



Fig. 5. Fragment of fossil bovid mandible, from Sterkfontein extension site, which had been gnawed by rodents

such it is the first clear-cut example of the utilization of bone from the Sterkfontein area and probably the best at present known from the australopithecine era. It certainly appears to be clear evidence of the artificial utilization of bone at that time-level. Since this specimen came from the same breccia which has yielded the stone artefacts from this site, it must presumably for the present be attributed to the makers of the latter. In my opinion^{1,2}, *Australopithecus* is unlikely to have made the stone artefacts

—it seems more likely that *Telanthropus* was responsible. Probably, therefore, the latter was also responsible for the bone tool. It is not impossible, in view of the evidence accumulated by Dart, that *Australopithecus* had an 'osteodontokeratic' but not an established stone culture, but that *Telanthropus* did have the latter. If this is the case, it is possible that the Sterkfontein bone tool, but not the stone industry, was of australopithecine origin. It is, in any event, interesting to note that the specimen came from the back portion of the cave, as it was at the time of accumulation, among a mass of bones. The remainder of the deposit at that level has a much smaller proportion of bone.

I am indebted to the director of the Archaeological Survey and to Dr. R. Mason of the same organization for the loan of Natufian bone implements from Mount Carmel for comparative study.

¹ Robinson, J. T., and Mason, R. J., *Nature*, **180**, 521 (1957).

² Robinson, J. T., *Leech*, **28**, 94 (1958).

³ Singer, R., *Amer. Anthropol.*, **58**, 1127 (1956).

CHEMISTRY IN THE PRESERVATION OF ANTIQUITIES

AT a joint meeting of Sections B (Chemistry) and H (Anthropology) held during the York meeting of the British Association, Dr. A. E. A. Werner and Mr. R. M. Organ of the British Museum Research Laboratory discussed the subject of chemistry in the preservation of antiquities.

Dr. Werner said that the application of the chemist's specialized knowledge to the problems that arise in the preservation of antiquities may be taken to involve, first, the recognition of the symptoms of deterioration exhibited by antiquities and the realization of the ultimate causes for this deterioration expressed in terms of the physical and chemical structure of the object, and, secondly, the evolution of sound methods of conservation based on theoretical considerations and tested by practical experimentation—preferably, of course, on trial pieces or objects of minor importance specially acquired for the purpose.

In the past, the methods used in the conservation of antiquities were largely of an empirical nature and the materials used were limited to those of natural origin which approximated most closely, in their chemical and physical properties, to the needs of the particular work in hand. Typical examples of such materials are waxes such as beeswax and paraffin wax, natural resins, and animal and vegetable glues. However, in the past three decades or so, there have been remarkable advances in high-polymer chemistry which have led to the introduction of many new synthetic materials, possessing a combination of chemical and physical properties not normally found in materials of natural origin. The assessment of the potential value of these synthetic materials in the elaboration of more reliable methods for the preservation of antiquities was discussed with special reference to specific problems in the preservation of antiquities of an organic nature.

One outstanding problem is the question of the most suitable method for the treatment of wooden objects which are obtained from excavations in a so-called water-logged condition. Old water-logged

wood may have a water content of more than 100 per cent of the dry matter in the wood, and its actual physical state will depend upon the degree of degradation, that is, the extent to which the cellulosic cell-wall structure has broken down. If this has reached an advanced stage, the wood will be quite soft, almost like cheese, and will have a very low mechanical strength. In considering the problem of stabilizing old water-logged wood, there are two factors to be considered. The first involves the actual removal of the large excess of water without causing serious deformation of the wood, and the second involves the consolidation of the wood to restore sufficient mechanical strength so that it can be handled with ease.

If the water is allowed to escape by ordinary evaporation, surface tension forces exerted on the weakened cell walls will cause them to collapse. Hence, special techniques have been evolved. One such technique is the so-called alum process, in which the wood to be treated is immersed in a super-saturated solution of alum at a temperature of about 95° C. until complete impregnation is achieved. The idea behind this method is to replace the water by a solid, alum being used because it can be dissolved in a very small amount of water. A more refined method is the use of the well-known biological technique for drying tissues by immersion in successive baths of ethyl alcohol followed by immersion in baths of ethyl ether. If the final ether bath contains a resin such as dammar in solution, the resin will remain after evaporation of the ether to stabilize the wood structure. This is a relatively expensive process and involves a serious fire risk, so that it is confined, in practice, to the treatment of small objects, where it has been found to give excellent results. The well-known technique of freeze-drying can also be applied. The water is frozen to ice which is evaporated from the wood under vacuum, so that any tendency for the cell-wall structure of the wood to collapse due to exertion of surface tension of liquid water is avoided. Experiments

made in the British Museum have shown, however, that the results are unreliable, and the method is very slow and time-consuming, since it requires more or less constant supervision unless an expensive automatically controlled refrigerating unit is installed.

