Frustrations of fur-farmed mink

Mink may thrive in captivity but they miss having water to romp about in.

Animals may suffer in captivity if they are strongly motivated to perform activities that their housing does not permit. Here we investigate to what extent these limitations affect caged mink and find that these animals will not only pay high costs to be able to perform a range of natural behaviours, but they will also release the 'stress' hormone cortisol when prevented from indulging in swimming, their favourite activity. Despite arguments that mink housed in fur farms have successfully adapted to captivity, these animals may suffer by being deprived of resources that exist in the wild.

Fur farming is widespread in North America, Scandinavia and Europe, with some 30 million mink pelts being produced annually worldwide. On these farms, American mink (*Mustela vison*) are kept in wire-mesh cages (dimensions are typically 0.9 × 0.4 × 0.3 m), with access provided to a single nest box, drinking water and paste-like food. It has been claimed that this causes frustration to the animals[1], which in the wild would patrol territories 1–4 km long, use several nest sites, and hunt by following scent trails, investigating burrows, and diving and swimming for aquatic prey[2]. Others argue that the excellent health and breeding success of farmed mink are evidence of successful adaptation to captivity[3,4].

We have objectively investigated this issue of possible deprivation by measuring the costs paid by farm-raised mink to reach resources that will enable them to behave naturally. Because of the key role of pleasure in motivating preference[5,6], the results should pinpoint the activities that are important for the welfare of farmed mink.

Eight male and eight female mink were individually housed in closed-economy[7] set-ups, each consisting of a conventional farm cage, plus seven similarly sized resource compartments. These compartments contained, respectively: a water pool measuring about 1.5 m × 0.5 m and filled with 0.2 m water (Fig. 1); a raised platform, reached by a 2-m vertical wire tunnel; novel objects such as traffic cones and packaging, which were changed daily; an alternative nest site (a box of hay); toys for manipulation and chewing (tennis balls, for example); and a plastic tunnel. The seventh compartment was left empty to control for the importance of simply making extra space available. Costs to 'pay' to reach the new facilities were imposed by weighting one-way entrance doors by 0, 0.25, 0.5, 0.75, 1 or 1.25 kg for seven successive days.

The animals' activity in each compartment was automatically recorded throughout the day and night, allowing us to calculate four measures of value (Table 1). We found that the animals rated the water pool as the most valuable resource: it attracted the greatest total expenditure and had the highest reservation price, greatest consumer surplus measures of utility, and the most inelastic demand (Table 1).

We next tested the reactions of seven male and seven female mink to having their access blocked to four resources, for 24 hours each, by monitoring their levels of cortisol, which is produced in response to stress[8]. The resources chosen were of high, intermediate or low value, as judged by the cost the animals would pay to reach them (the water pool, alternative nest site or empty compartment, respectively), and the fourth was an essential physiological resource — food. During each trial, urine was collected for assay of excreted cortisol; levels of creatinine were also determined to correct for any differences in urine concentration.

Figure 1 A caged American mink (*Mustela vison*). This one has access to a water pool, a highly valued resource enabling the animal to indulge its natural instinct for diving and swimming.

Table 1 Value to farmed mink of resources allowing natural behaviour

Resource	*Elasticity of demand*	*Consumer surplus (kg)*		*Reservation price (kg)*	*Total expenditure (kg)*
		Travel cost	*Aggregate*		
Water pool	0.26 ± 0.04*¶	81.41 ± 9.97*¶	24.00	1.25 ± 0.00*¶	134.33 ± 11.18*¶
Alternative nest site	0.41 ± 0.08*†¶	60.72 ± 5.67*†¶	22.75	1.17 ± 0.05*	114.83 ± 13.27*†¶
Novel objects	0.58 ± 0.08†‡	54.58 ± 5.02*†¶	22.50	1.16 ± 0.04*	83.62 ± 9.93†¶
Raised platform	0.57 ± 0.07†‡	50.87 ± 7.65†¶	22.25	1.14 ± 0.06*	82.17 ± 16.11†
Toys	0.62 ± 0.05†‡	24.30 ± 3.25‡	21.00	1.06 ± 0.07*	34.11 ± 6.39‡¶
Tunnel	0.73 ± 0.07‡¶	21.61 ± 1.72‡¶	20.75	1.06 ± 0.06*	26.33 ± 3.66‡¶
Empty cage	0.77 ± 0.06‡¶	9.19 ± 0.90§¶	17.00	0.84 ± 0.07†¶	8.76 ± 1.34§¶

