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AESTHETICS IN NATURE: CASE STUDY OF THE PEACOCK TAIL FEATHERS

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Abstract

Nature contains many examples of beautiful forms and textures. In addition, nature has examples of beauty for beauty's sake as with the display feathers of the peacock. There are many birds that have display feathers whose only purpose is to attract a mate. These examples of beauty for beauty's sake are important because the main function is beauty. In these cases, nature reveals important principles about aesthetics. This paper describes the aesthetic features of the peacock tail and the mechanisms that produce those features.

Keywords: Aesthetics, thin-film interference, patterns

1 Introduction

The aesthetic features of products such as motorcars and bridges can be critical to their success. The form a motorcar is usually the first thing that a potential customer notices about a car. In addition, people now take many aspects performance and reliability for granted in modern cars. Therefore, aesthetics is often a differentiator between competing products. Nature contains many examples of beautiful forms and textures. In addition, nature has examples of beauty for beauty's sake. For example there are many birds that have display feathers whose only purpose is to attract a mate. These examples of beauty for beauty's sake are important because the main function is beauty. In these cases, nature reveals important principles about aesthetics.

2 Inherent and added beauty

Aesthetic merit in appearance is produced by attributes such as patterns, brightness, variety, curves, blending or any combination of such attributes. An object can have two types of aesthetic beauty: inherent beauty and added beauty. Inherent beauty is a beauty that exists as a bi-product of mechanical design. In contrast, added beauty is a type of beauty which has the sole purpose of providing a beautiful display. These two types of beauty can be seen in manmade products like buildings and bridges. An example of inherent beauty is found in the shape of a suspension bridge. A suspension bridge has a curved cable structure because this is an efficient way of supporting a roadway. However, the end result can be a very elegant and beautiful design.

An example of added beauty can be seen in the decoration of a classical column. The classical column has an elaborate form with intricate carvings and grooves. There is no mechanical reason for a classical column to be any more than a plain cylinder yet the designers embellish the column with elaborate patterns just for the sake of adding beauty.

Charles Darwin recognized that the beauty of male creatures like the peacock had a function of providing a beautiful display: ‘A great number of male animals… have been rendered beautiful for beauty’s sake’; ‘the most refined beauty may serve as a charm for the female, and for no other purpose’; ’that ornament and variety is the sole object, I have myself but little doubt’ [1].

3 The peacock tail

Most species of bird have two types of tail feather: flight feathers and tail-coverts. The flight feathers provide stability during flight, while the tail-coverts cover and protect the tail region of the bird. In the vast majority of birds, the tail-coverts are small feathers just a few centimetres long. However, some birds like the peacock have very large tail-coverts for decorative purposes. (It should be noted that a peacock is a male peafowl whilst a peahen is a female peafowl.) The only purpose of the peacock tail feathers is to attract females. During the breeding season, the peacock will often display his tail feathers in an attempt to woo a peahen. The reason why it is generally the male that has a beautiful coloration is that the female must spend long periods on the nest and therefore, must be well camouflaged.

The peacock tail feathers are sometimes called decorative or ornamental feathers but most people refer to them simply as the peacock tail feathers. An adult peacock has an average of 200 tail feathers and these are shed and re-grown annually. Of the 200 or so feathers, about 170 are ‘eye’ feathers and 30 are ‘T’ feathers. The ‘eyes’ are sometimes referred to as ocellations. The length of the feathers varies from a few centimetres to over 1.5 m. The peacock tail feathers are some of the longest and most brilliantly coloured feathers in nature. The unique length and structure of the peacock tail feathers is acknowledged by bird experts [2].

4 Aesthetic features of the peacock display

When a peacock displays his tail feathers, a magnificent ‘fan formation’ of feathers forms a beautiful backdrop to the body of the peacock, as shown on the front cover of this book. To produce this fan-like arrangement, the feathers must be very accurately aligned. Another remarkable feature of the displayed feathers is that they are ‘deployed’ into position by muscles in the peacock’s tail. Not only can the peacock deploy the feathers, but he can also make them vibrate and produce a characteristic hum. Another beautiful feature of the displayed feathers is that the eye feathers are spaced apart with a remarkable degree of uniformity. All the eyes are visible because the feathers are layered with the short feathers at the front and the longer feathers at the back.

The eye and T feathers have complimentary shapes because the T feathers have a profile which is the inverse of the shape on the eye feathers, as shown in Fig. 1. Each individual eye feather and T feather is an object of outstanding beauty in itself. The eye feathers contain beautiful patterns with brilliant colours, whilst the T feathers form a beautiful border to the fan.

