Conservation in Wales

The Role of Science in Conservation

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Contributors

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Taxonomy is dead… long live taxonomy. Understanding the science of preservation in museum natural science collections.

Julian Carter

Taxonomy is the practice and science of classification. The word finds its roots in the Greek τάξις, taxis (meaning 'order', 'arrangement') and νόμος, nomos ('law' or 'science'). This paper looks at the origin of Natural History Collections, their use for naming and classifying living organisms and the development and understanding of preservation technologies. Examples of the research into museum conservation work undertaken at Amgueddfa Cymru – National Museum Wales (AC–NMW) are given with reference to the zoological collection. Equivalent research work also occurs with the botanical and geological collections housed at AC–NMW.

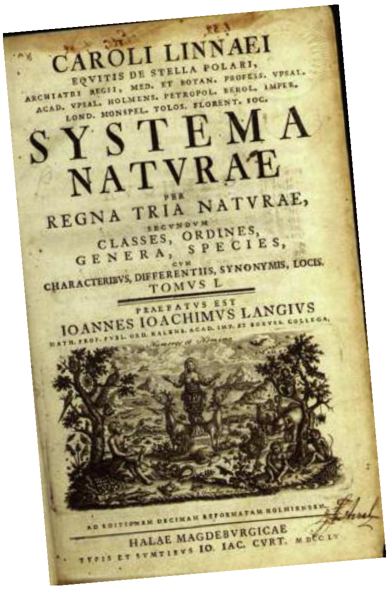
CAROLI LINNAEI
SYSTEMA NATVRAE
PER
REGNA TRIA NATVRAE,
SECVNDVM
CLASSES, ORDINES,
GENERA, SPECIES,
CVM
CHARACTERIBVS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMVS I.
PRAEFATVS EST
IOANNES IOACHIMVS LANGIVS
HALAE MAGDEBVRGICAE

Figure 1: Cover page of Carl von Linnaeus' iconic work, Systema Naturae.

The development of a science

Taxonomy has been, and still is, central to the study of the natural world. In the 16th and 17th centuries natural history collections were initially put together as displays that were in quest of the absurd, curious or monstrous (Yanni 1999). This was the classic 'cabinet of curiosity' which was more of a reflection on social values of the time than a scientific resource. For such study these 'cabinets' were virtually useless being effectively disorganised and poorly described. Systems that attempted to describe and name plants and animals arose, but these went from accurate descriptions to the completely fanciful. This was further complicated by the use of many different names to describe the same plant or animal. There was thus a growing need to standardise how the natural world was described and to bring together an orderly and usable system of classification (Asma 2001). This order was brought about during the 1700s most notably through the studies of Carl von Linnaeus, who in his work *Systema Naturae* (Figure 1) brought together the binomial classification system which remains in use today.

Collections come of age

As the study of the natural world became more defined as a science so did the development of natural history collections. Initially the preservation of such material was only possible with dry inert materials such as horn, bone, skin, shells, corals, or robust insects (Reid 1994). It was not until the development of the use of fluid preservation that it became possible to preserve moist, soft biological material. The history of modern fluid preservation effectively dates back to 1660s when William Croone presented to the Royal Society two whole puppies preserved in the 'spirit of wine'. By the end of the seventeenth century, techniques for the preservation of specimens were starting to become established (e.g. Reamur 1748). This period also saw the development of natural science collections from eminent collectors such as John Tradescant and Hans Sloane, and later from important workers in the history of modern systematics and evolution such as Linnaeus himself, Joseph Banks, and Charles Darwin. Overall the 18th and 19th Centuries saw many important scientific expeditions, the specimens from which now form the core on which modern natural science collections have been built. This widespread collecting resulted in the further development of biological museum methods such as the use of formaldehyde as a chemical fixative, many of which persist in current museum practise (e.g. Hangay and Dingley 1985).

Understanding preservation chemistry

The long term aim is to preserve, as best we can, the chemical structure and morphology of a specimen. Whilst some of the specific histochemical changes caused by many of the standard methods of preservation have been actively researched in the last 50 years (Pearse 1980), the overall effect of preservation treatments on biological material is still poorly understood. The development of many of the methods currently used for collection preservation has been a result of trial and error, and pure chance. Fixation and preservation technologies have changed little since their discovery, and have not been developed by hard scientific research. Many of our existing methods of preservation have significant drawbacks e.g. the use of ethanol as a preservative causes shrinkage and colour loss (Figure 2). Recent attempts have been made to develop new techniques. A good example would be the use of the phenol derivative Phenoxetol

Figure 2: Fluid preserved Grass snake showing colour loss, which is a key problem of alcohol preservation.

(Steedman 1976). This was introduced in the 1970s as an alternative to ethanol preservation as it did not cause shrinkage and retained better colour. However there are an increasing number of reports of specimens in Phenoxetol preserved vertebrate collections starting to deteriorate badly (Crimmen 1989), illustrating the problem of developing long term preservation techniques.

New roles for natural science collections

Recent years have seen dramatic advances that have provided new and powerful tools in identifying the relationships and identities of living organisms through the use of methods that look at molecular data, most notably DNA analysis. It was only in the mid 1980s that the Polymerase Chain Reaction (PCR) was developed which enabled specific pieces of DNA to be isolated and replicated to enable further analysis (Saiki et al., 1988). Today this is an affordable bench top science that allows researchers to readily assess and analyse the DNA in a specimen. The use of natural science collections thus enters a new era in which the requirements of modern biochemical research have to be addressed and balanced with the more traditional requirements of whole specimen morphological studies. Many large institutions, especially in the United States, have begun to compile tissue banks for the specific preservation of biological samples for biochemical studies (Dessauer et al, 1996). However, these compilations require large-scale cryo-preservation, which is expensive and requires constant monitoring in case of power or equipment failure. Such facilities are outside the resources of most institutions holding biological collections. It is thus hoped that future improvements in preservation technology can provide effective solutions for preserving our biological collections for both morphological and molecular use.

So why continue with traditional morphological based studies? After all it is now possible to identify a specimen without looking at it, and as we are increasingly living in a digital world then why keep specimens in a museum? Just collect the image and get its DNA profile? Fortunately there is a very real role for natural history collections and taxonomic studies in today's society as they are a vast information resource (Figure 3). Our specimens span time and geography, and represent many species that may now be extinct, are highly endangered, or impossible to study and collect due to political issues (Thomas, 1994). They provide vital information as to the past as well as a resource for the future and are used in many fields of research such as species identification, mapping biodiversity, climate change, mapping genes for evolutionary studies, DNA information to map disease vectors. Understanding our natural world has never been more important. We all need clean water, air and food in order to live which ultimately depends on healthy and functioning ecosystems. We can only conserve biology effectively if we can understand it, both at the level of the individual species and how it fits in within the ecosystem as a whole. A prime example based on the research work of AC–NMW is the BIOMOR marine biodiversity projects (e.g. Mackie et al. 1995). These projects map the nature of the seabed around Wales and identify all the benthic (seabed) animals. This work has identified a very bio-diverse landscape and is very detailed so that by repeating the studies we can gather information on issues such as climate change, changing water quality, and changing uses of the seascape. Museum taxonomists now combine their hands-on identification skills with DNA analysis methods for research into areas such as species identification, population genetics and evolutionary relationships. This has led to new initiatives in an attempt to document the diversity of life on earth such as the 'Barcode of Life' project (www.barcodinglife.org) which aims to collect and database a specific DNA sequence for all known organisms. Natural history collections and the expertise of their curators are an important resource for such projects.

Figure 3: Pinned beetles, many collected over a century ago, now form part of important biological data sets.

The role of conservation science

Science in museum conservation has an important role to play in enhancing our understanding of preservation and conservation chemistry in natural history collections. Having dedicated museum conservators working on natural history collections is a much newer role than in traditional areas such as art and archaeology. Many technicians and curators have, and do, perform this role in many institutions and there is a growing body of knowledge being put together especially through the efforts of groups such as the Society for the Preservation of Natural History Collections and the Natural Science Collections Association. Through the support of such groups studies continue, aimed at improving our knowledge of collection preservation methods and how our collections can be properly utilised for scientific studies, education projects and exhibitions. This has resulted in improvements in the care, conservation and overall perceived value of our natural science collections (e.g. Rose et al. 1995; Carter and Walker, 1999).

Conservation science within AC–NMW

The AC–NMW houses a large and active department in the biological sciences which has a wide range of taxonomic expertise such as marine worms, molluscs, insects, mosses, lichens and flowering plants. These activities have resulted in the development of a large and actively used natural history collection currently housing over 3 million specimens. A collection of this size requires a lot of management, conservation and curation.

The growing use of natural history collections as a biomolecular archive has required an attempt to assess how current and past methods of preservation affect DNA. Unfortunately we often don't know how older collection material has been treated as the recorded data can be very poor. However there has been a wide range of papers written that have looked at preservation methods and the affect on DNA extraction and subsequent analysis (e.g. Post et al. 1993; Dillon et al. 1996; Hall et al.1997). Most of these research efforts have tended to come from a purely molecular research perspective and not from a museology perspective. Museum conservation science attempts to consider the multiple roles that preserved museum specimens may have to play such as within educational projects and in use within exhibitions, as well as for research.

