

Research on trichromacy in primates

[Environment](#), [Animals](#)



The ability to see in color is unique to humans and some other primates. It is called trichromacy because the retina of the eye uses three types of light-activated pigments to generate color vision. The majority of non-primate mammals however are dichromats, their vision is based on only two types of photopigments. Therefore, whilst frequent among primates, the property of color vision is not widespread among mammals (Jacobs & Nathan, 2009). Although there has been extensive research into this field, there is still no single accepted explanation for the appearance of trichromacy in primates (Jacobs, 1998). This essay will review what we currently know and do not know about the evolution of trichromacy, with specific focus on the two different genetic mechanisms which may have contributed to the trichromatic vision seen in Old World and New World primates. I will also consider suggestions for research that might improve our understanding of this area in the future.

There are a number of stages which characterize the appearance of trichromacy in primates. In short, for color vision to arise, there must be the presence of cone cells in the retina of the eye, each containing a type of photopigment made up of an opsin protein, which are specialized in their sensitivity to various light wavelengths. The cone cells become stimulated when light reaches our eyes, and the brain extracts color information by interpreting the responses of these cone cells. Therefore, the likelihood of achieving color vision is increased with the presence of a greater number of photopigments for the brain to interpret and compare. The discovery that in Old world and New world primates trichromacy arose from two different

genetic mechanisms has helped to improve our understanding of its evolution.

Humans and Old World primates are known as ‘routine’ trichromats. That is, for both male and female primates, trichromacy arises from three classes of cone photopigments in the retina, each containing different spectral sensitivities. These photopigments are known as short-wavelength sensitive (S), middle-wavelength sensitive (M), and long-wavelength sensitive (L). Researchers have used comparisons of these pigment genes with those of non-primate mammals to provide insight about their origin. For example, genes with sequences that closely resemble the human S pigment have been found to be widespread among vertebrates. It is therefore assumed that the S pigment was possessed by ancestral species and did not evolve recently.

Research using sequence comparison has found that on the X chromosome in all species of old world monkeys, the MWS and LWS genes are positioned very closely. This has led to the conclusion that these genes originated by gene duplication of the LWS pigment up to 40 million years ago. It is thought that following the duplication event, subsequent mutations led to two pigments with differing spectral sensitivities, an L photopigment and an M photopigment. For trichromacy to have been maintained and continued throughout generations of Old World primates, it must have provided considerable survival advantages which were subsequently favored by natural selection.

The evolution of trichromatic vision in New World primates however, is not as straightforward. Unlike the Old World primates, these species have just one photopigment LWS gene on the X chromosome, and that gene is polymorphic. This means that it includes different allelic copies of the X-linked pigment gene, which in turn translates to the appearance of pigments with differing spectral sensitivities. The result of this is that, because the alleles are X-linked, and only females have two X chromosomes, trichromacy is limited to a subgroup of new world female primates. The remaining new world males and homozygous females, are dichromats- they are red-green color blind. The group of New World primates who do have color vision are referred to as ' allelic' trichromats.

An exception to this however, has been discovered in the New World Howler monkeys. Both males and females of this species have been found to carry all three genes, leading to trichromacy in both sexes. Sequence analysis of these genes has been used to conclude that this duplication probably occurred after the old world and new world divergence, and therefore is a more recent duplication than that of the old world primates. This implies that the changes in color vision mechanisms which have led to the appearance of trichromacy in old world and new world primates were independent of one another.

Although what we do know about the appearance of trichromacy in primates has certainly increased, some aspects of its evolution remain unclear. For example, the assumption that the two mechanisms of trichromacy in New World and Old World primates evolved independently has not been widely

accepted. Researchers have pointed out that this explanation relies on the assumption that all genes are completely independent, and by consequence, does not take into account the potential role of gene conversion. Gene conversion is the process whereby in an individual with two different alleles of a gene, cell division may convert one allele to the other. This therefore raises the possibility that old world gene duplication originated from various pigment alleles which already existed in both groups of primates, yet over time this has been disguised as a result of gene conversion. This may have led researchers to the potentially false assumption that duplication came first. Support for the hypothesis that these genes arose before the duplication event comes from analysis of the M and L genes of the howler monkey have been found to be very similar to the opsin alleles from which the allelic trichromacy of other New World primates has originated. However, much of the evidence from studies on molecular genetics is not clear cut, and the same findings can be used to infer different conclusions. As a result, the question of which came first- duplication or divergence, remains unanswered.

Another ongoing debate surrounds the question of whether the changes in color vision mechanisms were initiated by, or dependent on something external in the environment of primates, such as the appearance of colored fruits. This has been proposed by Allen (1879), who suggested that the simultaneous evolution of colored fruits and color vision in some primates, would have provided survival benefits to both species; “ the animals in getting food, the plants in perpetuating themselves and spreading into new regions”. Allen (1879) has therefore hypothesized a coevolution between

colored fruits and trichromacy in primates. Exactly how a cone cell “decides” to express just one pigment gene is not entirely clear.

The nature of coevolution means that one trait cannot evolve without the other, they are mutually dependent. However, when applied to the appearance of trichromacy in primates, there are a number of problems with this suggestion. Although fruit is a major part of many primates’ diets, they are not restricted to fruits alone, and are known to eat a variety of other resources, such as insects and leaves. A similar scenario stands for the plants, as demonstrated in study by Gautier-Hion et al (1985) which found that excluding primates, up to 68 types of fruit were consumed by various different animal groups such as birds and elephants among others. There is however, evidence of certain plant species whose survival is entirely reliant on consumption by a single group of primates. Although it is worth noting that this applies only to very small minority. Consequently, whether trichromacy coevolved with colored fruits, or whether trichromacy simply led to frugivory in primates remains unclear. It seems most likely that trichromacy appeared as a result of genetic changes, and has since been shaped and spread by the variety of advantageous purposes it serves. These include, the identification of fruit, aid with different visual tasks and sexual displays, which are known to involve bright colors.

In conclusion, what we know about trichromacy is that it’s a unique characteristic of certain primates, and there appear to be two different genetic mechanisms operating among old world and new world primates which have led to its appearance. Whilst there are numerous aspects about

the evolution of trichromacy which we still do not know, I have focused exclusively on two issues which remain unconfirmed. Firstly, whether or not the mechanisms by which the old world and new world primates achieved trichromacy were entirely independent of each other. Secondly, if the appearance of colored fruits and foraging success could have acted as a causal factor in bringing about trichromacy. To address these questions, future studies will benefit from investigating the link between behavioral ecology and changes in genetic mechanisms, and further examining how the frequency of trichromacy specific genes among primates has been shaped by selection.