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The new physiology of vision—Chapter XXIV. Floral pigments and the perception of colour

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Studies on floral colour are of great assistance in giving both breadth and depth to our understanding of the visual sensations excited by polychromatic radiation. We may recall here a few striking examples which have already found mention in earlier chapters. The tree known as *Lagerstroemia flos reginae* has two varieties, one of which exhibits great clusters of rose-coloured flowers, and the other produces similar clusters of flowers having a purple hue, flowers closely resembling each other in all other respects. Spectroscopic examination reveals that the rose-red flowers exhibit a nearly complete extinction of the green sector and thus belong to the colour category (1011), and that, on the other hand, the purple flowers exhibit an extinction of the yellow sector and hence belong to the category (1101). Similar and very striking differences appear in the spectra of the light transmitted through a bract of a rose-red variety of *Bougainvillea* and through a bract of a purple variety.

In numerous cases, the efforts of horticulturists to introduce improved varieties of flowers which enjoy popular favour have resulted in producing forms which exhibit more attractive colours as also new colours. Spectroscopic examination enables us to determine the spectral character of the light diffused by the flower petals of the different varieties and hence to connect their differences in this respect with the differences in their perceived colours. In the preceding chapter dealing with the colours of roses, we have already had an illustration of the usefulness of such studies, especially when they are supplemented by an examination of the absorption spectra of the floral pigments extracted from the petals with the aid of acetone as a solvent. The investigation revealed that great differences in the perceived colours can arise as a consequence of the same floral pigment being present but in very different quantities in the petals of the roses. On the other hand, it also emerged that differences in colour appear in various cases which are ascribable to actual differences in the nature of the floral pigments. The results obtained with the roses suggested that the matter would be well worth pursuing in other cases of interest. We shall accordingly devote the chapter to setting out some further significant results which have been obtained in this field.

Pelargoniums: These flowers (often referred to as geraniums) are highly esteemed by reason of their very attractive and continuous display of colour. The blooms appear in clusters, and these are massed against a green background of leaves of peculiar shape. One particularly brilliant and colourful pelargonium exhibits a scarlet hue, but there are also other varieties a comparative study of the colours of which is evidently called for. The spectroscope reveals that the scarlet-hued flowers show by reflected light the spectral range extending from 570 mμ towards longer wavelengths, thus including both the red sector and a considerable part of the yellow sector. But the rest of the spectrum is missing, and in particular, the blue sector is not to be discerned. The brilliancy and high degree of saturation of the colour of the flowers are thereby made intelligible.

Examining other varieties of pelargonium, one meets with colours which are akin to scarlet but are less brilliant and less saturated in hue, e.g., orange, a pale orange and an orange-pink. The spectroscope reveals that they exhibit in addition to the part of the spectrum shown by the scarlet flowers, also part of the blue sector, while a gap appears between 480 and 550 mμ which is evidently the region of the spectrum most strongly absorbed by the flowers. The varieties which exhibit the blue sector more strongly and the gap in the spectrum less conspicuously are also those in which the colour of the flower is lss brilliant and less saturated in hue. This indicates that the same floral pigment appears in these varieties as in the scarlet pelargoniums but in smaller quantities. This inference is confirmed by extracting the pigment from the scarlet flowers using acetone as a solvent. On diluting the extract by addition of acetone, we observe similar progressive changes in the colour and spectral character of the light transmitted by the solution.

There are also other pelargoniums which evidently form a class by themselves, viz., those exhibiting a red colour, rose-pink and pale pink hues. In all these cases, the red sector of the spectrum makes its appearance but the yellow and the green sectors are weakened, while, on the other hand, the blue sector of the spectrum continues to be visible. The extinction of the yellow and the green sectors is complete in the case of the red flowers, but less so in the case of the rose-pink or pale pink varieties. The blue sector also gains intensity in the latter cases. One may infer from these facts that the floral pigment present in pelargoniums is different in the scarlet and in the red varieties. In the latter, the pigment has a strong absorption in the yellow sector of the spectrum, while in the former such absorption is absent. This inference is confirmed by extracting the pigments respectively from the two varieties of flowers using acetone as a solvent and examining the spectrum of the light transmitted through a column of the extract under comparable conditions.