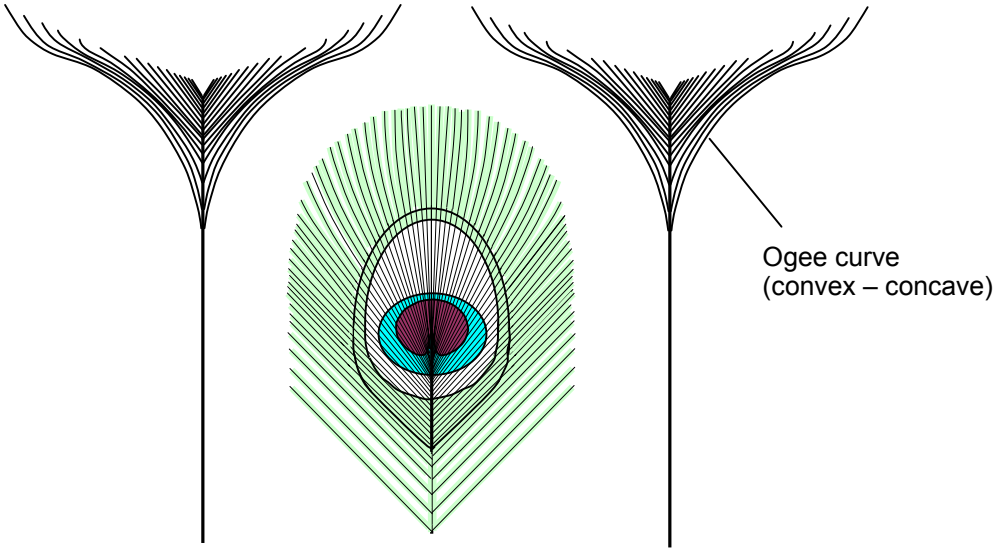

Fig. 1 Peacock tail feathers

5 The structure of the peacock tail feathers

The basic structure of the peacock tail feather in the eye region is shown in Fig. 2(a). For comparison, the structure of a typical flight feather is shown in Fig. 2(b). Like the flight feather, the peacock tail feather has a central stem with an array of barbs on each side. In addition, these barbs are covered with a large number of barbules. A large peacock eye feather may contain up to 300 barbs and one million barbules.

Even though there is a basic similarity with a flight feather, the peacock tail feather has an unusual overlapping barbule structure. The barbules are like long segmented ribbons which overlap to form a smooth surface on top of the barbs. (Under a microscope the barbules are slightly curved and the surface has a bubbly appearance.) Each barbule contains at least 20 separate segments. Since a large peacock feather contains up to one million barbules, there may around 20 million barbule segments in a large peacock feather.

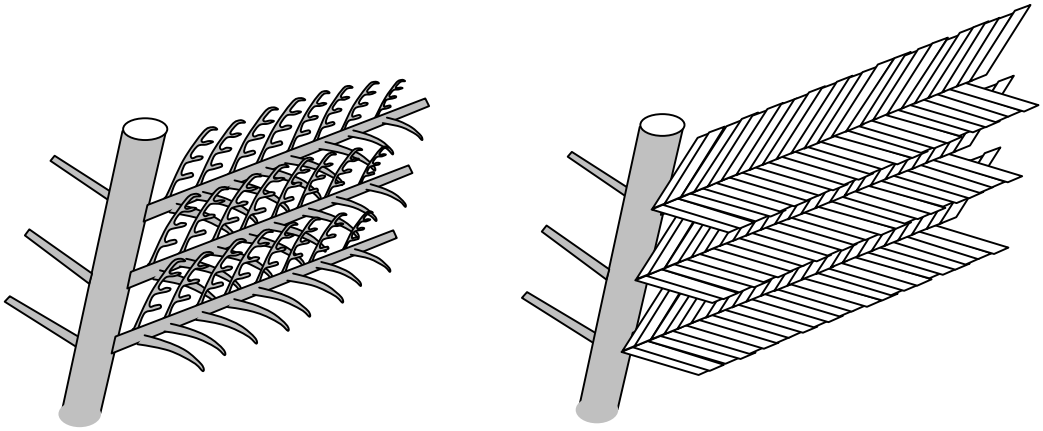

Fig. 2 Structure of peacock tail feather

6 Thin-film interference in the peacock tail feathers

The colours in the peacock tail are not pigment colours but structural colours which are produced by an optical effect called thin-film interference [3]. The thin-film interference takes place in the transparent segments of the barbules and produces bright and iridescent colours. An iridescent colour is a colour that changes with the angle of view. The barbules are dark purple in the 'pupil' of the eye, blue in the 'iris' of the eye, bronze around the iris and green on the fringes. Away from the eye region, the barbules are uniformly green.

