Biology for art's sake

Paintings and other works of art are under attack from insects and fungi. Conventional pesticides don't help — they, too, can damage precious artefacts. Hannah Hoag meets a biologist who is finding gentler alternatives.

At first glance, Robert Koestler's office looks like the workplace of any academic entomologist. Papers litter the desks, and graphs tracking the respiration rate of various insects are pinned to the wall. Yet up one flight of stairs lie galleries filled with Monet paintings, fragments of textiles dating back 5,000 years, and a seventeenth-century wall panel from the bedchamber of Louis XIV.

For more than two decades, Koestler, who trained as a cell biologist, has been employed by the Metropolitan Museum of Art in New York City to help conserve its artefacts. He is almost one of a kind: there are no other research biologists employed by art museums in North America, and only a handful worldwide. "I saw a niche that wasn't occupied, so, like a good biologist, I exploited it," he says.

In 1991, Koestler began testing a technique to suffocate insects using inert gases. He settled on argon because it kills quickly and sinks to the bottom of the container, forcing oxygen out. He now travels to museums around the world to offer his expertise. He is also working on ways to eliminate fungi and the mouldy stains they create without damaging the artworks and manuscripts that they affect.

Koestler joined the Met, as the museum is affectionately known, in 1981. Since 1973, he had been running a scanning electron microscope facility for studying biological specimens at the American Museum of Natural History, also in New York. The Met, which was interested in acquiring a similar machine, initially approached him for advice. When the museum purchased its own microscope, it also offered Koestler a job.

As he helped conservators to examine works of art at the microscopic level, Koestler

Artistic licence: Robert Koestler has expanded the palette for the safe preservation of artefacts.

became fascinated by the organisms attacking some of the artefacts. He suspected that common chemical treatments used to eliminate these invaders were doing more harm than good. In particular, Koestler began to study the effects on oil-based paints of the gas fumigant Vikane (sulphuryl fluoride). "It was horrendous," he says. The pigment colour or gloss changed in 10 of the 11 paints he tested¹, probably as a result of reactions with impurities in the fumigant.

A brush with fate

Koestler's timing was impeccable. Three weeks after the paper on Vikane was completed, a curator moved *The Holy Family with the Infant Saint John the Baptist*, a wood panel painted by Andrea del Sarto, a member of the Florentine school, shortly before his death in 1530. It was infested with insects, later identified as drywood termites (*Cryptotermes brevis*). Koestler urged conservators not to use Vikane, and set about providing an alternative, kinder, treatment. "I guess I saved that painting," he says.

Koestler's answer was to suffocate the

insects with argon², an inert gas commonly used to fill electric light bulbs. Today, he has the method down to a fine art. When *Nature* visited the Met, he and Črtomir Tavzes, a post-doc from Slovenia, were treating three twentieth-century items from the museum's Costume Institute. Together with several small white packages containing iron (II) oxide to scavenge any oxygen, Tavzes sealed the items in a heavy Mylar bag. He then nicked a small hole in one corner of the bag and fed in a tube, which forced the air in the bag out of a hole at another corner, replacing it with humidified argon. Once the oxygen concentration dropped below 400 parts per million, Tavzes heat-sealed the bag and set it aside for several weeks. "Insects can hold their breath for an awful long time," says Koestler. Lyctus beetles, for instance, which feed on hardwood, take three-and-a-half weeks to succumb.

The method kills most insects and bacteria, and some fungi. Koestler has treated thousands of objects all over the world — including a six-metre-high altarpiece in Slovenia — without damaging the artwork, or exposing conservators to dangerous chemicals.

This has required him to become an expert in insect breathing habits — hence the graphs showing the carbon dioxide output of ants and carpet beetles pinned to a board in his office. The graphs reveal that a single adult beetle releases CO₂ at less than a quarter of the rate of a typical ant. Koestler used to measure the CO₂ output of infested objects to determine how long to apply the treatment³, but that process was cumbersome and lengthy. Today, he can determine the appropriate treatment for each piece after a thorough visual examination.

Having conquered insects and bacteria, Koestler is turning his attention to those fungi that cannot simply be suffocated. They are the conservator's nightmare. Hundreds of different fungi, including species of *Penicillium* and *Fusarium*, can give the pages of precious manuscripts a green or pinkish hue, or spread ugly black stains across paintings and drawings.

The hills are alive...

The extent to which some artworks are under fungal attack becomes obvious when they are examined microscopically. One of the most unusual Koestler has seen is a painting by the American artist John Chumley, dating from around 1960. It depicts a pastoral autumn scene with hills, a stream and a rolling fog. "But as you got closer to the painting, you realized the fog was literally moving," says Koestler. Under the microscope, *Penicillium* filaments stood up and waved⁴.

Chemical and laser treatments can eliminate some fungal species, but others survive. Koestler's recent work has focused on a stack of mouldy sketches acquired by the Met in the late 1960s. The collection contains more than 400 drawings and watercolours by Louis Comfort Tiffany, an American artist of the late nineteenth century, who is best known for his art nouveau stained-glass objects and windows.

Many of the sketches are the only remaining record of Tiffany designs that were lost, or never built. Among them is a delicate watercolour of a marble and glass mosaic

Fungal attack: both *Angel Appearing to the Three Marys at the Tomb* by Louis Comfort Tiffany (above) and John Chumley's *Autumn* (below) bear scars from colonies of fungi.

baptismal font. The sketch hangs in the museum's American Wing, but it is partially obscured by splotches of black and other colours, caused by the fungi that took up residence. Other items, not on display, are in an even worse state.

"The greens, blues and yellows are easy to deal with," says Koestler — they can be removed with lasers or organic solvents. But the black marks, made by the pigment melanin from fungal cell walls, are a real headache. "We can cover them up or use bleach, but many items are not displayable," Koestler says.

In 2000, Italian microbiologist Maria Pia Di Bonaventura joined Koestler's lab

as a postdoc, and set to work investigating the fungal communities living on the Tiffany sketches. To identify the species present, she isolated and sequenced the DNA that encodes RNA found in ribosomes — cellular organelles that manufacture proteins⁵. She also tried to culture some of the species. "The two methods gave us an idea of the different fungal species that had colonized this drawing at different times," Di Bonaventura says.

Paper trail

Di Bonaventura believes that the fungi that left the stains are not those that are now living on the paper. Because different fungi — and the mess they leave behind — respond to different treatments, this information should help conservators design specific methods, perhaps involving enzymes, to remove the stains. "The molecular characterization of these fungi is taking the whole field of art conservation into a completely different realm," says Robert DeSalle, curator of invertebrate zoology at the American Museum of Natural History, and a co-investigator on the Tiffany fungal project.

Tavzes and Koestler continue to build on Di Bonaventura's research. They are modifying the argon treatment to treat fungal infestations⁶, and experimenting with ultraviolet light to eradicate spores. The researchers are also collaborating with a group associated with the pulp and paper industry to develop an enzymatic process to decolourize the melanin stains. "It's a case of high-tech knowledge being transferred," says Tavzes. Although the system is promising, it is far from perfect, requiring a temperature of 90 °C and pH 10 to work — which could damage the sketches.

As one of the few biologists involved in art conservation, Koestler is in hot demand. That gives him a busy and satisfying working life, and sees him trotting around the globe. But what he would really like is for more museums and galleries to recognize the important role biological expertise can play in preserving precious works of art for future generations. "We need more biologists who can look at the whole system and say here is the problem, and here is the solution," he says.

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This work by Andrea del Sarto was saved from termites by a dose of argon.