Hibiscus rosa sinensis: Reference has been made in an earlier chapter to the large brilliantly coloured flowers of this plant. Seen either by reflected or by transmitted light, its petals exclude all parts of the spectrum of wavelength less than 600 mμ, thus accounting for their red colour. The characters of the floral pigment responsible for this spectral behaviour are better understood when it is extracted with the aid of acetone, leaving the petals colourless. The extract exhibits a deep red colour and an intense absorption covering all wavelengths less than 600 mμ. Using short absorption paths or else by diluting the extract with acetone, thereby allowing light of smaller wavelengths to come through, a strong absorption band between 580 and 590 mμ reveals itself, as also another strong band between 530 and 550 mμ. There is also a weak absorption band at about 500 mμ. The blue sector of the spectrum can be seen coming through, though only weakly.

A rose-pink hibiscus (a hydrid of the rosa-sinensis type) has also been examined. As seen by reflected or by transmitted light, its petals showed a powerful absorption of the green sector, the rest of the spectrum remaining practically unaffected. The flower thus belongs to the colour category (1011). The acetone extract of the pigments of the flower examined in a 2 cm absorption tube showed a rose-pink colour. The blue sector of the spectrum could also be seen coming through very clearly. Absorption bands could also be seen in the green and the yellow sectors in the same positions as with the extracts from the red hibiscus. There is thus good reason for assuming that the pigments in the two cases are identical. Longer columns showed the change in colour from a rose-red to a deep red to be expected in the circumstances and also a more powerful absorption of all wavelengths less than 600 mμ.

Hibiscus syriacus: The plant thus named is a native not of Syria but of India and is common in Indian gardens. It differs from *Hibiscus rosa sinensis* in the shape of its leaves and also in the manner of its flowering, the blooms appearing along the stem of the plant in the axils of leaves. The flower when it fades and closes up exhibits a blue exterior. But when the flower is open, the petals exhibit a purple hue. Spectroscopic examination reveals that this has its origin in the appearance of an absorption in the region of the yellow sector from 560 to 590 mμ, the rest of the spectrum presenting its normal appearance. The flowers of *Hibiscus syriacus* (*Indica*) thus belong to the colour category (1101). The floral pigment can be extracted using acetone as solvent. The extract has a beautiful purple colour and transmits both the blue and the red sectors freely. With short columns, a strong absorption band appears in the yellow sector of the spectrum covering the spectral region from 560 to 590 mμ. With longer columns, this region is completely extinguished, and a weak band in the green between 510 and 530 mμ also makes its appearance. A very weak band is also seen in the red sector between 610 and 630 mμ.

Bignonia magnifica: This is a climbing plant which grows vigorously and is very showy, as it bears flowers in great profusion in large panicles. The colour of the fresh flowers is a rich purple. Examination of the spectrum of either the reflected or the transmitted light shows that the pigment present in the petals exercises an absorbing power in the spectral range between 500 and 600 mμ, this being much more pronounced between 560 and 590 mμ, thereby effecting a nearly complete extinction of the yellow sector of the spectrum. On the other hand, the red sector is unaffected, while the blue is only slightly weakened. If the flowers are kept immersed in water for 24 h, the extraction of the pigment by use of acetone becomes readily possible. The acetone extract (if not too highly concentrated) exhibits a purple colour by transmitted light. Wavelengths greater than 600 mμ are freely transmitted and the blue sector also comes through, though sensibly weakened. Two dark bands are seen in the spectrum, one between 530 and 550 mμ, and another between 580 and 590 mμ, while the region from 550 and 590 mμ has its intensity reduced to a small fraction of its normal value.