Since none of the above techniques may be regarded as being uniformly successful, experiments have been in progress in the British Museum Laboratory based on the use of the synthetic polyethylene glycol waxes. These waxes, although possessing the characteristic physical properties of waxes, have the rather unexpected property of being soluble in water. They are available in a polymeric series ranging from soft waxes rather like 'Vaseline' to hard waxes similar to the typical paraffin waxes. It has been found that the wax of average molecular weight 4,000 (the actual material used is known by the trade name of 'Carbowax 4000' produced by Union Carbide Chemicals Co.) is suitable for the treatment of water-logged wood. The new technique which has been evolved consists in immersing the wooden object in a 12 per cent aqueous solution of the 'Carbowax 4000' at room temperature and slowly increasing the temperature to c. 60° C. over a period of many weeks. The water in the wood slowly diffuses out and is replaced by the wax. During the period of treatment, the solution is allowed to evaporate so that at the end the wooden object is lying immersed in molten 'Carbowax'. This technique is particularly suitable for wood which has suffered a considerable degree of degradation while in the water-logged state and is in a spongy condition.

If the structure of the water-logged wood has not suffered too severely, and still retains a certain degree of structural strength, an alternative method of treatment can be adopted. The wooden object is allowed to dry out slowly by being placed under conditions of gradually decreasing humidity. Under these conditions, the wood will dry without suffering distortion apart from a slight flaking of the surface layer. Consolidation is achieved by impregnation with an epoxy resin which is brushed on to the wood as a mobile liquid which readily permeates the wood, where it solidifies *in situ* at room temperature, thus conferring upon the wooden object the necessary mechanical strength. These epoxy resins, which have the highly desirable property of setting to a solid without undergoing appreciable contraction, are of general application as agents for the impregnation of wooden antiquities which are in a fragile state, for example, wooden objects which may have been severely weakened as the result of attack by insects.

In the case of leather objects which may be recovered from excavation in a fragile state as the result of being water-logged, or in a brittle condition due to excessive desiccation, immersion in molten polyethylene glycol wax of grade 1,500 at a temperature of about 45° C. affords a simple method of preservation. The hydrophilic wax removes the water and consolidates the water-logged leather, whereas in the case of the brittle leather, the absorption of the polyethylene glycol wax restores to a marked degree the flexibility of the leather so that it can be handled with ease and, if necessary, reshaped without fear of breaking. Two other synthetic waxes which have proved of value in the formulation of a wax mixture for the surface protection of antiquities are the microcrystalline waxes which, owing to their special physical structure, are superior to the conventional paraffin waxes and the hard polyethylene waxes of relatively high melting point.

Another field in which new synthetic materials have found extended use in conservation is that of adhesives. When considering the use of adhesives in the restoration of fragile antiquities, the single factor which is of major importance is the question of the amount of shrinkage which can occur when an adhesive sets; if this is large, strains are set up which may weaken the bond or cause distortion of the bonded complex. In this respect the most suitable adhesives are those based on epoxy resins; these represent a class of adhesive which sets by chemical reaction *without* the loss of any volatile material.

The presence of soluble salts which have been absorbed by porous objects while buried in the earth prior to their excavation—for example, Egyptian ostraka—may be the latent cause of deterioration. When such objects are exposed to atmospheric conditions in which there are large fluctuations in the relative humidity, these salts tend to be transported to the surface where they crystallize out, thus obscuring the surface and, in the course of crystallizing, causing the surface layer to flake away; in the case of ostraka, this would result in the loss of the actual writing. These soluble salts can be removed by the simple process of washing in water; but, before carrying out the washing, it is necessary to consolidate the surface of the object in order to prevent any flaking away of the surface. This consolidation can be readily achieved by the use of a special soluble modified nylon—a material produced by Imperial Chemical Industries, Ltd., under the trade name 'Maranyl soluble nylon polymer C 109/P'. This material is soluble in either methyl alcohol or ethyl alcohol, and when a 5 per cent solution in one of these solvents is brushed on to the object prior to washing, it deposits a surface film which is not only permeable to water (thus permitting elution of the soluble salts), but also possesses a marked degree of flexibility so that it does not exert any undue contractile force on the frail surface layers. This material also possesses adhesive properties which render it very suitable for the reattachment of flaking paint on wall paintings. It was used, for example, in the treatment of a fragment of a tempera wall painting from a tomb at Thebes of the XVIIIth Dynasty in which the paint layer was tending to blister badly. A warm 5 per cent solution of soluble nylon was brushed over the areas of flaking paint and gentle pressure applied. The alcoholic solution, having a much lower surface tension than an aqueous solution, readily flows into the minute cracks in the blisters and spreads out underneath the flakes of detached paint, drawing them back into position; in this way a secure bond was formed between the reattached paint and the ground. Furthermore, the surface film has a matt appearance so that it does not leave an aesthetically undesirable sheen on the treatment areas of the painting.

Mr. Organ dealt with the problems that arise in the preservation of bronze antiquities. He first described the causes of corrosion and the build-up of the corrosion layers. Metallographic examination shows that in the majority of bronze alloys the metal consists of a two-phase system. Prior to excavation, these contiguous phases have often been in contact with water which had percolated through the soil and contained dissolved salts. An electrolytic system is thus set up in which one of the two phases corrodes to form insoluble salts which are deposited on the surface of the object in the form of minerals which comprise the well-known 'patina' characteristic of

antiquities. Cross-sections of a corroded bronze were shown in illustration.

