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PIGMENTATION IN ANIMALS: A STRATEGY TO LIFE

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ABSTRACT Colour in animals is mainly due to the presence of Pigmentation in their skin, fur, feathers, scales, or other body parts. This coloration can play an important role to provide various purposes, such as camouflage, communication, protection from harmful UV radiation, regulation of body temperature, and even social signaling. Animals achieve pigmentation through different mechanisms like pigment cells, structural colours, biochromes, and selective absorption. Some animals have pigments that selectively absorb certain wavelengths of light while reflecting others. This absorption and reflection result in specific colors. Pigmentation often plays a crucial role in animal survival and reproduction. It helps animals to blend into their environment to avoid predators or prey, attract mates through displays of vibrant colors, or signal dominance or submission within a social hierarchy.

KEYWORDS : Pigmentation, Biochromes, Melanin

INTRODUCTION

Organisms, such as animals, plants and bacteria, use colours to communicate with others. For this, they use pigments and special structures that reflect, refract, scatter or absorb light (Morehouse and Outomuro, 2019). Coloration in animals is an important factor, which vary among species or populations and it plays significant role in intra- and interspecific communication, thermoregulation, predator avoidance and other ecological interactions with direct impact on individual fitness (Rodríguez *et. al.,* 2020).

In animal kingdom, cephalopods, crustaceans, fishes, amphibians, and reptiles have well developed pigmentory effector systems (Blaney, 1952). They use a bright coloration, to show their quality and to attract potential mates (Mc Graw, 2005). The colour pigments are produced by pigment cells (chromatophores). These pigment cells can be divided into four types (I) Melanophores: contain melanin granules or melanosomes (ii) Iridophores: contain guanine-rich reflecting platelets (iii) Xanthophores: contains carotenoid vesicles and pteridine-rich pterinosomes (iv) Erythrophores: which also contain carotenoid vesicles and pterinosomes. These all pigment cells are present in cold-blooded vertebrates and only melanophore is found in mammals and other homoiotherms animals (Thody and Shuster, 1989). Thody and Shuster (1989) suggested that on the basis of appearance and location in the skin melanophores can be further divided into two types i.e., dermal and epidermal melanophores. Dermal melanophores are large basket-shaped cells and are responsible for the rapid, chromo motor colour changes. Epidermal melanophores are located at the dermo-epidermal junction. They are not involved in rapid chromomotor colour changes and because of their limited ability to mobilize their pigment, they are also known as melanocytes. The melanocytes are responsible for hair pigmentation and are active only when the hairs are in growing condition (anagen). Skin pigmentation (melanin) is an important photoprotective factor, broadband UV absorbent, and has antioxidant and radical scavenging properties (Brenner and Hearing, 2007).

Classification of Pigments

The biological pigmented compound can be classified by two ways: (i) based on structural affinities and (ii) natural occurrence. A natural pigment can be synthesized and accumulated in, or excreted from living cells. Some pigment such as oxidized phenols and anti-coagulatn coumarins may be formed by dying cell. Price *et.al.,* (2008) suggested that pigments are basically compounds that absorb particular wavelengths of light and can contribute to the color of biological patches. They also explained that pigment-based color patterns can change through direct regulation of pigment-containing cells, or indirectly through adjustment of the light interacting with the pigment through regulation of iridophores.

Pigmentation in Microorganisms

Maoka (2020) reported that in photosynthetic bacteria, some species of archaea and in animals carotenoids is found as tetraterpene pigments. In animals caraotenoids are either directly accumulated from food or partly modified through metabolic reactions and it play important roles such precursors of vitamin A, photo-protectors, antioxidants, enhancers of immunity, and contributors to reproduction. Carotenoids are composed of eight isoprene units with a 40-carbon skeleton (C40 carotenoid). It consist a polyene chain with nine conjugated double bonds and an end group at both ends of the polyene chain. Carotenoids can be divided into two groups, (i) carotenes and (ii) xanthophylls. There are 50 different type of carotenes present in nature. Some of them are hydrocarbons. For example α-carotene, β-carotene, β,ψ-carotene (γ-carotene), and lycopene (Britton *et. al., 2004*). Xanthophylls, are carotenoids which contain oxygen atoms as hydroxy, carbonyl, aldehyde, carboxylic, epoxide, and furanoxide groups in these molecules such as β-cryptoxanthin, lutein, zeaxanthin, astaxanthin, fucoxanthin, and peridinin (Maoka, 2020).