The purple orchids: Of particular interest is the spectroscopic behaviour of orchids which exhibit a purple colour. The author has had an opportunity of examining several such orchids and found that they behave similarly. It is therefore sufficient here to consider the particular orchid known botanically as *Spathoglottis plicata*. This is a native of India and it is very hardy and can be grown on the ground or in pots like any other ordinary plant. The flowers are produced on spikes two or three feet long and the plant can easily be recognised by its palm-like leaves and the long spikes which hang out and bear flowers along their length and at their ends. The remarkable feature is that the spectrum of the light either reflected by or transmitted through the petals of the orchid exhibits a clearly defined set of absorption bands well separated from each other. The first band which is sharp and quite dark covers the spectral range from 575 to 600 mμ and thus in effect extinguishes the yellow in the incident light. The second band is not quite so dark nor is it quite so well defined. It appears in the spectral range between 530 and 555 mμ. A third and much weaker absorption is noticed in the spectral range between 490 and 510 mμ. The rest of the spectrum including both the red and the blue sectors remains unaffected.

The floral pigment can easily be extracted from the petals of the purple orchids with the aid of acetone. The extract has a purple colour by transmitted light and exhibits the three absorption bands in the same positions. But there is a remarkable change in their relative intensities. The second band appearing in the green is now more conspicuous than the first band in the yellow. The third band is also quite conspicuous. Finally, the blue sector shows a distinct weakening. It will be noted that the positions of the absorption bands both as seen directly with the petals and also in the acetone extracts are the same as those observed in the transmission of light by acetone extracts of red roses as set out in the preceding chapter. It is thus clear that we are here concerned with a definite chemical entity which plays a highly important role in the production of floral colours. What is specially remarkable is that when it appears in the petals of orchids, its spectroscopic behaviour manifests itself in such a clear and unmodified fashion.

Petrea volubilis: This is the botanical name of a climbing plant which is a great favourite in Indian gardens by reason of the beautiful sprays of purplish-blue star-like flowers which it bears in profusion and which give the plant the popular name of the Purple Wreath. Racemes of flowers which are from 15–20 cm in length crowd the plant, covering it up in a mass of colour. The most prominent feature of these sprays are the calices which remain after the true flowers have fallen off. The latter are quite small and their five petals have a much deeper colour. They can be seen resting on two or three of the end calices, one of the five having a white splash in the middle.

Spectroscopic examination shows that the colour of the sprays which is very striking as seen from a distance owes its origin to a weak absorption which manifests itself in the wavelength range between 570 and 600 mμ and results in a sensible reduction of the intensity of the yellow sector of the spectrum, while the rest of the spectrum is not visibly unaffected. The tiny flowers of a deeper colour show the same feature but in a more accentuated fashion, and give also an indication of an absorption band in the red at about 620 mμ.

The floral pigment which gives rise to the observed colour can be readily extracted from the flowers using acetone as a solvent and its absorption spectrum can be studied by observations on the light transmitted through a column of the extract of appropriate length. The extract can be prepared using either only the calices or only the true flowers. The results are of the same nature in both cases. The colour of the transmitted light is purple. Two bands are visible in the green sector of the spectrum, one between 520 and 535 mμ, and the other between 560 and 580 mμ, the latter being much the stronger of the two. A third absorption band is also observed in the red sector between 615 and 630 mμ.

Iris germonica: Iris form a very interesting class of plants which are remarkable for their curiously constructed flowers of attractive and gorgeous colours. *I. germonica* has creeping root-stocks, sword-like leaves and bears flowers on erect stocks. The particular variety studied has flowers which exhibit petals of a blue-violet colour. Spectroscopic examination of the light diffused by the petals shows a large diminution of the intensity of the yellow sector of the spectrum and also a strong absorption in the red sector. The floral pigment can be readily extracted with acetone and the solution exhibits a beautiful purple colour. Spectroscopic examination of the light transmitted through a 2 cm tube shows three absorption bands one in the green between 510 and 525 mμ, another in the yellow between 550 and 580 mμ and a third in the orange red between 610 and 620 mμ.