Assessing current preservation methods

It is fortunate that some of the methods that have been extensively used to preserve specimens can preserve important bio-molecules such as DNA. This is true with the use of ethanol in fluid preservation. Ethanol works as a preservative by altering the shape or conformation of protein molecules through the removal of water and can be described as a 'pseudo-dehydrating fixative'. This removal of free water removes one of the key molecules that can damage DNA through hydrolytic damage. Some of the oldest fluid specimens to have their DNA successfully analysed were preserved in the 1800s in rum! (Criscuolo 1994). Today we still use ethanol based solutions as a key preservative. At AC–NMW the standard preserving solution is Industrial Denatured Ethanol (IDA) diluted to 80% with water. This balances the shrinkage caused by strong ethanol concentrations and IDA is used on cost grounds. However for molecular preservation tissue samples or whole specimens are put into absolute ethanol, and preferably stored in a freezer. But could we simply use undiluted IDA as this would be cheaper? Unfortunately this does not seem to be the case. Research at AC–NMW directly comparing absolute ethanol with IDA found that while the overall quantity of extractable DNA in a sample was similar the quality was not (Figure 4). The problem stems with the denaturant used which is methanol. This small molecule can directly displace structural water that retains the double helix formation of the DNA molecule causing a weakening in the sugar phosphate back-bone of the molecule.

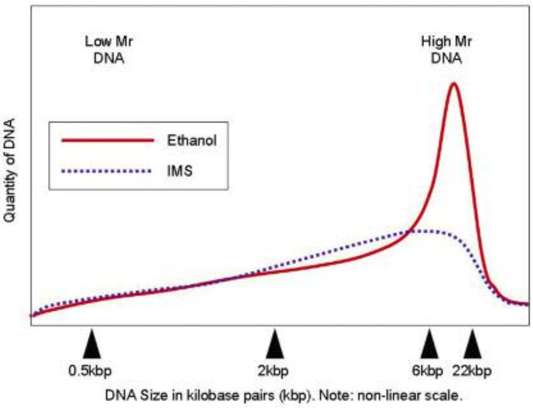

Figure 4: Graph illustrating the differences in DNA quality between ethanol and Industrial Denatured Alcohol (IDA) preserved samples. The samples have been denatured to separate the double stranded DNA into single strands which causes the IDA treated samples to fragment, whilst the ethanol preserved samples retain significant quantities of high molecular weight DNA as shown in the peak at the end of the graph.

Drying can also be effective in preserving DNA and has long been the primary method of preservation. Studies on ancient DNA have shown that DNA survives best in cold, dry conditions where the biological samples are effectively dehydrated by the field preservation environment (Herrmann and Hummel, 1994). Hence materials such as dried skin, bones and teeth have yielded DNA for analysis. This demonstrates that how a sample is dried can have a considerable effect on the condition of the DNA. Using work at AC–NMW as an example, it has been found that specialist drying methods such as critical point drying (CPD) and freeze drying or specialist chemical drying treatments such as hexamethyldisilazane (HMDS) can considerably improve the quality of the preserved DNA in a specimen (Figure 5). This is probably down to these methods removing all free water from the preserved specimen, but there may well be additional factors enhancing the stability of the DNA to damaging factors such as air moisture, oxygen and chemical attack.

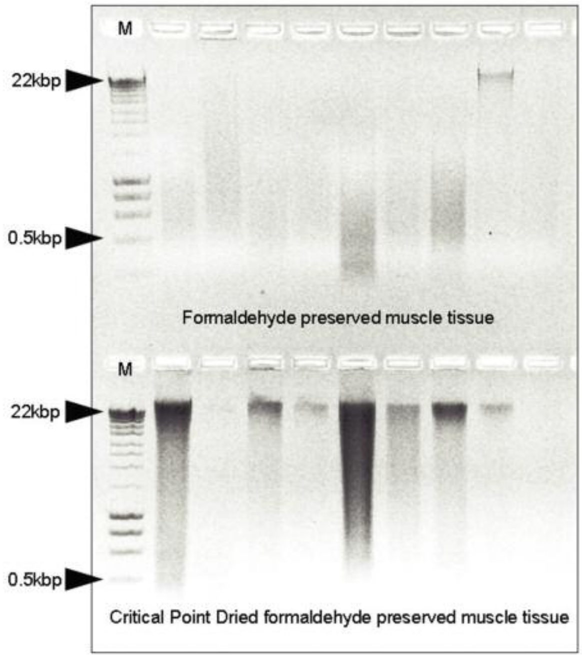

Figure 5: Comparison of the DNA extracted from formaldehyde preserved muscle tissue samples. The top samples represent the DNA extract from the original preserved material, whilst the bottom samples have been subsequently dried using Critical Point Drying (CPD) prior to DNA extraction. The quantity of extractable DNA has improved with the CPD treatment. The dark streaks represent DNA visualised using staining techniques. M – molecular weight marker, with weights labelled as kbp (kilo-base pairs).

DNA though is just one part of the complex chemistry that makes up an organism. While attempting to preserve valuable molecular information we also need to consider the whole morphology of the specimen that we as individuals can more directly relate to and recognize, and which forms the basis of taxonomical investigation. Proteins are a key structural component in preserved animal tissues. By assessing the changes induced on the preserved proteins it is possible to gain an insight into the effects of a particular preservation or conservation treatment. Studies at AC–NMW have been exploring the possibilities of using Fourier Transformed Infra Red (FTIR) spectrometry to explore these changes. One of these projects has been to consider an alternative to the aldehyde fixative formaldehyde, usually referred to as 'formalin'. Formaldehyde reacts with functional groups on proteins to form cross links, and is termed a chemical fixative. It is recognized as being very poor for the preservation of DNA but is very useful for preserving whole specimen mounts and histological information and hence is still widely used. However, concerns about its toxicity and possible carcinogenic effects have resulted in the search for an alternative. One possibility already identified is a chemical called DMDM Hydantoin which replaces the use of formaldehyde in products such as cosmetics. It is termed a formaldehyde releaser so should still preserve biological tissues in a similar way. An FTIR study has indicated this to be the case with protein samples preserved in formaldehyde and DMDM Hydantoin clumping together with chemiometric analysis (Figure 6). Similar work has been done looking at protein tissue in ethanol solutions and whether different pH environments have an effect on the preservation. Monitoring samples preserved in a range of pH environments using FTIR spectroscopy has indicated that there is a difference between samples preserved in a lower pH environment (pH 3 to 5) to those in a more basic environment (pH 9 to 13) (Carter 2009). This is shown in Figure 7 where differences in the spectral data of the two groups have been separated using the multi-variate statistical analysis technique of principle components analysis (PCA). This is an ordination technique that condenses data and can reveal differences in similar looking datasets such as the FTIR spectra obtained in this study.

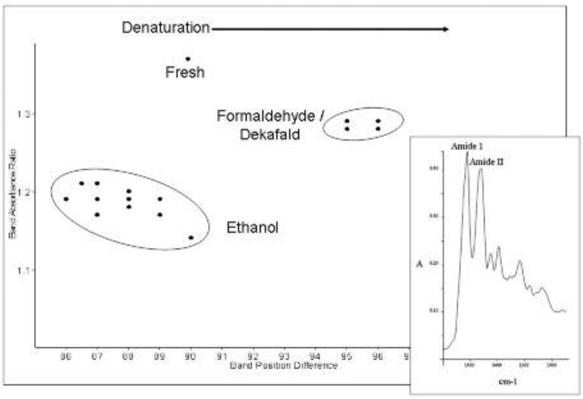

Figure 6: The insert to the graph shows the Amide I and Amide II peaks characteristic of the FTIR spectrum of proteins. By analysing the differences in the amide I and amide II band positions and height ratios a combined plot can be drawn as shown. This separates the alcohol treated samples from the formaldehyde / DMDM Hydantoin treated samples, and also demonstrates that the chemical changes caused by DMDM Hydantoin are similar to formaldehyde.

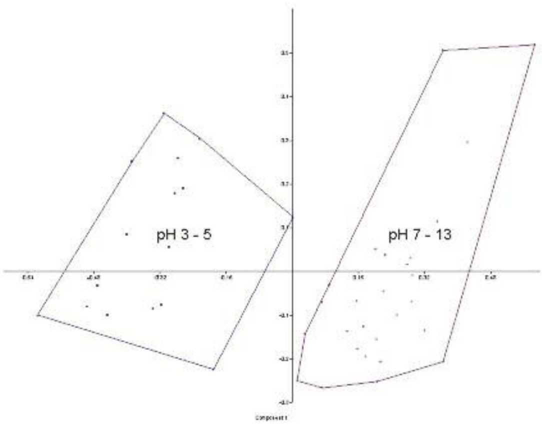

Figure 7: Multivariate statistical analysis of FTIR spectral data using principle components analysis (PCA) showing the broad separation of protein tissue preserved in 80% ethanol but at differing pH levels. Results suggest that there is a difference between the samples preserved initially at pH 3 to 5 to those preserved in pH 7 to 13. The PCA analysis is an ordination technique that can reveal small differences in similar looking data sets such as the FTIR spectral data used in this study.

As these examples show, science within museum conservation is playing an integral part in improving our knowledge on the chemistry of preservation and conservation treatments being used with natural history collections. Importantly this work is based on a direct understanding of the needs of the users of these collects including taxonomists, whose work has formed the basis of these important collection resources. These days the taxonomist themselves are becoming an endangered species, but hopefully these skilled researchers can be protected and conserved so that the study of taxonomy may continue.

…over the course of centuries, museum collections grow into their own cumbersome beasts that require much care and feeding. It is no simple task to conserve these collections. Their information remains embodied in tissue and stone, even in an age in which we prefer our information abstracted and digitized…

Journalist Carl Zimmer

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Scientific method in the transformation from students to professionals.

Jane Henderson

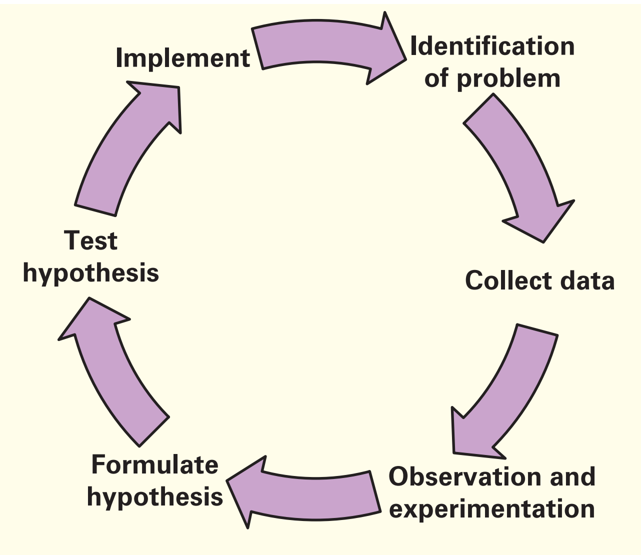
What does science offer conservation?

