

Albiflora - stranger than paradise



- Introduction
- Taxonomy
- Genetics
- Pigments
- Insects' view

- Introduction

Why can we find orchids of one and the same species with different colours? The answer depends on the genetic design of a given species.

1. Some orchids have a genetic blueprint which allows flowering in different colours. For example, *Dactylorhiza sambucina* mostly has yellow flowers, but there are also quite many plants with red flowers. Yellow-flowered plants produce yellow-flowered offsprings and vice versa. But cross-pollination has also produced intermediate colours ¹. This colour dimorphism seems to be a special characteristics of *Dactylorhiza sambucina*.

2. Colour variation is one of several possibilities how orchids vary. Species with a great morphological variety often also differ in flowering colours as well - e.g. *Anacamptis morio*.



3. Beyond this broad spectrum of variations some orchids also show individual genetic characteristics which result in white flowers. These forms are described as genetical disorders, as an absence of pigments which define the colour of a flower. The terms associated with this phenomenon are hypochromia (in contrast to hyperchromia which means excessive pigmentation, i.e. a very intense colouring) and albiflora. Alba or albiflora forms are devoid of any coloured pigmentation, and are pure white ². The formation of red flower pigments can be curbed or blocked with some individuals. In the case of species which have red flower pigments there can be flowers with with red in different hues or white flowers ³. An example is the white variation of *Anacamptis pyramidalis*.



4. Some people describe this individual genetic specialty as albinism: Thus, a plant whose flowers are devoid of any red pigmentation is termed an albino - these flowers can be green, yellow, or white, or a combination of all three. But in a strict botanical sense, an albino is a plant which lacks chlorophyll: Thus, albinism is a complete absence of green pigment that would normally be present. Since most of the orchids presented here have green foliage leaves, they are not albinos, but albiflora forms. Sometimes the white colour dominates just a part of the flower. In other cases the whole flower is pure white, even the pollinia.

Only a plant without any colour pigments, the foliage leaves included, should be named an albino as it has been described with *Epipactis helleborine* or with *Malaxis bayardii* in Massachusetts named as *Malaxis bayardii* forma *kelloggiae* ⁴.

There is one common characteristics of albiflora forms and albinism: Both phenomena are genetically recessive - an offspring might retain the white flowers but can also develop flowers in the normal colour. But with some species the white flowering forms are quite common and develop stable populations. With tropical orchids albino forms have got their own horticultural value and are being cultivated accordingly. This interest has promoted some early research with interesting results. It was, for example, possible to produce a coloured orchid by crossing two albino orchids.

Terms like „disorder“, „anomaly“ or „deficiency“ refer to a certain norm or standard and define the white flowering orchid just by the negative fact of not complying with this norm. This concept with its deprecative connotations shall not to be used here. Instead white flowering orchids of a coloured species are viewed as a specialty or a way where nature is exploring a new path of evolution. The result will be known only in a few million years.



nature as a lab: *Orchis simia* „albiflora“ (left) and *Orchis purpurea* x *simia* (right)

- Taxonomy

Alteration of the genetic design resulting in white flowering is not a sufficient condition to determine a new species. Even a classification as a subspecies seems not to be appropriate. As early as 1905, an orchid guide printed in the U.S. stated: Nearly every plant has albino freaks, and that alone would not be sufficient to split those two closely resembling orchids into two species⁵. Regarding taxonomy, i.e. the scientific classification of certain species, the colour of flowers is irrelevant. There are also historical reasons for this fact: The scientifically correct description of a species requires a herbarium record. But with pressed and dried plants the colour is no longer discernible.



Quelle:
Schweizerische Orchideenstiftung
am Herbarium Jany Renz

So the white-flowered plants of a given species with a different flower colour are characterised as a variety or a form indicated with the appendix „var.“ or „f.“, e.g. „var. albiflora“. The process of describing a variety or a form is the same as with a new species. Only the taxa described with all these requirements are scientifically valid. Among them there has to be a description in Latin. Here, as an example, the description of *Orchis quadripunctata* var. *albiflora*, registered by Chryssoula and Antoine Alibertis in *L'Orchidophile* 87/1989, p.112:

Planta 10 cm alta. Folia lanceolata maculata. Bracteae valde parvae, minutulae. Inflorescentia relative densa, flores 10-14. Sepala 6 mm. Petala 4 mm. Labellum 7 mm, trilobum, album. Lobi laterales multo majores quam lobus medius, qui incisuram gerit. Calcar multum tenne (11 mm), 4 maculas ad basim labelli gerens. Terra typica: Graecia, insula Creta. Antiskari 250 m. Holotypus: 23-02-86 in herb. Ch. et Ant. Alibertis N°51 bis.