The 'price elasticity of demand', widely advocated for assessing animal welfare[5], was calculated as the gradient of the log–log plot of visit price versus visit number for each resource[7,9]. 'Consumer surplus', used by human welfare economists to assess resource value[10], was calculated by measuring the area under two types of demand curve: a plot of visit price versus visit number, analogous to the 'travel cost method' of environmental economists[11], and an aggregate plot of price versus the number of subjects prepared to pay each price[9]. 'Reservation price'[9], akin to the 'break point'[12] of experimental psychologists, was calculated as the maximum price paid to reach each resource. 'Total expenditure' per unit time, as given precedence by behavioural ecologists[13], was also calculated, the values shown here being those calculated for the six weeks of the experiment. All values are given as means and standard errors ($n = 16$), except for 'aggregate consumer surplus'. Low values for elasticity of demand indicate little decline in visit rate as visit costs increase; for all remaining measures, a high numeric value indicates a high usage value.

*†‡§ Resources whose values differ significantly at $P < 0.01$ (Tukey's *t*-test).

¶ Resources that significantly contribute (at $P < 0.01$) to a general linear model (Minitab 12) of the form 'value equals mink (sex) + sex + resource + sex × resource', where 'mink' is a random factor.

When deprived of food, the minks' urinary cortisol increased by 50.0 ± 16.1% over baseline (paired $t = 2.77$, d.f. = 13, $P < 0.05$); it increased by 33.8 ± 11.2% when access to the water pool was denied ($t = 2.75$, $P < 0.05$). These two effects did not differ significantly ($t = 2.47$, $P > 0.05$). Cortisol excretion was not increased by blocking the other two resources. Consistent with cortisol's metabolic functions[8], the animals' excretion of the hormone in response to being denied access to food or to the water pool correlated with an increase in their physical activity (food: $R = 0.49$, $P = 0.07$; water pool: $R = 0.70$, $P = 0.005$; $n = 14$). Overall, however, changes in activity only reached significance during food deprivation ($t = 2.45$, d.f. = 13, $P < 0.05$).

Our results indicate that fur-farmed mink are still motivated to perform the same activities as their wild counterparts, despite being bred in captivity for 70 generations[4], being raised from birth in farm conditions, and being provided with food *ad libitum*. The high level of stress experienced by mink denied access to the pool, rated as the most valuable resource, is evidenced by an increase in cortisol production indistinguishable from that caused by food deprivation. These results suggest that caging mink on fur farms does cause the animals frustration, mainly because they are prevented from swimming.

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Structural colour

Now you see it — now you don't

The dazzling iridescence seen in some hummingbirds[1] and tropical butterflies[2] arises from natural optical phenomena, the brightest of which originate in nanoscale structures that produce ultra-high reflectivity and narrow-band spectral purity[3]. Here we investigate the coloration of male *Ancyluris meliboeus* Fabricius butterflies[4], which have patches of unusual microstructure on their ventral wing scales. We find that this highly tilted, multilayered arrangement produces a bright iridescence of broad wavelength range and generates a strong flicker contrast from minimal wing movement.

The microstructure in the iridescent scales of *A. meliboeus* comprises multilayers of cuticle and air within a discrete *Morpho*-like[2] ridging that runs the length of each scale (Fig. 1a). These layers are tilted at about 30 degrees to the base of the scale, causing two distinct optical effects. In the first, abrupt termination of each cuticle layer at the upper ridge surface presents a strong periodicity of about 700 nm, which contributes a diffractive component.