Rarely in conservation do we deal with certainty. It is often uncertain what the best conservation approach is, although it is often a lot easier to be certain what is not a good approach. Science can provide information to conservators about the materials being considered and it offers an understanding of processes especially when variables are limited, but it does not resolve the certainty problem. So what does science offer? Is the biggest contribution that science has to offer conservation scientific method? As this paper is about teaching students, the definition used for the purposes of this paper has been sourced on 'wikipedia'.

Scientific method: 'systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses'

(Wikipedia 2009)

The original source of this quote preceded the statement by noting that method involved the identification and formulation of a problem. This definition has been adapted to illustrate method in conservation (Table 1). The paper will examine this process and how it is taught and learned.



How do conservators make decisions?

I was recently involved in a debate about whether interpretation or care of objects was the primary action in conservation. This discussion made me think about the way conservation decisions are made. After years in conservation I look at an object and several treatment options come straight to mind. I am not necessarily clear how I know this. Experienced conservators have tried and tested their methods in a range of different contexts, drawing empirical conclusions and making decisions so that over time they become impervious to the process by which they made those decisions. With experience scientific method can become instinctive for many conservators. Is this the definition of expertise? Certainly, this seems to fit with the language of the 'Novice to Expert' scale that ICON has adopted for their accreditation process (Table 2, overleaf). This process spells out the graduations of a developing profession. If an expert conservator 'moves between intuitive and analytical approaches with ease' (ICON 2008), it may be the case that they use a scientific method unconsciously.

If some conservators have honed their abilities to the point where they are no longer explicitly aware of the relationship between intuition and analytical thinking, it is no wonder that when viewed from the outside conservation can appear ritualistic. My experience as a teacher of conservation is that students attempting to learn conservation hope to replicate this apparently easy insight. However, the desire to jump over the knowledge and skill acquisition stages can only lead to technician level outcomes.

What decisions do conservators need to make?

I recently heard a paper at a conservation conference about moving a large mural from a very deprived and drug afflicted area, at the costs of hundreds of thousands of dollars to a much 'nicer' area where it would be at less threat from people around it. The first question from the audience was 'what kind of PVA did you use? The question shocked me and has concerned me ever since.

Science can be over simplified in conservation as relating only to the materials that we use and their interactions. Without doubt these relationships are critical; much damage has been done by people claiming to be conservators and failing to understand the relationship of materials added to the objects that they are supposedly caring for. It can be useful to consider the relationship between PVA and a paint layer but conservation is about more. Conservators should ask:

- What was the problem?
- What data do we need to collect?
- What alternatives are there?

The answers to these questions should not just be about facing materials, but about the drug dealers in the park where the mural currently stands, the money available to resolve the problem and the goals and values that informed a decision to save the art by removing it from the people. Conservators need to make decisions in the context of social values. To do this we need data.

	Knowledge	Standard of work	Autonomy	Coping with complexity	Perception of context
1. Novice	Minimal, or 'text-book' knowledge without connecting it to practice	Unlikely to be satisfactory unless closely supervised	Needs close supervision or instruction	Little or no conception of dealing with complexity	Tends to see actions in isolation
2. Beginner	Working knowledge of key aspects of practice	Straightforward tasks likely to be completed to an acceptable standard	Able to achieve some steps using own judgement, but supervision needed for overall task	Appreciates complex situations but only able to achieve partial resolution	Sees actions as a series of steps
3. Competent	Good working and background knowledge of area of practice	Fit for purpose, though may lack refinement	Able to achieve most tasks using own judgement	Copes with complex situations through deliberate analysis and planning	Sees actions at least partly in terms of longer-term goals
4. Proficient	Depth of understanding of discipline and area of practice	Fully acceptable standard achieved routinely	Able to take full responsibility for own work (and that of others where applicable)	Deals with complex situations holistically, decision-making more confident	Sees overall 'picture' and how individual actions fit within it
5. Expert	Authoritative knowledge of discipline and deep tacit understanding across area of practice	Excellence achieved with relative ease	Able to take responsibility for going beyond existing standards and creating own interpretations	Holistic grasp of complex situations, moves between intuitive and analytical approaches with ease	Sees overall 'picture' and alternative approaches; vision of what may be possible

Figure 2: ICON's novice to expert scale ICON 2008

Conservation in context

One criticism that can be made of a discussion of conservation decision making in a wider context may be the lack of scientific method involved and, following from that, the poor quality of data under consideration. There are techniques that can be adopted to attempt to consider a wider context in a formal way: for example stakeholder analysis is useful for considering the needs of others (Leadership Champions 2008). However, even this process is challenging. Consider the concept of consulting with stakeholders about the future of an historic site. Who do we define as stakeholders and whose needs are we preoccupied with? My experience in the heritage sector is that we like to consult with spokespeople from faith or ethnic groups, owners, experts, indigenous groups, educated visitors and possibly even well behaved school children. However, I wonder if we selectively eliminate the data we do not want to hear, in this case the undesirable stakeholders, gun firers, vandals, skateboarders, Arthurians, self-styled druids and so on.

To operate a scientific method in conservation that extends beyond the analysis and the selection of materials, it is necessary to consider how to formally collect and work with data such as stakeholders in a rigorous manner. Well established conservators may easily integrate a range of social and environmental factors into their decision making because they have become imbued with the values of their institution (McKenna, 2006). They will be aware of possible future uses of an item, the conditions on display or in storage and the resources for long term care. As before, expertise may make a complex evaluation appear intuitive. This process is also described as 'unconscious intelligence' which Gigerenzer defines as judgements which appear quickly in consciousness, that a person is not fully aware of the underlying reasons for but provides sufficient confidence to act (2007:16). However, when operating unconsciously our reasoning is prone to bias (Kahneman et al 1982) and consequently conservators should question how consistent their methodology is. When faced with conflicting demands from drug dealers who find the mural a convenient point to hide behind, vandals determined to spray paint a marble frieze or a newly formed religious group laying claim to an historic site, do conservators follow any method before they rule out their stake in the artefact? Conservators have not yet developed sufficient mechanisms to collect valid data on the wider context in which they make decisions.

Process control

Evidently there are dangers in the intuitive approach to conservation. Seamless expertise that goes un-reflected upon can become ritual, as Waller and Michalski describe in their 'paradigm shift' paper (2005). The paper argues that the way that conservators carry out tasks could sometimes be described as process control. If a conservator is not able to respond to good quality feedback and make adjustments in response to that, their practice is a little more than ritual. This brings into focus two critical issues for decision making in conservation: the quality of data (feedback) and our ability to attend to it and to take it on board (respond).

Problems of data

The quality of the data that conservators use to make decisions is critical. Is it enough to argue:

'I have been using Paraloid B72 for the consolidation of poorly fired archaeological ceramics (and the assembly of fragments) for more than 30 years and have not found any problems with items treated this way decades ago' (Conservation distlist May 09).

Whilst Paraloid B72 as a consolidant is not necessarily a wrong treatment, if the observations of 30 years is the only data being considered, a significant amount of damage could be done before conservators find out things are not as good as they first appeared. There is much more data on the properties of Paraloid B72 (De Witte 1978, Koob 1986) but how many conservators are researching the literature and how many are relying on the observations of 30 years? Other papers discuss the issues of weaknesses in the literature in more detail (Lambert 2009) but other concerns about the quality of data are discussed here.

Consistency of description

Conservation has many inconsistencies, one of which is in describing the problems we face. Consider the issue of pollution, it is easy to see the damage caused by pollutants, but how do we quantify this for comparison? The problem is obvious but the units of measurement needed to describe and compare the problem are less so. For pollutants we may measure mass, perceivable levels, known safety, known damage, best available technology or limits of detection (Martin 2000, Grzywacz and Tennent 1994, Thomson, 1986). This problem occurs across a multitude of areas and is not easily resolved by standards which often serve to simply add to the range of variables to consider.

Ignoring the data

Too often conservation actions appear to ignore available data. An example is environmental recommendations, especially recommended temperatures. It is not uncommon to see a recommendation of 18˚C (MGC 1992). This figure is based on a fairly outdated understanding of human comfort levels and UK government targets for energy consumption. Most materials are chemically more stable at lower temperatures (Michalski 2000): most people are more comfortable above 18˚C. There is evidence for suitable temperatures for collections but this appears to be ignored as the more familiar but largely irrelevant 18˚C materialises again and again in recommendations.

Data with limitations

A student recently asked me 'why do we study the Erhardt and Mecklenburg paper on RH fluctuations? Someone told me it was rubbish.' The critique of the paper offered by the student was that the experiments on the wood were too far from real life problems. Whilst it is true that museums rarely collect small blocks of wood and try to preserve them in fluctuating RH, the experience of those small blocks does tell us something about how wood responds to humidity. The conclusions that conservators draw from the blocks is a matter of what other data they collect. Of greater concern than the limitations of a well conducted scientific trial, is the question of what other data conservators are collecting that would inform a decision on acceptable humidity fluctuations. The data we need would include information on climate, resources, sustainability, user needs and so on. If these issues should be factors in the decision making process, how do we collect this data?