Since in many cases there is no such official classification, the white forms often are described with quotation marks: *Anacamptis morio* „albiflora“.

Names used for white-flowered, albiflora or near-albiflora forms:







albiflorum/albiflora - white-flowered
album/alba - white
alboflavum/alboflava - whitish yellow
alboviride - whitish green
candidum/candida - pure white
flavescens - yellowish
virescens - greenish
pallidum/pallida - pale
immaculatum/immaculata - spotless

- Genetics

The first botanist who has crossed two species of plants was the British gardener Thomas Fairchild (1667-1729). He combined two species of carnations, putting the pollen of *Dianthus barbatus* on the pistil of *Dianthus caryophyllus*, to create a hybrid form of both. Fairchild was heavily criticised for manipulating God's creation, but the interest to get new kinds of flowers was greater.

A long time it was assumed that crossing of flowers with different colours is just like mixing paint on an artist's palette. Thus, a hybrid of a red and a white-flowered plant would have a pink colour. In 1866, the Augustinian monk Gregor Johann Mendel proved this theory false. Mendel (1822-1884) discovered the concept of recessive alleles, one of the insights which were later called the laws of Mendelian inheritance. A genetic allele (or DNA sequence) is recessive, when an individual of a certain species needs two copies of the relevant genes so that a certain genetic trait is expressed. If the individual has only one copy, by the male or the female side of inheritance, the trait is not expressed - in contrast to a dominant allele.

Mendel studied the flower colour of peas and found out that the dominant allele is purple and the recessive allele is white. Individuals with both alleles purple (PP) have a purple colour as well as individuals with one allele purple and one allele white (Pp). Only peas with both alleles white (pp) develop white flowers.

		 pollen ♂	
		B	b
 pistil ♀	B	 BB	 Bb
	b	 Bb	 bb

Following Mendel, Charles Chamberlain Hurst (1870-1947) was the first who studied albinism in orchids. He discovered that actually two genes are responsible for a certain flower colour: „Factor C enabled the formation of colour, while the other factor, R, determined what particular colour would appear“⁶. Each of these genes also exist in an inactive form, c and r. Coloured plants have inherited one or two of the active alleles: CC and RR, Cc and RR, Cc and Rr or CC and Rr. Albinos have either cc or rr. C and R are understood as dominant alleles which determine certain enzymes required by the production of pigments - among them the anthocyanins, which are especially important for flower colour.

Since then, much more detailed research into the genetic processes of determining flower colour has been done. „At least 35 genes are known to affect flower colour in petunia“⁷. Among them are regulatory genes, which influence the timing, distribution, and amount of anthocyanin pigmentation.

The gene, a certain region of the chromosome, contains the coding for creating the enzymes which are necessary for the biosynthesis of pigments, for their „biochemical pathway“. Thus, the genetic makeup, which is called the genotype, defines the phenotype of a flower, its visible characteristic.

Scientists are producing transgenic plants in order to introduce pigment relevant genes which are not available naturally. Thus, there are transgenic petunia plants with foreign genes which allow the production of pelargonidin, an anthocyanin with a deeply red colouring. There are two different ways for such a genetic engineering in order „to change flower colour: (1) introduction of genes encoding novel enzyme activities, and (2) inactivation of endogenous genes“⁸. This can be done by the method of RNA interference (RNAi), when special genes are inactivated so they can no longer produce their specific amino messengers.

In the case of our albiflora orchids, nature is going the second way: the biosynthesis of flower colour pigments is blocked. Since there are so many different genes, regulatory genes and enzymes participating in this complex process, there are also different possibilities how this process is blocked or reduced.