The occurrence of the so-called 'bronze disease' in museums is connected with the presence of cuprous chloride as a component in this mineral structure. This material not only reacts with moisture and oxygen in the air to form basic cupric chloride (which is the light green material that appears as the characteristic spots of bronze disease) but also attacks the underlying bronze with the formation of cuprite. Hence action directed towards preserving a bronze object must be aimed at nullifying the activity of this particular salt.

In those cases where it is desirable to retain the mineral patina on a bronze, the reactivity of the cuprous chloride may be overcome by the use of special chemical reagents, namely, (a) sodium sesquicarbonate solution or (b) specially prepared solid silver oxide.

In the first method the object is immersed in successive solutions of sodium sesquicarbonate, which has little visible effect on the patina, but is sufficiently alkaline to neutralize the hydrochloric acid produced when the cuprous chloride is slowly converted into cuprite: $2\text{CuCl} + \text{H}_2\text{O} \rightleftharpoons \text{Cu}_2\text{O} + 2\text{HCl}$. The second technique, involving the use of silver oxide, was specially developed in the British Museum Laboratory for the treatment of objects which for some particular reason cannot be immersed in an aqueous solution; for example, a bronze object inlaid with enamel-work. The aim of this procedure is to seal off the corroding areas containing cuprous chloride by applying over them a layer of silver oxide powder which reacts to form an impervious layer of silver chloride.

When it is desirable to remove patina, which may be not only unsightly but also concealing valuable detail on the object, the various layers of mineraliza-

tion can be successively removed by chemical means. First, the green basic carbonate is dissolved by immersing the object in alkaline Rochelle salt, then the cuprite is destroyed using dilute sulphuric acid, and, finally, the cuprous chloride layer is removed by cathodic reduction in alkaline solution. When this treatment has been completed, there will still be residual chlorides remaining in the porous metal; these must be removed completely if the object is to remain in a stable state under normal museum conditions. This can only be successfully achieved by a special process of intensive washing in many successive baths of distilled water. The progress of the washing is followed by measuring the electrical conductivity of the successive baths of wash-water until it falls to a minimum and the absence of chloride is established. It has recently been found that this process, which used to take up to eight months for completion, can be speeded up by a factor of as much as ten by the use of ultra-sonics.

When the mineralized layers are removed, the object may sometimes be in such a frail state that some form of mechanical support is necessary. In the past, material such as wood or plaster and adhesives such as shellac and nitrocellulose were pressed into service *faute de mieux*. An improved technique was recently developed in the British Museum Laboratory using a suitable epoxy resin which can be supplied as a liquid which sets *in situ* to form a reinforcement. This material is ideal for the purpose because it adheres well to the metal, sets without shrinkage so that no contractile stresses are exerted on the fragile object, and it is transparent so that no details of design are obscured. This technique was successfully used to strengthen a unique silver hanging bowl excavated at St. Ninian's Isle, Shetland, which, after removal of corrosion products, was as thin as an egg-shell.

A. E. A. WERNER

GENETICS AND THE ORIGIN OF SPECIES

TO assess the magnitude of Darwin's contribution to biology one hundred years after the publication of "The Origin of Species", it is necessary to recognize that Darwin developed his ideas in a very different climate of biological thought from our own. Darwin's recognition of the dynamic nature of species was made at a time when species were regarded as the static products of natural creation.

Species, as aggregates of individuals subject to variation and constantly being replaced by those of their progeny which escape from the hazards of their environment, represent a concept which we owe to Darwin and which still lies behind our knowledge of evolution.

Modern theories of genetics have sprung from Mendel's demonstration of the particulate nature of inheritance and the subsequent discoveries that the heritable determinants, or genes, are located in the chromosomes. The idea that genes are subject to mutation and liable to re-assortment at meiosis represents the crude mechanism of the variation on which natural selection must operate, but behind this lies the more fundamental aspect of gene evolution and the biochemical mechanism of their operation.

If the symposium in Sections D (Zoology) and K (Botany) of the British Association at the recent

York meeting gives an insight into modern evolutionary thought, it is clear that geneticists are at present largely concerned with the manner of gene action and the process of modification in genetic constitution which selection induces. Several speakers pointed out that the precise effect of a gene is modified by the genetic environment of the gene so that successful species come to possess a highly integrated gene-assemblage. As Prof. K. Mather (Birmingham) emphasized, the main features of an organism affected by selection are controlled by swarms of genes acting together. The effects of separate genes are balanced, and selection shifts the balance, giving gradual and not jerky evolutionary change. Moreover, it is only in this way that we can understand how an organism can achieve the complex selection-advantage we find, for example, in mimicry, where a strong degree of visual similarity with the model must be obtained before selection will operate. In the case of the African butterfly, *Papilio dardanus*, in which the female mimics several models, Dr. P. M. Sheppard (Liverpool) described how the range of variation in mimic characters of the progeny of hybridization of geographical races indicated polygenic control. Dominance of mimic features has been selected, so that hybrids between races which naturally meet ensures