Responding to data

Where conservators do access scientific data, how well do they respond to it? There is a very human tendency to selectively ignore data or feedback (Tavris and Aronson 2007). The problem is that at a first level we tend to make a hypothesis and then only seek data that confirms it: very few of us try to disprove our own theories. This means it is easy to find evidence that confirms our perhaps wrong theory but never seek out data that may challenge it (Tavris and Aronson 2007). Additionally, we are also selective in attending to messages that do not conform to what we already believe. In other words we will actively ignore things that conflict with our existing beliefs (Reardon 1991: 46). Finally, evidence shows us that even when we are offered poor quality evidence we are likely to follow it if it conforms with our existing patterns of decision making and that we will conclude that our behaviour, however wrong, is correct (Tavris and Aronson 2007). This is something of a triple whammy. It seems that it is human to collect poor data and selectively ignore any data that conflicts with what we believe. This creates a pattern of behaviour with little or no good quality feedback. Expertise without reflection turns a professional conservator back into a technician.

Having considered the problems in operating a scientific method in conservation, it is necessary to discuss how to pass on the best of our understanding to students. Although they can only become fully formed professionals in the work-place, the foundations are delivered in education (Dardes 2009). How unconscious intelligence can be dissected and discussed with students is a challenge for all those teaching conservation. Another challenge is to require a scientific approach and the selection and use of valid data in a profession where that process is not consistently delivered. Finally although feedback is a natural process of education students need to develop their own reflective skills so that they participate in critical evaluation and develop this as a skill rather than act as passive recipients of grades. My thoughts on how to teach conservation have been stimulated by the recent development of a new two year MSc programme in Conservation Practice at Cardiff University.

Learning conservation: First the basics

Before students can begin to develop and apply knowledge, there are some underpinning facts and skills that anyone operating in a conservation environment needs to acquire: looking down a microscope; operating an x-ray machine; manipulating a scalpel; following a risk assessment and so on. In Cardiff University's three year undergraduate degrees most of this information is taught in the first year. In the two year MSc programme in Conservation Practice this learning will be condensed into one module. Once this induction period is over the next task is to escalate the level of skills in line with the levels described in Icon's novice to expert scale.

Advancing knowledge

It is not only skills that need to be developed in students to transform them into conservators. Would-be conservators develop from an entry level of having knowledge and an ability to marshal facts up through an intermediate stage of comprehension where basic knowledge is applied in a limited context.

In the context of conservation, this will mean the students develop from entry level tasks such as cleaning surfaces with a range of solvents or operating several different mechanical cleaning processes on one item, to the intermediate phase of carrying out a process which involves slightly more complex tasks where the application of knowledge is tested. For example, cleaning archaeological waterlogged leather where there is both mechanical and chemical cleaning and the requirement to learn about collagen, hydrogen bonding and materials for the preservation of the leather so that they can select an appropriate approach. Reaching this stage of learning about conservation is comparatively simple. The students may find integrating the theory and the practical elements difficult but, with support, they can usually manage it.

When the learning process progresses to higher levels such as analysis, synthesis and evaluation, the students are more challenged: but what better topic than conservation to present these challenges? Considering a purely academic description of evaluation, this requires: intellectual problem solving, making personal judgements based on available data, and systematically evaluating alternatives to select a solution from those competing alternatives. This description, using purely educational terms clearly applies to conservation processes.

The curriculum for the first year of the MSc in Conservation Practice will contain elements which are primarily about skills and some which are primarily about comprehension and application. A substantial section of the course element will be devoted to practical projects where students work on objects that bring both of those sides together. In teaching conservation in Cardiff, one of the critical tools used to encourage the students to formally gather data on their evolving understanding and developing scientific method is their project note books.

The project note book as a tool

Staff at Cardiff University encourage students to actively reflect on their own experience and learning in a reflective log known as a project note book. Staff try not to be over prescriptive on the format of this log which initially presents students with some difficulties. However as the students begin to evolve a formal explanation of their own conservation approach, these notebooks provide an opportunity for the students to record as they learn, allowing reflection which maximises their learning experience (table 3).

Stages in scientific method	Quotes from students in the PNB
Identify problem and collect data	The more I look at the wings the more I see what's wrong with them and the more problems I find to consider.
Observation and experimentation	This should take a day or two, maybe longer. I am not sure as I have never done anything like this before... So I will probably mess it up and have to do it over.
Formulate hypothesis	...it became obvious that all the cleaning and stabilization techniques have disadvantages… After deep thought (that took so much time) I decide to treat the object mechanically.
Test hypothesis	The fragments look amazing I am super.

Table 3: Examples in students own words of scientific method in practice

Do the students enjoy us encouraging them to develop individual personal solutions? Some students find it hard, to quote from a recent student evaluation form 'I feel like I am teaching myself'. Compared to some learning environments where students are supplied with data and required only to organise and present it, this approach presents a challenge. There are advantages and disadvantages of this method of teaching. The positive qualities are that self-directed learning encourages independent thought and research; offers no technician way forward; provides room for individuality and in time develops self belief. However students can feel abandoned and have a crisis in confidence. Experience in Cardiff is that the crisis of confidence is a delayed reaction. Initially students are happily ignorant, it is only as their learning develops and they discover the 'known un-knowns' (Rumsfeld 2002) that they realise how big and complex a task conservation is. At that point students realise that nothing is simple and that every phase needs more research. It can seem as if the conservation treatment will never be completed and as the magnitude of the task develops some students lose confidence that they will ever complete the task.

Classroom discussions

In addition to recording their thinking in the PNB students meet with staff to discuss their progress on a particular project. Depending on the student, the project and the staff member, this discussion can fall somewhere between a chat about what level to clean a copper alloy coin to a full grilling about the entire conservation strategy involved. This is not always any student's favourite experience but it does challenge their hypothesis, and establishes whether they are gathering and responding to valid data. Without external stimulus, it is too easy to create over confident assessments of our own certainty.

Conservation in context

Students at university are automatically isolated from owners and context. At Cardiff University, students are provided with contact information of owners and a requirement to formally consider their needs. Yet in the past students have committed or proposed to commit all of the following apparently silly mistakes:

- Making boxes so big they will never fit on a shelf
- Treating a research collection with toxic materials
- Providing environmental specifications impossible for the building
- Writing instructions to owners they could never understand let alone follow
- Making packaging so complex it requires a full page of instructions.

All of these examples arose from students who are otherwise intelligent and successful. My belief is that the problem illustrates less a weakness of students and more a challenge for the profession. Seeing students operate out of context makes it clear that the scientific method of conservation in context is significantly under developed compared to materials science itself. As a result the new MSc in conservation will offer a module that is purely about method. The Module 'Method in Conservation' will aim to focus in on how scientific method should underpin every aspect of conservation practice. This will encompass understanding the decay of materials, the analysis of artefacts to inform treatment, devising options for treatment and specifying the future care of conserved materials.

Conclusion

Conservation requires that we understand materials and decay mechanisms and that we research and test treatment options. But we must go further; conservation is more than simply the preservation of materials. Conservation lies in the preservation of significance or value. Choices need to be made that start from defining those values. There are tools to help collect this data, for example developing statements of significance (Clark, 1999, 2001, Walker and Marquis-Kyle 2004) but as a profession we are weak in understanding and applying scientific method to conservation decisions. Yet it is precisely this approach that will help develop the next generation of conservators and will sustain, refresh and maintain the current generation of professionals.

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Seeing the light: The use of contrast to enhance conservation lighting of museum displays.

Melanie Keable

Abstract

A brief discussion of the results of a study into the use of contrast lighting to enhance the appearance of lux controlled displays; with relevance to the concept of apparent brightness and perception of object detail.

Introduction

Within museums it is widely known that conservation lighting often calls for low lux levels for the preservation of objects (Cayless and Marsden 1983; 385, Loe 1987; 39-49, Cassar 1995; 88-92, Phillips 1997; 40 Wilson 1994; 1-3,).

Compensation for these low lux levels within the wider lighting scheme usually involves the manipulation of contrast. The most common method involves a dark room lit with a few bright points of light illuminating the display cases. Both architectural design and museum display design recommend a ratio of 3:1 Object illuminance: Background illuminance to provide optimal task illuminance.

- A minimum of 2:1 is recommended for objects to be discernable from the background.
- A Maximum of 6:1 to give distinct or significant difference for an object to have visual dominance.
- A ratio of 10:1 is sometimes used for emphatic displays despite the loss in optimal performance.

(Tregenza and Loe 1998; 81-97)

Despite the scientific evaluation of these conditions as optimal for visual performance visitors often comment of displays feeling dark and oppressive. Indeed museums have been plagued with the label of dark stuffy institutions since their foundation. While current design schemes aim to create more people friendly spaces, visitors still feel uncomfortable with conservation lighting. Belcher (1991; 125) states 'Exhibition is essentially a visual experience'. It follows that if museum visitors feel uncomfortable or unable to see the display properly they will not enjoy the museum experience. As Calder (2006; 36) states 'Good lighting is a balance between conservation and creating an atmosphere'. However, this occasionally comes at the expense of contrast guidelines. Yet these displays meet with visitor's approval based on their perception of the display.

Many other factors affect the appearance of museum displays, contrast and apparent brightness (Tregenza and Loe 1998). These include:

- Morphology and reflectance of objects
- Appearance of background
- Methods of lighting (diffuse, directional etc.)
- Colour of light
- Atmospheric mood desired for the exhibition.
- Ergonomics

These all need to be considered and understood in order to understand the role of apparent brightness in creating visitor friendly lighting schemes. Apparent brightness is a matter of psychological perception using the contrast between two areas to create an impression of brightness independent from lux levels (Belcher 1991; 124-126).

Previous studies into conservation lighting such as the defining work by Loe (1987) focused on the average visitor's ability to discern detail balanced against the photochemical degradation caused by light. Instead this study aimed to look at the psychological impact of contrast lighting on museum visitors and its ability to alter their perception of the museum environment.

