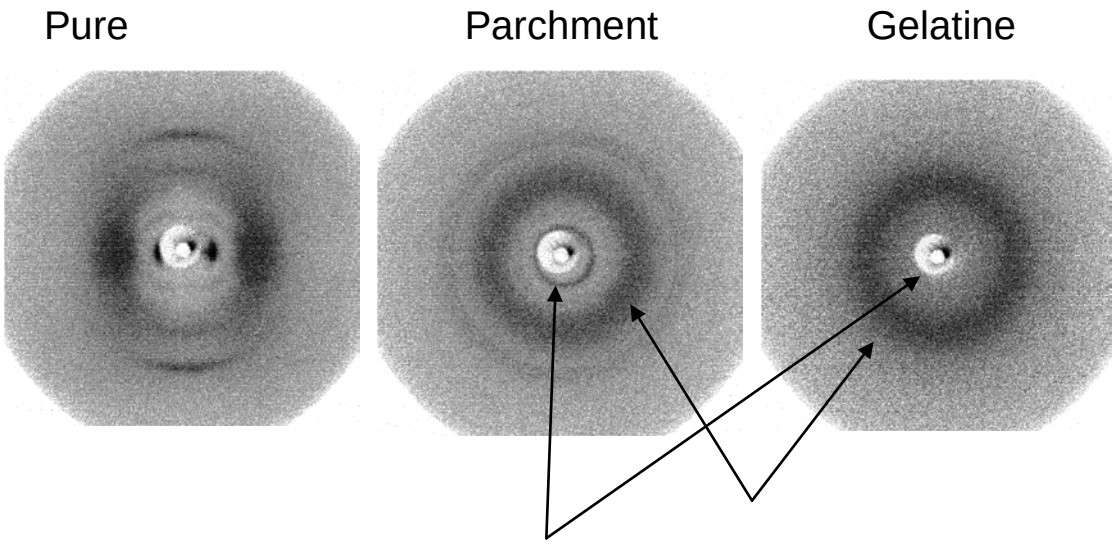

Figure 3: Schematic showing three X-ray diffraction patterns.

Fourier Transform Infrared Spectroscopy (FTIR)

When infrared light is exposed to objects, it causes chemical groups within that object to vibrate by giving them energy. The energy needed to induce the vibration is very specific because of the steric forces that surround each chemical group. When the chemical nature of an object or its structure changes, then the steric forces within the object can also change. This change can be measured using FTIR spectroscopy. For example, in some of our recent work we investigated whether discolouration of parchment was associated with degradation of the collagen structure or a change to its chemical nature. We found that discolouration was not linked to the presence of gelatine, but was most likely due to chemical changes such as the Maillard reaction(Gonzalez et al., 2013).

Mechanical testing

When water is added or removed from parchment, alterations in the mechanical properties can be induced due to changes in relative humidity. At The National Archives we use a Dynamic Mechanical Analyser to make mechanical measurements of parchments at different relative humidity.

References

GONZALEZ, L.G., WADE, M., BELL, N., THOMAS, K. & WESS, T.J. 2013. Using Attenuated Total Reflection- Fourier Transform Infrared Spectroscopic (ATR-FTIR) to study the molecular conformation of parchment artifacts in different macroscopic states *Appl. Spectrosc.* 67.

HODGE, A.J. & PETRUSKA, J.A. (eds.) 1963. *Recent studies with the electron microscope on ordered aggregates of the tropocollagen molecule,* London: Academic Press.

KENNEDY, C.J., HILLER, J.C., LAMMIE, D., DRAKOPOULOS, M., VEST, M., COOPER, M., ADDERLEY, W.P. & WESS, T.J. 2004. Microfocus X-ray diffraction of

historical parchment reveals variations in structural features through parchment cross sections. *Nano Letters* 4: 1373-1380.

KENNEDY, C.J. & WESS, T.J. 2003. The structure of collagen within parchment - A review. *Restaurator- International Journal for the Preservation of Library and Archival Material* 24 61-80.

MAXWELL, C.A., WESS, T.J. & KENNEDY, C.J. 2006. X-ray Diffraction Study into the Effects of Liming on the Structure of Collagen. *Biomacromolecules* 7: 2321-2326.

POOLE, J.B. & REED, R. 1962. The preparation of Leather and Parchment by the Dead Sea Scrolls Community. *Technology and Culture* 3: 1-26.

WESS, T.J., DRAKOPOULOS, M., SNIGIREV, A., WOUTERS, J., PARIS, O., FRATZL, P., COLLINS, M., HILLIER, J. & NIELSEN, K. 2001. The Use of Small-Angle X-Ray Diffraction Studies for the Analysis of Structural Features in Archaeological Samples. *Archaeometry* 43: 117-129.

WESS, T.J. & NIELSEN, K. 2002. *Analysis of Collagen Structure in Parchment by Small Angle X-ray Diffraction*. London: Archetype Publications.

ZHOU, P., MULVANEY, S.J. & REGENSTEIN, J.M. 2006. Properties of Alaska Pollock Skin Gelatin: A Comparison with Tilapia and Pork Skin Gelatins. *Journal of Food Science* 71: C313-C321.