We analysed the structure's reciprocal space[5] to find out how the periodicity of the multilayers and diffracting elements scatter incident light. The diffractive component appears to combine additively with the interference from the underlying multilayer to produce a broad range of coloration, as well as a limited reverse colour change with angle compared to that associated with conventional flat multilayering.

The second, more striking effect arising from the tilted multilayering accounts for the strongly bistable nature of the wing reflectivity in diffuse white light: it is either 'on', when an observer sees one of a broad range of colours, or it is 'off' and produces no reflected iridescence. The 30-degree layer tilt causes a 60-degree portion of the wing's 'observation hemisphere' (Fig. 1b) not to appear iridescent ('dark zone' in Fig. 1b).

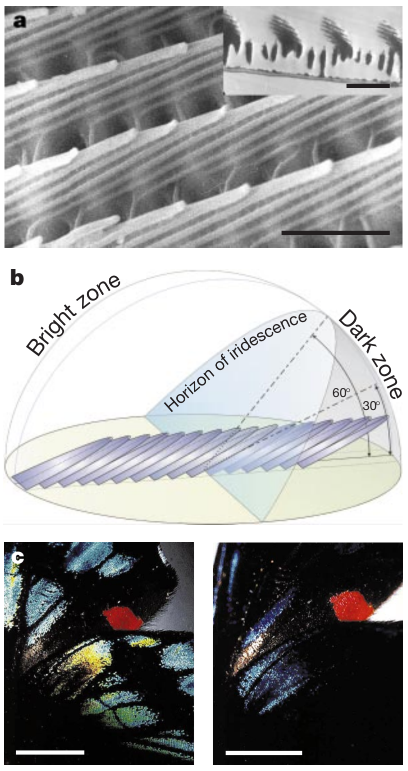

Figure 1 Tilted multilayer ridging divides the observation hemisphere above the iridescent scales of the butterfly *A. meliboeus* to produce strong colour flicker. **a,** Scanning electron microscope image of the surface of an iridescent scale. Inset, transmission electron microscope image of the cross-section through an iridescent scale at 45° to the line of ridging. Scale bar, 1 μm (inset, 2 μm). **b,** Tilt-induced bright and dark zones in the observation hemisphere over an iridescent scale. **c,** Real-colour images showing the same portion of the butterfly's wing under diffuse illumination: left, image with the camera in the wing's bright zone; right, image after moving the camera 15° round the observation hemisphere into the dark zone (the red region is coloured by pigmentation). Scale bars, 4 mm.

Over the remaining 120 degrees of the hemisphere, diffuse light produces iridescent reflection. Under identical illumination conditions, other structurally coloured insects and animals are seen as iridescent at angles over the entire hemisphere above their reflecting surfaces.

This structural arrangement is important in signalling by the butterfly. On or near the edge of the *A. meliboeus* dark zone, wing movements of no more than a few degrees generate ultra-high-contrast colour flicker in reflectivity (Fig. 1c). In species whose observation hemispheres have no dark zone, wing movements of large amplitude are necessary to achieve colour flicker.

Intermittent colour flicker is a useful conspecific trigger stimulus[6], which becomes increasingly supernormal at higher and higher frequencies until the flicker-fusion frequency of the observer's visual system is reached[7]. However, inertial and physiological constraints usually prevent the wings from producing flicker signals at frequencies approaching those of visual flicker fusion[6].

Ancyluris meliboeus avoids the need for large wing movements by means of this ingenious optical structure. By virtue of strong diffracting elements above the multilayering on its iridescent scales, this butterfly produces a broader colour range than would be accessible through interference alone — hence its alias as a "living jewel"[8].

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erratum

A viable herd of genetically uniform cattle

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