

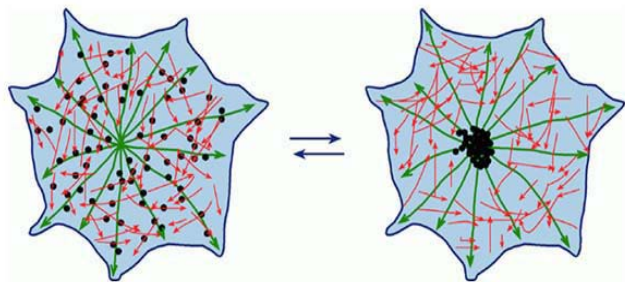




chromatophores. They are genetically controlled and specific to the species.

**Mechanism of color change**

The pigment granules are transported along microtubules at rates of about 1µsec either towards or away from the cell centre. When pigment granules are aggregated at the centre of the cell, major portion of the cell becomes unpigmented and appears lightly coloured, known as *blanching*. When pigment granules are dispersed throughout the cell, the cell is uniformly pigmented and appears darkly coloured, called colouration.



Dispersed melanosomes

Aggregated melanosomes

**Figure 3:** Movement of Melanosomes in melanocytes  
(Gelfand and S. Rogers, 1999)

**4. Colouration in ornamental fishes**

The fishes with colourful and diverse pigmentation patterns are called ornamental fishes and they are one of the most sought after pets of the world. However, colours and even its absence can have ornamental value e.g. Albino fish. Albino varieties of ornamental fishes have less melanin pigment or they lack melanin. Albinism in animals is considered as a pigmentation abnormality; however it is beneficial for ornamental fishes. The manipulation of colour in ornamental fishes has always attracted researchers. The methods used for the improvement in colouration are genetic engineering and nutritional supplementation of pigments.



(a) Gold fish (*Carassius auratus*) (b) Yellow platy (*Xiphophorus maculatus*) (c) Koi carp (*Cyprinus carpio*) (d) Kissing gourami (*Helostoma temminckii*) (e) Denison's barb (*Puntius denisonii*) (f) Albino butterfly discus (*Symphysodon aequifasciatus*)

(Courtesy: Aquarium, Central Institute of Fisheries Education, Mumbai-400061)

### Special functions of colouration in fish

1. **Camouflage**- a resembling color to the background/environment to escape from the predators
2. **Conspicuous colouration**- a different colouration from the background so as to attract the mate
3. **Obliterative shading**- also called counter shading, dorsal dark coloration and ventral light coloration, make the outline of the fish inconspicuous so as to escape from the aerial predators
4. **Disruptive coloration**- a disruptive pattern, which breaks the solid outline of the body to confuse the predators



**Figure 4:** Special coloration patterns in fish (a) Camouflage grouper (b) Conspicuous coloration of lion fish (c) Counter shading in shark (d) Disruptive coloration in Jackknife fish

## 5. Regulation of Coloration

The regulation and mechanisms of coloration and pigment translocation has been well studied in a number of different species, including amphibians and teleost fish. It has been established that the process is regulated by hormonal or neuronal means or both.

### 1) Neuronal Regulation

In bony fishes the pigmentation is under the control of sympathetic nervous system whose signals are communicated by chemicals released by neurons. Some chromatophores have 2 types of innervations, adrenergic and cholinergic. Norepinephrine signaling induces the aggregation of pigments, causing blanching, while acetyl choline induces dispersion of pigments, triggering coloration. It is synthesized from dopamine by dopamine  $\beta$ -hydroxylase in the secretory granules of the medullary chromaffin cells. It is released from the adrenal medulla into the blood as a hormone, and is also a neurotransmitter in the central nervous system and sympathetic nervous system, where it is released from noradrenergic neurons in the locus coeruleus. The actions of norepinephrine are carried out via the binding to adrenergic receptors. Norepinephrine signaling induces the aggregation of pigments, causing blanching, while acetyl choline induces dispersion of pigments, triggering coloration.

### 2) Endocrine Regulation

It mainly includes hormones called melanocortins, which are melanocyte stimulating hormone (MSH), melanocyte concentrating hormone (MCH) and adrenocorticotrophic hormone (ACTH). Estradiol and testosterone also affect coloration by way of controlling sexual dichromatism. Melatonin also plays an important role in endocrine regulation of pigmentation. Somatolactin is involved in proliferation and aggregation of chromatophores. The chromatophores respond to circulating hormones (e.g., epinephrine, melanophore stimulating hormone, melatonin) and neurotransmitters (e.g., norepinephrine-SNS) via identified cell-surface receptors. Norepinephrine and epinephrine produce pigment aggregation and paling of the skin (blanching reaction). Pigment cell signaling is mediated through cell surface alpha adrenergic receptors, which respond to catecholamines. Pigment dispersion is activated by an increase in cAMP levels while aggregation occurs when cAMP levels are reduced. In addition, fish integument contains some specialised regulatory factors called MSF (melanocyte stimulating factor) and MIF (melanocyte inhibitory factor).