Experimental aims

- To investigate people's reactions to a variety of contrast lighting schemes in terms of perception of ability to see fine detail and comfortable viewing conditions.
- To attempt to quantify intrinsically unquantifiable concepts of perception in order to evaluate peoples responses.
- To evaluate people's response to the lighting schemes provided and to look for applications to the wider museum context, in terms of manipulating contrast to enhance visual comfort and the viewing experience.

The experiment

The experiment consisted of a sliding scale of contrast levels across a desk. This allowed for a measure of quantification as the data becomes number orientated rather than tied to linguistic descriptive. Participants were asked to define minimum and maximum points were the lighting changed away from the level they found acceptable. The scale of contrast ratio ranges from 20:1 to an inverse ratio of 1:5.

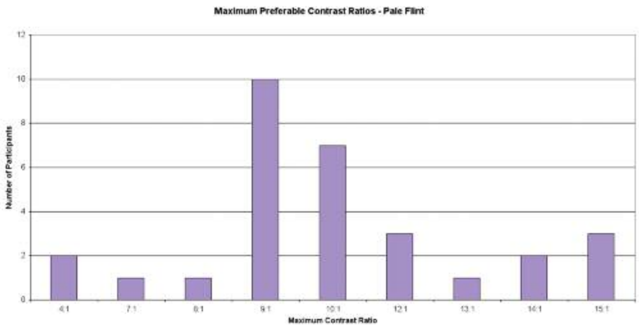
Two worked flints were used as the objects in this experiment; one pale and glossy and the other dark and matte. Light and dark objects reflect light by different amounts and should thus produce different contrasts (Wilson 1994). It was hoped that by using two extremes the results obtained will be the two outer limits. If only one object was used this could create a false overview of results. This method should provide an average set of results for a more complete picture of the perception of lighting. This was designed to provide repeatable, comparable and quantifiable data.

The presence of visual defects in the observers was also recorded.

Results

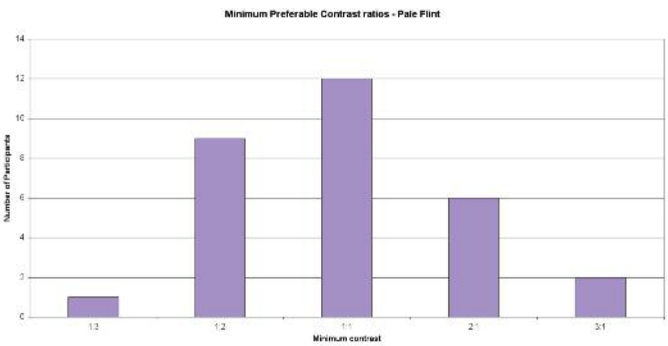
While the experiments did not supply a full overview of the lighting conditions found within the museum, the setup of the experiment provides an overview of people's opinions on the use of contrast to manipulate lighting conditions to help preventative conservation.

Graph 1 shows the preferred maximum contrast ratio for the pale flint lay between 9:1 and 10:1 over half of the participants choosing one of these two values. This falls outside of the contrast guidelines but indicates the point at which the detail visible on the object starts to change away from the ideal. A point of interest here is the presence of two participants choosing the value of 4:1 as their preferred maximum. These not only coincide with the current contrast guidelines, but illustrate the reason for guidelines as they exist today. As the optimal level for task illuminance is 3:1 meaning the detail becomes less visible at 4:1. The two participants who chose these results were those who had some prior knowledge of the recommended lighting conditions.



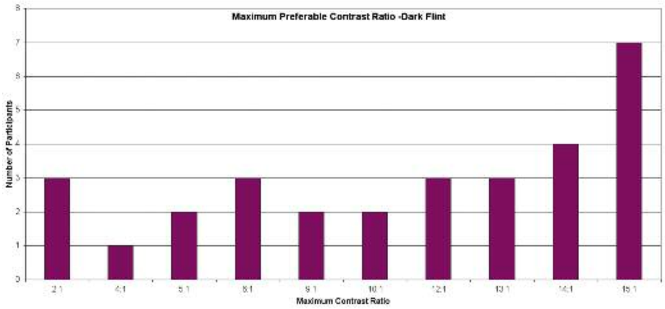
Graph 1

There is an apparent trend towards a ratio of 1:1 being favoured for the minimum preferable contrast ratio (Graph 2). However, a range between 1:2 and 2:1 offers the most appreciated level. The value of 2:1 is expected as it offers the ability to differentiate the object from the background. At 1:1 the object and background illumination are equal, thus the object would not immediately stand out and attract attention without the viewers focus already being placed upon this object. The result of 1:2 is interesting as this shows a greater amount of illumination on the background indicating a substantial loss of detail. However, this may be explained by the presence of a bright background giving the perception of a light environment creating the perception of a high illuminance upon the object.



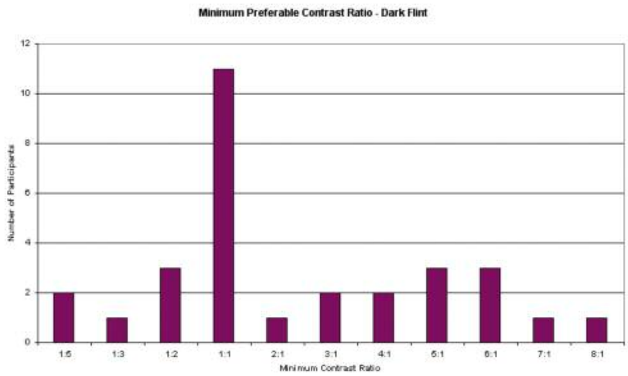
Graph 2

There is a level of variation between the results for the pale and dark flints. The strongest correlation of results exists between ratios of 14:1 and 15:1 (Graph 3), interestingly the results again do not exceed 15:1. The maximum range of results for this flint are less concentrated they confirm the pattern lain down by the pale flint. The difference may stem from the colour contrast of the flints and their backgrounds. An interesting result presented here is the ratio of 2:1 being suggested as the upper limit for contrast and ability to define detail. The contrast guidelines for museum display offer 2:1 as the minimum level as this is the point where objects are just definable from the background. Anything less than this and the definition of the object above the background is lessened.



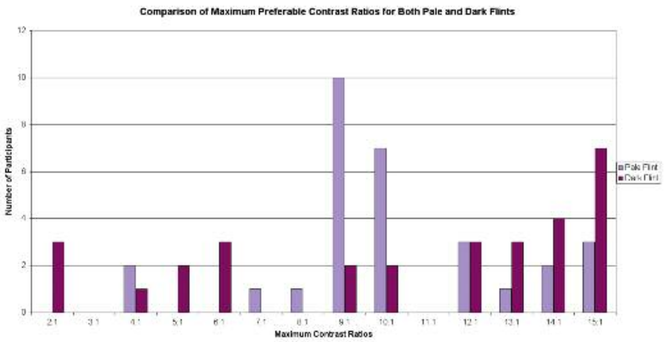
Graph 3

The minimum preferred contrast ratios for the dark flint more closely mirror that of the pale flint with a clear preference for a contrast ratio of 1:1 (Graph 4). There is a preference for the lower ratios as well, indeed up to 1:5. This is the lower extreme of the contrast ratios that were available to the participants in this experiment, offering a much brighter background illumination than object illumination. There is a resurgence of preference at ratios 5:1 and 6:1 and it would be of interest to see if these results continued and perhaps grew in preference if the sample size is increased. As with the other results for the maximum level there are two anomalous results here. The suggestion of 7:1 and 8:1 as the minimum levels of contrast when they both exceed the maximum ratio laid out in the guideline is very intriguing.



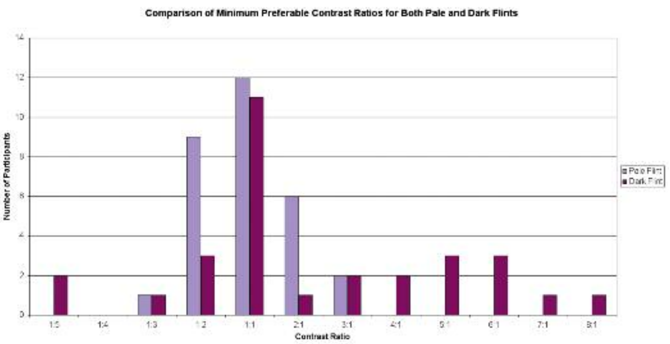
Graph 4

Graph 5 shows a comparison between the maximum preferable contrast ratios for both flints. This illustrates the reason two flints were chosen for this experiment. Due to the nature of the dark and light flint these should hopefully offer the extremes of the preferable contrast. Further study could be used to see if results from other objects with differing surface finished and colours produce preference that lies within these two extremes not outside of it. However, as it is the range of results collected shows that people's view points are very subjective, with varied expectations concerning their lighting requirements.



Graph 5

A much stronger trend (Graph 6) can be seen in the minimum preferable contrast ratios for the pale and dark flints. Both the pale and dark flints produce similar results in terms of preferred contrast. However the results were much clearer on the pale flint where it was easier to discern details.



Graph 6

Discussion

Results suggest people are comfortable with contrast levels that lie outside of the recommended contrast guidelines. Visitors to the museum enter with no expectation regarding definition of detail and lighting schemes; especially when they have no prior experience with the objects. Instead what people look for is the perception of having light: being in a bright environment. Apparent brightness is therefore perhaps paramount, as if the light appears bright people assume they have plenty of light and are able to see.

The presence of results as far ranging as 15:1, suggesting some people still are not aware of a loss of contrast even at these levels. However as the available contrast people could have selected rose as high as 20:1 it is clear that the value of perceived brightness over definition of detail has an upper limit. Does this have implications for the wider museum context? However, expanding the contrast guidelines to the levels suggested here would carry a significant cut in task illuminance. Should science be overruled in favour of perception and viewer comfort levels?