Thin-film interference can be produced in one or more layers of a very thin and transparent material. Usually the thin film is placed on a dark surface. The thickness of the transparent material must be close to the wavelengths of visible light. Visible colours have wavelengths of between 0.4 μ and 0.8 μ and thin films typically have a thickness of between 0.3 μ and 1.5 μ (μ = one micrometer). Another requirement for thin-film interference is that the thin film must have a refractive index that differs from air (so that the light is retarded when it passes through the thin film). One common example of where thin-film interference occurs is in oil slicks on a wet road. When a car spills drops of oil on a wet road, the oil will often form a thin layer on the wet surface of the road. The resulting thin film produces blue and green colours even though oil itself is nearly transparent.

In the peacock tail feathers, thin-film interference takes place in three layers of keratin which surround the barbules. Each barbule is about 60 μ wide and 5 μ thick [3]. The foam core is 2 μ thick and the keratin layers are extremely thin, being about 0.4–0.5 μ thick [3]. Other types of birds, such as hummingbirds, pigeons and kingfishers, have some patches of flat iridescent barbules, but the peacock has the largest iridescent barbules of any known bird. The colours in the eye feather can only be seen on the front surface of the feather because this is where the barbules are positioned. The back of the feather is uniformly brown because the barbs contain a brown pigment.

The principle of thin-film interference is as follows. White light is reflected off the front and back surfaces of the thin film. The light which passes through the keratin is retarded (slows down) whereas the light which reflects off the front surface is not. Therefore, some of the colour components of white light which are reflected from the back surface become out of phase with the corresponding light-waves which were reflected off the front surface. When two wave trains of the same colour are out of phase, this causes destructive interference to take place and the colour is removed. In the case of white light hitting a thin film, the result of the interference is a reflected colour due to the remaining colour components of white light. In practice, interference occurs simultaneously in all three thin films.

The barbules in the peacock feather contain an amazing degree of optimum design. The thickness of the keratin layers is optimal for producing the brightest thin-film colour. The different colours in the eye pattern are the result of minute changes in the depth of thickness of the keratin layers [3]. The dark brown background colouring of the barbs is optimal because it prevents light shining through the back of the feather. The three layers add to the brilliance of the colours in the feather by adding multiple components of light. A further optimum feature in thin-film design is that the barbules are slightly curved in the longitudinal direction. This curvature causes a mingling of slightly different colours and results in a softening of the colours seen in the keratin layers.

7 Aesthetic features of the eye feather

Fig. 3 shows a picture of the top section of the peacock eye feather. There are several beautiful features to the feather:

- Bright colours
- Intricate eye pattern
- Loose barbs below the eye pattern
- Absence of stem in top half of eye pattern
- Narrow stem in bottom half of eye pattern
- Brown coating of stem near the eye pattern

The bright colours and intricate shapes of the eye pattern are the most striking aesthetic features. The loose barbs on the lower part of the feather are beautiful because they make a contrast with the neatness and precision of the barbs in the eye pattern.