- Pigments: The biochemical components of flower colour

There are four classes of pigments providing not only different colours but also fulfilling essential functions:

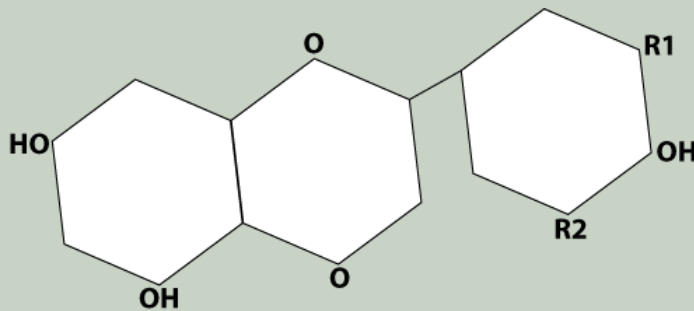
1) Chlorophyll: This green pigment is essential for the process of photosynthesis, which transforms light energy and carbon dioxide (CO₂) to glucose and oxygen (O₂). Chlorophyll makes good use of the blue and red portions of the the wavelength of light, but is not good in using the green portions: Red und blue light is being absorbed, green light is reflected. Therefore, the parts of the plant which contain chlorophyll, have green colour. Chemically, the pigment molecule consists of a magnesium core with 4 surrounding parts of nitrogen as well as 5 or 6 parts of oxygen, 28 to 72 parts of Hydrogen and 35 to 55 parts of carbon. They are not water, but lipid soluble and located in the chloroplasts of the cell. The name's roots are Greek: χλωρός (chloros is „green“) and φύλλον (phyllon is „leaf“).

2) Flavonoids: These water soluble pigments are based on the amino acid Phenylalanine, which is found in high levels in the breast milk of mammals. There are different groups of flavonoids.

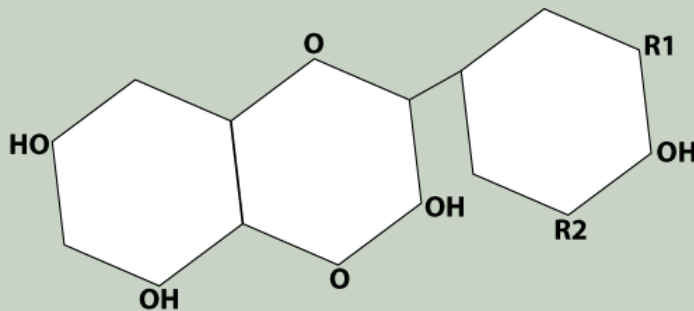
2 a) Anthocyanins: These pigments provide a broad range of colours from orange/red to violet/blue. The specific colour is determined by other pigments, metal ions and the pH value (they change from change from red in acids to blue in bases)⁹. Anthocyanins are most prominent in the petals of flowers - all the albiflora varieties of orchids are missing them. The colour provided by anthocyanins has several biological functions. One of them is to reflect light waves to the chlorophyll regions of the plants to increase the production of glucose. Furthermore, anthocyanins protect sensible parts of the plant from possibly destructive light effects by absorbing blue-green and UV light. Lust bont not least the colour of the flower is attracting pollinators. There are probably more than 550 different kinds of anthocyanins. Among them are the brick-red pelargonidin, the red cyanidin and the blue delphinidin pigments.

In a complex process of biosynthesis more than five enzymes are needed to produce the water soluble anthocyanins in the vacuoles of the cell. „Any even minor disruption in any of the mechanism of these enzymes by either genetic or environmental factors would halt anthocyanin production.“¹⁰ The name is derived from the Greek άνθος (anthos is „flower“) and κυανός (kyanos is „blue“).

2 b) Flavones and Flavonols. These flavonoids are called co-pigments, because they are colourless for the human eye, but can influence the colour of anthocyanins. The difference between both is that Flavonols have an additional hydroxyl in their molecular structure. „As they absorb UV, which insects recognize, they give colour and patterns to flowers to attract insects“¹¹. Flavones and Flavonols can be found in most white petals. There are no white pigments with plants, but white flowers reflect all visible light and are therefore white. „Noncoloured flavonoids provide ‚depth‘ to many white or cream flowers“¹².