Further study

The main conclusion to this study is that this is an area which requires further study to see if there are applications to the wider museum context. For this to be successful the influence of other factor upon the acceptability of different levels of contrast needs to be more thoroughly investigated. Can objects be grouped together by morphological characteristics and thus prescribed individual contrast guidelines?

The exact loss of visual acuity taken by manipulating the contrast away from the ideal task illuminance needs investigation to see if science and psychological perception can be brought together to create more comprehensive guidelines. If this can be achieved this could have implications not just for conservation and museum display but perhaps also for architecture, psychological perception and optometry.

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Is conservation science doing all it could? The case of ethyl silicate (TEOS).

Simon Lambert

Introduction

The House of Lords Science and Technology Committee inquiry into science and heritage recognised that conservation science should aim to increase support for "end-user led research" (House of Lords 2006, 30); that which is driven by the specific needs of conservation professionals. While the follow-up work on the National Heritage Science Strategy (NHSS) is currently underway, the timing seems appropriate to examine whether conservation science outputs are indeed meeting the needs of the end user. By examining some of the literature published on a specific conservation material, tetraethoxy orthosilicate (TEOS) or ethyl silicate – a substance that is used mostly for the consolidation of outdoor stone and that has been the object of numerous scientific studies worldwide – this paper questions the extent to which the information available to conservators is useful in helping them make evidence-based decisions.

TEOS in theory

TEOS is a silane monomer with four ethoxy functional groups ($–OC_2H_5$) attached to a central silicon atom. Its consolidation mechanism can be broken down into two phases (fig.1). First, with the help of a catalyst, TEOS is hydrolised by water to form a silanol (tetra-hydroxysilane); a process that is also accompanied by the release of an alcohol (ethanol: C_2H_5OH). Second, due to its instability, the silanol slowly condenses, bonding with free hydroxyl radicals (–OH), other silanols or other TEOS monomers, and releasing water. This last part of the reaction implies that TEOS can form chemical bonds with any material that has hydroxyl groups on its surface such as wood, brick, clay and several types of stone (Torraca 1988). The end product of the condensation reaction is silica gel (S_iO_2), a flexible inorganic polymer that remains entirely permeable to water vapour (Mavrov 1983; Lazzarini and Tabasso 1986; Brus and Kotlík 1996; Price 2006; Durnan 2006). TEOS thus consolidates through *chemical* adhesion, whereby new chemical bonds are formed between the product and the substrate, and not through *dispersive* adhesion as with acrylic polymers. As such, TEOS is irreversible, unless one also dissolves the siliceous component of the treated stone, destroying it with Fluorhydric acid (HF).

The specificity of cultural heritage

Any substance used to treat objects of cultural significance should be extensively tested before being accepted by the wider professional community. That being said, systematic conservation literature reviews can sometimes reveal important holes in the knowledge base. Many times, these holes are based on a web of assumptions that have never been verified. A major problem is that we *believe* that they have, and that what we know is sufficient. Surprisingly, even 40 years after its use became widespread, our understanding of how TEOS interacts with stone is rather poor (and much the same can be said of many conservation materials). Why is this?

According to a recent review of stone consolidants, knowing how conservation materials interact with substrates is "fundamental for the selection of the most suitable solution for any conservation treatment" (Tabasso and Simon 2006, 67). While TEOS should theoretically bind chemically with stone at the molecular level, conservation literature has never taken a firm position on the matter. Furlan and Pancella (1981, 648) claim that TEOS is "susceptible" to bind chemically with sandstone, Torraca (1971, 51) "hope(s)" it will, while Lazzarini and Tabasso (1986, 195) affirm that TEOS has an "affinity" with sandstone. In limestone, it has been said that TEOS merely fills the inter-granular space in the crystalline structure without forming any chemical bonds with the material (Mavrov 1983; Wendler 1997; Kemp 2006). Even a recent study that attempted to understand the interaction between TEOS and limestone and TEOS and sandstone using MAS NMR spectroscopy of the ^{29}Si nucleus fell short of providing any useful results: "At this time we do not know how to quantify the phenomenon of the chemical reactivity to evaluate how much it really influences the consolidant effectiveness of the applied products" (Zendri *et al*. 2007, 1106). Regardless of what happens on a smaller scale, many agree and have shown that TEOS increases the strength of deteriorated stone in a significant in laboratory tests (Furlan and Pancella 1981; Clifton 1984; Brus and Kotlík 1996; Wendler 1997; Aggelakopoulou *et al*. 2002), something which appears to be confirmed by natural ageing in situ after 11 years (Grissom et al 1999) and even 25 years (Wendler 1997).

1- Hydrolysis:

$$\underbrace{nSi(OC_2H_5)_4}_{\text{TEOS}} + \underbrace{4nH_2O}_{\text{water}} \xrightarrow{\text{catalyst}} \underbrace{nSi(OH)_4}_{\text{tetra-hydroxylsilane (unstable)}} + \underbrace{4nC_2H_5OH}_{\text{ethanol}}$$

2- Condensation:

$$\underbrace{nSi(OH)_4}_{\text{tetra-hydroxylsilane (unstable)}} \longrightarrow \underbrace{(SiO_2)n}_{\text{silica gel}} + \underbrace{2nH_2O}_{\text{water}}$$

Figure 1

Perhaps these product-material interaction mechanisms are difficult to establish because cultural materials are irregular in composition and structure when compared to industrial materials. We should never forget that products used in conservation were engineered for industrial uses. TEOS is used as a carpet coating, as a cross-linking agent in silicone polymers, in the electronics industry and as a component of Aerogel, a lightweight insulating miracle-product. Thus, TEOS has been extensively tested in these contexts because there is an important financial incentive to do so. With cultural heritage, as we all know, this is not the case. It has been said that TEOS is a promising corrosion inhibitor on industrial iron (Parashar *et al*. 2001). Surely, this does not mean it should automatically be used on archaeological iron. This is why we ought not rely blindly on the technical sheets that are so kindly supplied by the retailer when we purchase our conservation products.

The compositional variability of cultural materials can perhaps explain why the same experiments seem to be repeated endlessly by different groups of scientists to obtain results that are not significantly dissimilar. It is also possible that fundamental research, such as the characterization of materials and their properties, is not particularly appealing in a field that is as result-driven as conservation, where a significant desired outcome is to arrest decay. Systematic fundamental research in conservation takes a formal commitment from the research institution itself. This has been known to occur, for example in large well-funded centres like the Canadian Conservation Institute who examined adhesives in conservation (Down *et al*. 1996), or the Getty Conservation Institute who looked at cellulose ethers (Feller and Witt 1990). However, these are but small islands in a sea of uncoordinated, parallel initiatives. If the state of knowledge on given conservation materials was thoroughly assessed, the resources available to conservation research worldwide could perhaps be better allocated.

The difficulties of fundamental research in conservation were confirmed by the House of Lords consultations (2006), which indicated that conservation scientists are mainly being solicited to resolve specific conservation problems and seldom to discover things that may or may not have an application at some later time. Nevertheless, many conservation products *appear* to work and *seem* to be stable and last a long time. So why should we worry? Relying on fundamental research alone cannot be the answer.

Tried, tested and true

Even when conservation research is applied research, important problems arise. Tests that are originally intended as aids to conservation decision making are often questionable from a methodological point of view. In other instances, these tests are so distant from 'real life' applications that understanding their practical application becomes difficult. It seems that as conservators, we are often asked to infer and speculate about conclusions, when the hard evidence just isn't there.

A good example are the tests aiming to determine the sensitivity of TEOS to soluble salts and acids. Using solid TEOS films applied on brass plates, Mavrov (1983) concluded that TEOS's resistance to sulphuric acid (H_2SO_4) and sodium sulphate (Na_2SO_4) grew with the thickness of the TEOS film. Further ahead, however, he observed that diluted TEOS products were more problematic and was unable to confirm that the problems would be resolved by applying several coats of the product. How is this useful to the end user, if the most commonly-used TEOS products come pre-diluted in ethanol (Conservare OH, Wacker OH, Steinfestiger OH) or in white sprit (Rhodorsil RC70, Estel 1000)? As it is highly unlikely that a conservator would make his or her own TEOS mixtures from scratch, I wonder why conservation researchers do not focus more on the substances that are currently accessible to the end user.

Further questionable tests are those that aim to determine the mechanical characteristics of TEOS-treated stone. In this case, the irregularity of natural stone is a major concern to create a standardised testing protocol to obtain reproducible results. To have any value at all, it seems that the tests must be conducted on homogenous samples, in other words, on artificially-fabricated stones. To create their artificial stones, Zendri *et al*. (2007) use ground calcium carbonate (C_aCO_3) or quartz (S_iO_2), which they immerse in TEOS to bind the particles together and act as the stone's cement. These samples are then treated with more TEOS in order to assess the product's consolidating strength. Although they explain the process in great detail, they offer no rationale to explain why they chose this mixture, or any indication as to how this artificial stone fares in comparison to natural stone. There seems to be something inherently wrong in wanting to standardise testing procedures when in the end, the application will ultimately be on a heterogeneous material.

Elsewhere, Clifton (1984) carries out thermal expansion tests on samples that were immersed for four hours in TEOS and quickly air dried at 105°C, ignoring the fact that TEOS's binding power is improved if the reaction is slow (Amoroso and Fassina 1983), as would happen in normal applications outdoors on dry stone. Furlan and Pancella (1981) look at how TEOS reduces water absorption after impregnation, but test their samples before the product has had a chance to polymerise completely. Amoroso and Fassina (1983) do similar tests, but neglect to say how much time has elapsed before the tests began.