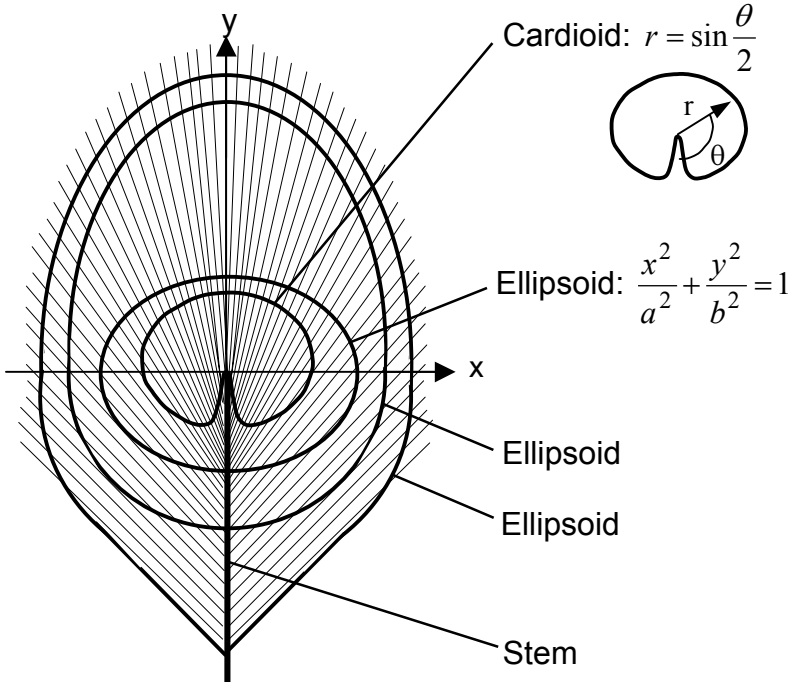

Fig.3 Patterns in the eye feather

The last three features in the list above are usually only noticed by very careful observers. However, they represent important 'finishing touches' which make an important contribution to the beauty of the feather. The absence of a stem in the top half of the eye is an important detail because it prevents the pattern from being completely divided into two sections. The stem is able to be absent because the barbs gradually change in their angle of orientation and fan-out right around the top of the feather. The narrowness of the stem in the bottom half of the eye pattern is important because this makes the stem fairly obscure. The brown coating of the stem in the area of the eye pattern is important because the stem is a natural white colour and this would be too conspicuous in the eye pattern. It is interesting to note that the stem is white everywhere except local to the eye pattern. This demonstrates that the brown coating near the eye pattern is a deliberate feature.

The eye feather contains remarkably precise patterns. The eye pattern is made up of rounded shapes that have a high degree of resolution. The 'pupil' of the eye is a dark purple cardioid shape and the 'iris' is a blue ellipsoid shape. These shapes are located within a pointed bronze ellipsoid which is surrounded by one or two green fringes. A very important feature of the eye pattern is that it is a 'digital' pattern which is formed by the combined effect of many thousands of individual barbule segments. Some patterns in nature are formed by natural growth mechanisms, as with the spiral shape of the nautilus shell. However, the eye pattern in the peacock tail requires the precise co-ordination of independent barbules and this cannot be achieved by a simple growth mechanism.

The way that barbules and barbule segments on adjacent barbs co-ordinate perfectly with each other to produce the eye pattern is amazing. On each side of the eye pattern, every single barb has a unique sequence and spacing of colours along its length. Yet all the barbs co-ordinate with great precision to produce the eye pattern. Along the length of the barb there are abrupt and minute changes in the thickness of the keratin films so that different thin-film colours are produced. The thin-film colours change from blue to dark purple then back to blue and then to bronze. The colours on the barb match the colours of adjacent barbs so that the eye pattern is formed. Observations under a microscope indicate that an individual barbule segment always has one colour but that a single barbule can contain segments of two different colours if the barbule goes across a boundary from one colour to another.

The abrupt nature of the changes in thickness is important because if the changes were gradual, then there would be a gradual change in colour. The abrupt change in thickness of keratin is an amazing feature because it involves a sudden and precise change in the dimensions of the barbule. Even more amazingly, along the length of the barb, the thickness of the keratin does not continually get thicker and thicker (or thinner and thinner) but it both increases and decreases in thickness. Such directional changes cannot be produced by simple growth mechanisms.

8 Discussion

The peacock case study illustrates several important principles for designers:

- Nature sometimes contains beauty for beauty's sake as in bird display feathers like the peacock tail.
- The peacock tail contains several striking aesthetic features.
- Some of the aesthetic features have a mathematical beauty.
- The colours of the peacock tail have a high degree of lustre and iridescence because of a high degree of optical optimisation.
- Aesthetics in nature can be used to inspire aesthetic features in man-made products.
- Nature shows that small details can be important in aesthetics.
- Nature shows that it is worthwhile putting significant resources into aesthetics.
- Nature can give clues to optimising aesthetic features such as iridescence.

Nature can be a very important source of inspiration for aesthetic ideas because everyone has an instinctive attraction to the natural beauty of nature.

9 Application: motorcar design

The motorcar is a product where aesthetics is critically important. Many customers assume that different motorcars have a similar technical performance and reliability. Because of this, aesthetics is a key differentiating factor between competing products. Therefore, many features of the motorcar have the function of attraction as with the peacock.

The motorcar has several aesthetic features which are related to the features found in the peacock. For example some modern motorcars have a pearlescent appearance due to very advanced painting systems [4]. These paints contain thin layers which produce a thin-film effect and hence produce an iridescent coloring system. Such a feature produces a very distinctive aesthetic effect.

Another aesthetic feature on modern motorcars which relates to the peacock is that of embellishments. The wheels of expensive cars are often sculptured into curvaceous and geometric shapes. The primary goal behind these shapes is not for structural efficiency but for aesthetic effect. Bright coloring is another feature sometimes found in motorcars. This is particularly true for sports models which often have a bright yellow or red coloring to enable them to stand out.

10 Conclusions

The peacock tail feathers have outstanding aesthetic features including bright colours, iridescence, mathematical patterns and matching stem. The features of the peacock tail can be copied by industrial designers in order to produce good aesthetic features in man-made products. The strong colours, patterns, iridescence could have applications to products such as cars and bicycles.

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