#### a) Melanocortins

Melanocortins are hormones produced by the cleavage of POMC (Pro-opio melanocortin) include ACTH, MSH, lipotropin and endorphin. The most important one is MSH (melanocyte stimulating hormone). This peptide hormone from pars intermedia directly acts on melanocytes and stimulates an increase in the tyrosinase activity, melanin content and intracellular levels of cyclic AMP. Instead of cyclic AMP or its analogue, dibutyryl cyclic AMP also can produce same responses through MSH activation.

#### b) MCH

MCH (melanocyte concentrating hormone) is a cyclic neuropeptide synthesized as a prohormone in the hypothalamus of all vertebrates. MCH signalling system may also involve in regulating food intake in fishes. This is antagonistic to MSH, which act through cell surface receptors and causes blanching instead of colouration.

#### c) MSF and MIF

MSF and MIF are intrinsic pigment cell regulatory factors in the integument of fish, which are involved in the differentiation of chromoblasts. It is observed that the inhibitory activity being stronger in the ventral surface. The light-coloured ventral surface of the catfish and other poikilotherms may result from the presence of higher levels of MIF than MSF. On the other hand, the stimulatory activity is more on the dorsal surface of the body in comparison with the inhibitory activity.

### 3) UV Stimulated Color Change

The ultraviolet light has a positive influence on pigmentation. The UV light not only impacts the amount of pigments produced, but also the density of the pigments or how spread out in the cell they are, which also affects the coloration of the fish. This has been proved in several colored fishes including gold fish. When fish are kept outdoors, they will receive ultraviolet light from the sun. UVA and UVB are both high-energy light, and can be harmful to organisms. Pigments can provide some protection

from this. Thus ultraviolet light stimulates the chromatophores to produce more pigment. In contrast to the natural sunlight, artificial lights in aquariums usually only provide a limited spectrum of light and generally do not produce ultraviolet light. Thus, in course of time chromatophores exposed to artificial light will produce less pigment and the fish will look paler, while those exposed to sunlight appears in vibrant color. It is recently reported that some of the fishes e.g. Damsel fish use ultraviolet rays for colour generation. The presence and expression of genes encoding UV-sensitive opsins also suggests the importance of UV communication in a number of fish species.

## 6. Conclusion

There are very few studies aiming to unravel the mechanisms underlying the evolution and expression of pigment-based colour patterns in fish. The diversity of chromatophores in fish itself indicates the importance of pigmentation in its physiological functions and survival. Therefore, it is imperative to conduct more studies on the regulation and evolutionary emergence of pigmentation pattern in different fish species. This will also help us to emulate and modulate colouration in fishes, contributing to the improvement of ornamental value of fishes.

## References

- [1] Anna C. Price, Cameron J. Weadick, Janet Shim, and F. Helen Rodd., 2008. Pigments, Patterns, and Fish Behaviour. *Zebrafish*, 5(4): 297-307.
- [2] Bagnara, J. T., kreutzfeld, K. L., fernandez, P. J. And cohen, A. C., 1988. Presence of Pteridine Pigments in Isolated Iridophores. *Pigment cell research*, 1: 361–365.
- [3] Borchers, A., David, R., and Wedlich, D., 2001. Xenopus cadherin-11 restrains cranial neural crest migration and influences neural crest specification. *Development*, 128: 3049–3060.
- [4] Budi, E. H., Patterson, L. B., and Parichy, D. M., 2008. Embryonic requirements for ErbB signaling in neural crest development and adult pigment pattern formation. *Development*, 135: 2603–2614.
- [5] Eickholt, B. J., Mackenzie, S. L., Graham, A., Walsh, F. S., and Doherty, P., 1999. Evidence for *collapsin-1* functioning in the control of neural crest migration in both trunk and hindbrain regions. *Development*, 126: 2181–2189.
- [6] Greenwood, A. K., et al., 2011. The genetic basis of divergent pigment patterns in juvenile three spine sticklebacks. *Heredity*, 107: 155–166.
- [7] Kelsh, R. N., and Parichy D. M., 2007. "Pigmentation" In: Fish Larval Physiology (Finn RN, Kapoor BG, Eds.). Science Publishers Inc.
- [8] Kelsh RN and Barsh GS., 2011. A Nervous Origin for Fish Stripes. *PLoS Genet* 7(5): e1002081. Lopes, S. S. et al., 2008. Leukocyte tyrosine kinase functions in pigment cell development. *PLoS Genet.*, 4: e1000026.
- [9] Parichy, D. M., Mellgren, E. M., Rawls, J. F., Lopes, S. S., Kelsh, R. N., and Johnson, S. L. 2000. Mutational analysis of *endothelin receptor b1* (*rose*) during neural crest and pigment pattern development in the zebrafish *Danio rerio*. *Dev. Biol.*, 227: 294–306.

- [10] Wucherer, M. F., and Michiels, N. K. 2012. A fluorescent chromatophore changes the level of fluorescence in a reef fish. *PLoS ONE*, 7(6): e37913.