Comparing information on ethyl silicate is often impossible because the data made available on the products being tested is incomplete. Repeatedly, the product's composition, including the percentage of the TEOS component, the solvent or the catalyst – variables which are known to influence the product's performance – are not reported (Wittmann and Prim 1983; Amoroso and Fassina 1983; Knight 1984; Clifton 1984; Jespersen 1982). In other instances, only commercial names are given (Munnikendam 1973), with no indication of the silane monomer it is made of, which can be TEOS, or ATEOS, or ETEOS, or MTMOS. All these problems are amplified by the multitude of interchangeable names for TEOS (silicate ester, silicon ester, silicic acid alkoxy ester, silicic ester, tetraethyl ester, silicon ethoxide, tetra ethyl ester orthosilicic acid, silicic acid, tetraethyl silicate, and ethyl orthosilicate). After this long list of complaints, is any of this literature useful?

The decision conundrum

Considering all its imperfections, how does the conservator navigate through all this fragmentary information? It seems that bits of the puzzle are offered here and there, but few attempts are made to bring all the useful elements together and offer the end-user reasonable assurance in selecting viable treatment options. That this is occurring in the first place seems somewhat of a surprise, since the underlying scientific structure of conservation literature does require a clear statement of background and methodology, a contextualised discussion of the results, and a conclusion

accompanied by a materials list. Is it reasonable for conservators to expect actionable information that can be justified by an evidence-based rationale? With what is out there at the moment, how does one decide?

One issue on which there are many diverging opinions is the curing time of TEOS. Based on the literature, it is highly problematic for the conservator to determine how long it takes before the treatment is stable enough to be exposed to the elements. Various publications have claimed that to dry, evaporate or polymerise, ethyl silicate requires 42 days to several months and is never really complete (Furlan and Pancella 1981), five weeks (Grissom *et al*. 1999), 28 days (Durnan 2006), three weeks (Lazzarini and Tabasso 1986; Liégey 1996), two weeks (Mattero and Tagle 1995), and even one week (Irwin and Wessen 1976).

In this particular case, would one choose three weeks because more references have been provided to support that time length? Who is to say that 10 more references claiming that two weeks is sufficient cannot be found? Surely, there is enough conservation literature out there to confirm any bias. Is this truly the way in which we should be making decisions to select treatments, that is, by evening out opinions that are often based on an incomplete and a sometimes multifaceted evidence base? Admittedly, determining if a product has dried or cured is pretty straightforward in the context of a laboratory, where the sample can be weighed over time to determine when the solvent has finished evaporating and the polymerization of S_iO_2 is complete. However, how can one be sure that the process is complete when working on the façade of an historic building? More importantly, however, does it matter? This is perhaps a case where honest and transparent leniency on behalf of conservation researchers would perhaps better serve the pragmatic context of treatments. What is wrong with admitting to a degree of uncertainty?

Bridging the great divide

Conservation literature relating to treatments can roughly be divided into two categories: the laboratory approach, which is sometimes based on abstract and theoretical realities, but meant to be an aid in 'real life' situations, and the case-study approach, which reports the details of a specific treatment in a real situation, but tries to anchor decisions on theory in some way. Both approaches have their flaws. Authors of case studies frequently claim that a treatment was 'successful', 'good', or simply identify the chosen treatment without offering any rationale. Meanwhile, contributors to the laboratory approach make important methodological decisions at crucial moments in the testing process, but may neglect to relate these decisions to their applications in real situations. To make informed decisions, I believe the conservator should have input from both approaches.

Nevertheless, the day-to-day reality is that conservators often make decisions based on an entirely different set of factors: experience, consensus in the conservation community, credibility of the source of the information, type of training received, resource availability, geographical location, personal satisfaction with past treatments, and even, on that new product or technique everyone is raving about. Just how many conservators outside the university context have the time, resources or interest in taking such rigorous evidence-based approaches? Peter Brimblecombe recently said that "conservators and managers of heritage do not read scientific journals; in fact they hardly seem to read anything at all" (House of Lords, 78). What this points to, is the fact that theory somehow needs to be bridged with practice; but in practice, few, it seems, may be resorting to theory. Have we lost sight of conservation's long struggle towards emancipation as a discipline worthy of its own science? Are we not constantly being encouraged and inspired by our representing bodies to become better professionals? It follows that as conservators, we should demand the same quality and rigour in our publications as in other scientific publications.

Is peer reviewing to blame?

In scientific journals, quality control is assured by the peer review process. Various refereeing procedures are used to weed out inconsistencies, contradictions, imprecision and overall poor quality. Although the specific criteria may differ, peer reviewing is essentially the same for high-impact scientific journals like *Nature* as for our low-impact publications such as the *Journal of the Institute of Conservation, Studies in Conservation,* the *Journal of the American Institute of Conservation,* and our international professional conference preprints, *IIC* and *ICOM-CC*. For all peer-reviewed publications, the procedures are similar: preliminary vetting by Editor in chief, reviewing by at least two – sometimes anonymous – subject specialist peers, final approval or rejection by the Editor in chief. Why, then, do some articles of questionable quality slip under the reviewers' radar and make it to publication unscathed? It is true that there can be many editorial motivations for including sub-par submissions. At a conference, for instance, it can be deemed to be in the best interest of the profession if a debate takes place to question certain ideas. Nevertheless, such optimism has its consequences; once the conference is over and the discussion has long died out (if it happened at all), the published preprints live on. For years to come, students and professionals use these volumes bearing the seal of approval of that institution, only rarely questioning their validity.

Walter Henry (1997) makes an interesting observation about conference papers:

When an author gives a talk describing a treatment, or an observation, the author is saying 'I, the author, have done this treatment, observed this phenomenon'. Because it is an assertion about the author's experience, not about the treatment or phenomenon, the assertion is, barring charges of outright dissembling, inherently unchallengeable.

Henry depicts an inward-looking field that has lost sight of the ultimate purpose of publishing one's findings: disseminating knowledge to further the advancement of the field. Are conservators hiding behind their professional uncertainty when they report case studies, and do conservation scientists gloss over theirs, under the pretence that clear-cut answers cannot realistically be expected in the cultural heritage sector? Jonathan Ashley-Smith (2000, 14) wrote that "[Conservators] would be more secure as professionals if they could be trained to be confident about their *un*certainty." For conservation science literature, this translates to increasing transparency, offering context and rationale for decision making, disclosing failed attempts openly, and adopting a focused, thorough approach that clearly identifies problems and shows how they are addressed by the work described.

Conclusion

As the National Heritage Science Strategy will ultimately be encouraging strategically-framed collaborations between university researchers and in-house scientists as a way of focusing on end-user led research, it is of prime importance to take up the issue of quality criteria for published conservation literature. For the moment, even *Studies in Conservation*, by far the most reputable source in the conservation field, is struggling to find papers that meet its stringent quality standards (Saunders 2009; Phenix 2009). It is such a shame when it sometimes would have taken so little (but a large effort and much humility) to increase the use value of a published piece. By omitting the reasons why certain approaches are taken or how decisions are made, there is virtually no prospect of weighing the feasibility of one treatment proposal over another. If the way in which the article will serve the end user is unclear, that is when we should pause and think. Although it would be tempting to put the blame on peer reviewing, it is a shared responsibility; we should be demanding a higher quality output, but we should also be aiming to produce it ourselves.

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Science and Budget in the Private Sector.

Graeme Storey

When I was asked to give this presentation I began to think about the science that we use in paper conservation and how that has changed in the 28 years since I qualified with my Diploma in Conservation from Gateshead Technical College (now part of the University of Northumbria). What struck me is actually how little things have changed.

To illustrate this let us look at Fig. 1. This is a typical group of prints brought to the studio for conservation. They are four landscape etchings belonging to Weston Park in Shropshire and are in very poor condition. Two are glued to wooden backboards, they are all discoloured and very dirty. My intention is to surface clean the prints, dampen then separate the two prints from their backboards as the adhesive softens, wash to reduce the discolouration, then press and return to the frames in a more stable manner i.e. with acid free isolating layers between print and wooden frame components.

These processes have not changed since I was a student. The materials used are essentially the same also; the commercially produced draft clean powder is essentially the same, so too the wash water, whether ordinary tap water or deionised water buffered with calcium hydroxide, the wet support fabric – Bondina – too and, of course, the end result is almost what we would have been aiming for in 1980. Perhaps now there is a desire to make the conservation work less obtrusive, most certainly in historic interiors.

Most of our work is for public collections and Fig. 2 shows a typical group of drawings ready for return to the client gallery. The drawings, once conserved, are hinged into all rag, acid free board overthrow window mounts, usually cut to one of several standard accepted sizes. Whilst the quality of board has improved over the years the hinges are still made from Japanese mulberry tissue paper and the adhesive is still a simple wheatstarch paste.

Fig. 3 shows a detail of our studio – a typical paper conservation studio – and these have changed little in the last three decades. The equipment is largely the same, the small range of solvents (I.M.S., acetone, ammonia, xylene), bleach (hydrogen peroxide), adhesives (wheatstarch paste, methyl cellulose and cellofas – sodium carboxy methyl cellulose) and the usual benchwork equipment; sink, light box, press and repair papers are little changed also.

So where does budget come into this? Because we are in the private sector, budget colours everything we do. With few exceptions clients do not contact us until there is a budget in place or at least the possibility of a budget. What do clients want from this budget? They want good, basic conservation as described above with as much collection benefit as the budget will allow. We find that our clients want good science, not groundbreaking science and to date, little that warrants a paper in it's own right.

So where do budget and science combine? The answer is in our approach to collections and the rise of preventive conservation. Studio conservation of individual works is expensive and it is unusual for a client's budget to stretch to hands-on conservation of a whole collection.