Flavones: The molecular structure of the flavonoids is built by oxygen and hydroxyl. Depending on the R1 and R2 groups there are 3 major flavones: Apigenin (R1 and R2: H), Tricetin (R1 and R2: OH) and Luteolin (R1: OH, R2: H)



Flavonols: The molecular structure of the flavonoids is built by oxygen and hydroxyl. The Flavonols have an additional OH group. Depending on the R1 and R2 groups there are 3 major flavonols: Kaempferol (R1 and R2: H), Myricetin (R1 and R2: OH) and Quercetin (R1: OH, R2: H)

3) Carotenoids: Belonging to the group of terpenoids, these pigments cover colour wavelengths from yellow to red. Together with certain red or purple anthocyanins they enable brown or bronze hues¹³. Carotenoids can be found in all parts of a plant - but they are often hidden by chlorophyll. As the chlorophylls they are lipid soluble, their containers are called chromoplasts. Similar to the anthocyanins, the carotenoids support the photosynthesis and they serve as a protection screen against destructive light. There are more than 600 carotenoids, their chemical structure being rather complex. The degradation of certain carotenoids have an important role in producing the odours of flowers. The name comes from the Greek καρότον (karoton) and the Latin carota, both meaning carrot.

4) Betalains: There are two different groups, the betacyanins with pigment colours from red to violet and the betaxanthins which appear yellow to orange. These pigments are similar to the anthocyanins, as they are water soluble components of the vacuoles. But in contrast to them, they contain nitrogen. Betalains can only be found in a few plant families, orchids are not among them. Betalains and Anthocyanins are mutually excluded¹⁴. The name was derived from the beet (Beta vulgaris) with their deeply red coloured roots.

- How insects view colours

While the human eye has just one single lens, insects view their environment with a compound eye consisting of thousands of ommatidia. Each has its own set of photoreceptors to receive visual signals: Bees have six green receptor cells responsible for motion vision and small target detection as well as one or two UV and blue receptors ¹⁵. Other insects like the swallowtail *Papilio glaucus* have also red receptors - as butterflies generally have a better ability to recognize colours than bees ¹⁶. The resolution of the compound eye is about 100 times worse than that of the human eye. Bees are near-sighted: A flower needs a giant size of 26 cm in diameter to be recognized in a distance of 1 meter; for viewing a 1 cm diameter flower a bee has to shorten its distance to 11.5 cm ¹⁷. Much better than sight is the odor perception of insects with bees having at least 130 receptors in their antennae.



It would be a good evolutionary strategy to develop enormous flowers in order to attract pollinators. But „larger flowers are more energetically costly to produce“ and „flower size is constrained by a complex series of interactions between the genes and processes governing organ development“ ¹⁸. Flower shape is more variable, but not as variable as its colour which is regulated by genes, enzymes, metal ions and pH value. There have been experiments showing „that both bumblebees and hummingbirds exhibit strong discrimination on the basis of petal colour“. These results make it „likely, although not certain, that colour is the only significant factor in the choices made by pollinators“ ¹⁹. It seems that insects are learning the colours and shapes of flowers which have awarded them with nectar. Since many orchids don't produce nectar it may be vital for them to be mistaken for a plant rewarding its visitor with nectar.

But a successful pollination depends on „multiple factors which are beyond the control of the individual plant or species“ ²⁰. One decisive factor is the vicinity of other flowers. Since „white, UV-absorbing (typically bee bluegreen) flowers are the most common in practically all temperate European and Mediterranean habitats“ ²¹, it might be a good strategy to develop white flowers: „An orchid with a common color can be fairly sure to find itself in the vicinity of other flowers with similar color“ ²².

In addition to colour, the patterns of petals may as well influence the way how insects recognise flowers. The lines and blotches on petals and sepals generate a „flicker“ effect due to their changing light intensity while an insect is flying over a flower with a marked pattern, and in experiments „the bees preferred those (flowers) with the most flicker“ ²³. In some albiflora varieties of orchids the colour of the petal pattern is preserved, while the surrounding area has lost all its pigments. But pure white flowers may have their own patterns as well, created by UV absorbing flavonols in the flower cells: „Flowers that are visited by insects with eyes sensitive to ultraviolet light often have patterns or markings that the insects are sensitive to, but which humans cannot see“ ²⁴.

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