Figure 1

Figure 2

Figure 3

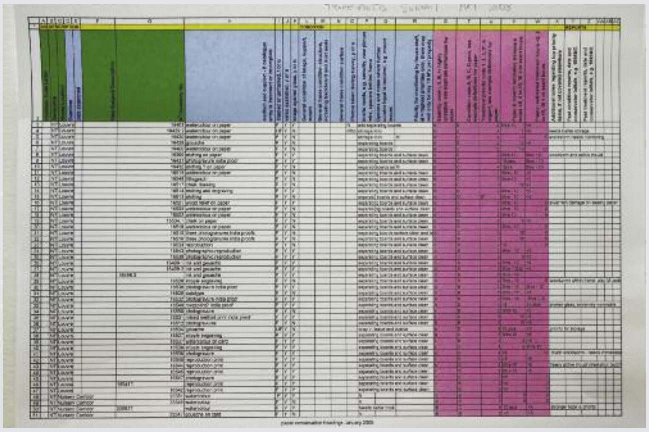

Figure 4

Figure 5

Figure 6

Preventive conservation gives much better value for money and can achieve better long term results. To illustrate this approach let us look at a recent (and ongoing) conservation project, the National Trust's (N.T.) work at Tyntesfield near Bristol. The N.T. acquired Tyntesfield in 2002. If the N.T. had taken on Tyntesfield and it's contents 10 years ago then our work as paper conservators would have been, in collaboration with curators and advisors, to identify the most important and/or the most seriously damaged works on paper, conserve these in off-site studios, then return the completed works to the House.

At Tyntesfield, paper conservation got under way in May 2008. There is no element of focusing on particular works. The approach is holistic and begins with an overview – a survey – of the whole paper collection, framed and unframed prints, drawings and watercolours. The paper conservator worked in partnership with the in-house conservation staff. In practice the paper conservator examined each individual work and dictated findings to either one of the conservation staff or a volunteer who typed the findings into a spreadsheet on a laptop. This allowed this small team of two to move around the House and examine work where it is displayed or stored, avoiding the need for moving a lot of pictures from one location to another. It also allowed the survey to fit the Tyntesfield ethos of allowing the public to see conservation in action, so the survey continued during opening hours and in public rooms.

The normal rate of progress for a survey like this is about 50 items per day. The inventory suggested up to 900 individual flat works on paper and the budget only covered 3 days of on-site work with a further day to write up conclusions. The current N.T. paper conservation spreadsheet, Fig. 4, was used but because of the time restrictions only specific information was put in. The most useful columns in this spreadsheet are the five highlighted in pink. They are:

- Stability (I [stable] – IV [highly unstable])
- Condition (A [good] – D [poor])
- Treatment Priority (1 [back of the queue] – 4 [priority])
- Paper and mount estimated treatment hours
- Frame estimated treatment hours

In three days we managed to at least look at all 900 works. Our findings showed that whilst the collection contained the usual paper conservation problems, acidic supports, foxing, discolouration, etc. the overriding problems were surface dirt and missing backboards. Once again, budget comes to the fore and these two problems will be tackled in time by the in-house conservation team, avoiding the expense of bringing in outside conservators. It is only after dirt and missing backboards have been addressed that we would expect to see any actual hands on conservation work, and probably not for several years.

In contrast to Tyntesfield and it's large collection, Fig. 5 shows Powysland Museum in Welshpool. A small though busy and inventive museum, largely due to it's energising curator, but one where it was recognised that the stores, Fig. 6, needed improving.

To get best use of the available budget (grant aid from CyMAL) the first step was a survey – one conservator and assistant for three days with a further day to write up a summary and make recommendations.

The spreadsheet, Fig. 7, in contrast to Tyntesfield and the N.T., is a simpler affair. Once again, though, the pink columns are the ones to concentrate on:

- Condition Code G, F or P (good, fair or poor)
- Stability Code (stable or unstable, priorities marked with an asterisk)
- Paper and mount estimated treatment hours
- Frame estimated treatment hours

In both cases estimates are given in number of hours, not in cost, so that the work can be placed perhaps many years from now with any conservator.

Unlike Tyntesfield, a recently acquired and previously neglected collection, environmental conditions and levels of cleanliness at Powysland were very good. The areas for improvement were in simple steps such as removing hanging devices from picture frames and interleaving frames with a sheet of card to avoid damage, Fig. 8, and in better storage materials i.e. polyester envelopes and acid free tubes. Because staff numbers are limited, once our recommendations had been agreed we ordered the materials within the client's budget, had board chopped to size before delivery etc. so that the time demands on staff were kept to a minimum.

Once again budget has been used to upgrade large areas of the collection before any moves are made to conserve individual items.

Fig. 9 shows a display of photographs from Powysland Museum illustrating another area where budget is a factor in changing our approach to conservation. The photographs in the illustration are digital copies of original photos. The digital copies are displayed allowing the originals to be kept safe in store, reducing the need for actual hands on conservation. This practice has become widespread in the last decade and, in the context of an historic interior, digital copies can be displayed in original frames making the digital copy even harder to identify in the eyes of the viewer.

Occasionally clients approach us even when they have no budget and Fig. 10 shows an example. In 2000 The Birmingham Conservation Trust were working to save a collection of working class, courtyard houses known as the Back to Backs in the centre of Birmingham. At the time, most of the staff were volunteers and their operating budget was minimal. They approached us for advice on how to remove and preserve the many wallpaper fragments they were finding as their staff worked through the houses. My advice was to remove as many of the paper fragments dry, i.e. with a palette knife or similar and to avoid, wherever possible the temptation to wet the wallpapers before removal as wet paper is so much more of a problem – it is difficult to handle and, if not stored correctly, may be a host for mould with potentially catastrophic results. The dry papers could simply be stored in labelled bags until such time as a budget was in place to conserve them.

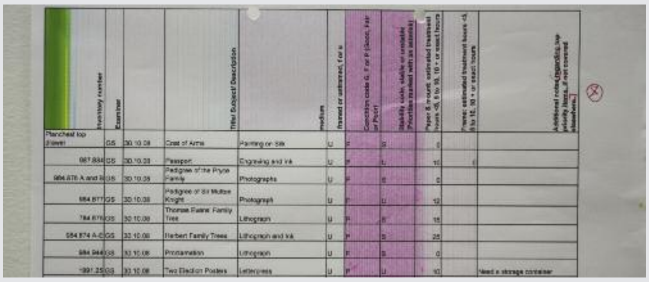

Figure 7

Figure 8

Figure 9

Figure 10

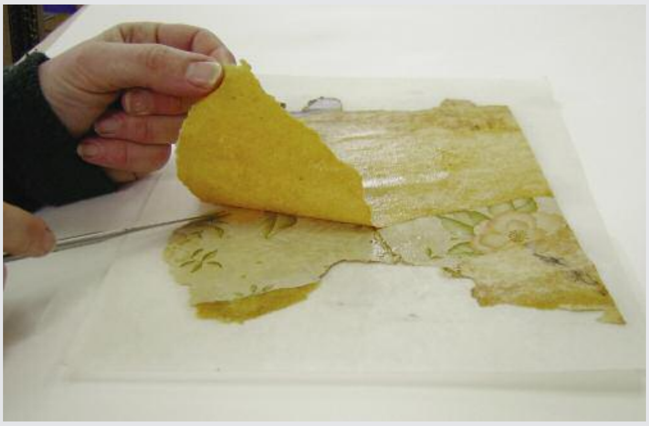

Figure 11

Figure 12

Figure 13

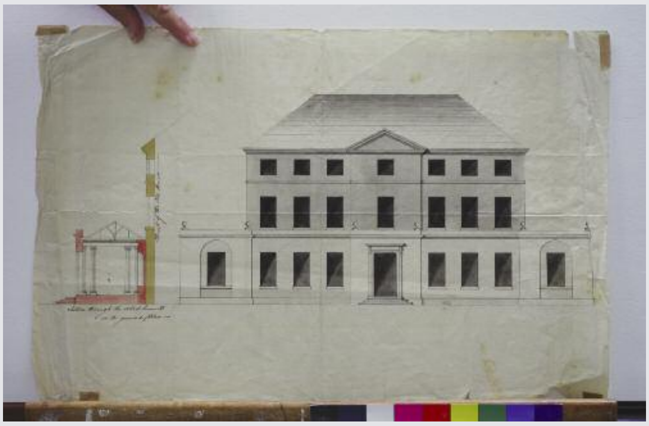

Figure 14

In 2001 The National Trust took over the administration of the Birmingham Back to Backs and began funding an ongoing project to preserve one sample of every pattern found at the Houses, Fig. 11. After conservation; surface cleaning, separation of layers (which is revealing some very interesting patterns), washing, tear repair and pressing, the papers are being returned to the Houses in polyester envelopes in ring binders (Secol) and are used by the interpretation teams during tours of the houses, Fig. 12. The next stage of the project, for which funding is not yet in place, will be to research and date the patterns to get a better idea of the internal histories of the Houses. Budget, or lack of it, dictated the initial approach to the conservation of these papers and our presence as conservators in the actual Houses has not been necessary.

Figs. 13 and 14 are two examples from our current project at Tatton Park in Cheshire. Tatton Park holds a very extensive collection of architect's drawings relating to the House, both proposed and actual building works. These are heavily accessed by researchers but are not in very good condition and hence are vulnerable to physical damage. The aim of the project is to make a full size digital copy of each drawing. These copies can be made accessible to the public and the originals held in permanent high quality storage, although available to specific requests. This dictates the amount of conservation work that is necessary, and to some extent what interventive conservation is important.

Our priority is to make the drawings safe to handle for the copying process, i.e. all tears to be repaired, any dog eared edges or corners to be filled to avoid snagging and any creases reduced to a minimum so as not to distort the images.

I hope that these illustrations show that science and budget work hand in hand in the private sector and both dictate our approach to conservation. The actual benchwork practice has changed little but with preventive conservation a holistic approach and consideration for the collection as a whole often take precedence over the conservation of individual works, or certainly are a precursor to remedial conservation.