Microorganisms (fungi and bacteria) are alternate source of naturally derived pigments (Arulselvi *et. al.,* 2014). Bacterial and fungal pigments have wide range of applications such as antibiotic, antioxidant, antifungal agent, dyeing of wool fabrics, anti-inflammatory and anti-allergic properties with large economic potential (Kim *et. al.,* 2007; Nagia and El-Mohamedy, 2007; Correa Llanten *et. al.,* 2012; Miao *et. al.,* 2012; Venil *et. al.,* 2020) and have an enormous advantage over plant pigments, including easy and rapid growth in low cost medium, easy processing, and growth that is independent of weather conditions (Manikprabhu and Lingappa, 2013).

In 1952, Blaney explained the role of melanin in animal pigmentation. He suggested that melanin can be formed from the amino acid tyrosine Generally melanins in animals can be divided into two categories, such as light-colored, red/yellow, alkali-soluble sulfur-containing pheomelanin (pheo means dusky/cloudy, it is predominant in red hair/freckles phenotype), and second one is dark colored, black/brown, insoluble pigment eumelanin (eu means good) and it is commonly found in dark skin, and black hair (Ali and Naaz, 2015). In insects, a large verity of beautiful colour pattern can be observed, it is due to pigmentation and these pigments are produced by epidermis during developmental stage (Bankar *et. al.,* 2018). This pigmentation is helpful for many biological activities, such as camouflage, mimicry, aposematism or warning, selection for sex, and communication by signaling, metamorphosis, growth, and developmental stages (Alcock, 1998) body protection, signalling, and physiological adaptations (Badejo *et. al.,* 2020). Melanins (eumelanin and pheomelanin) are also used for several other functions including cuticle sclerotization and color patterning, clot formation, organogenesis, and innate immunity (Whitten and Coates, 2017). Colours also convey many other information which are valuable for species identification, distinguishing individual quality, and revealing ecological or evolutionary aspects of animals life (Badejo, 2020). Naturally occurring pigments in insects can be used for welfare of mankind. The most common use of these pigments is in edible colors and they are rich source of proteins in food industry (Bankar *et. al.,* 2018).

Pigmentation in Insects

According to Shamim *et. al.* (2014) the colour in insects is mainly due to the presence of various pigment molecules in the cuticle or underlying epidermis or due to the presence of physical structures, but in some, the fat body and haemolymph also provide colour if the cuticle is transparent. Insect can synthesise pigments such as anthraquinines, pterins, tetrapyrroles, ommochromes, and papiliochromes, or they absorbed them from the antioxidative carotenoids and flavonoids of their host plants (Gulsaz *et. al.,* 2014). Beside body coloration, ommochromes act as visual pigments, melanins protect against ultraviolet radiation, and tetrapyrroles facilitate oxygen transport to cells (Bankar *et. al.,* 2018). According to Heath *et. al.*, (2013) carotenoids are involved in functional activities of almost all green-colored insects. The larvae of *Manduca sexta* appear blue and green after fed on artificial and natural diets (green plants), respectively. The green pigment is made up by of two chemicals, namely, biliverdin, and lutein (Meldola, 1982). According to Moraes and coworkers (2005) black- and red-type eye forms of are made up of ommochromes of the xanthommatin type. They observed that the variation in color of the insect eye was due to activity of the xanthommatin concentration (Moraes *et. al.,* 2005, Muri and Jones 2014). Beard *et. al.* (2002) reported that in wild-type mosquito, *Anopheles gambiae*, has ommatin precursor (3-hydroxykynurenine) and a dark red-brown pigment spot composed of two or more low-mobility xanthommatins in eyes.

Flavonoids (plant secondary metabolites) create orange colours in insects (Lindstedt *et. al.,* 2010). Bile pigments or bilins are responsible for greenish and bluish tints, violet, and golden colours due to structural interference (Chapman *et. al.,* 2013). Some insect have specific pigments, like aphins, producing a variety of tints in aphids (Shamim *et. al.,* 2014) and papilochromes, resulting in yellow, orange, and red colours in butterflies (Stavenga *et. al.,* 2014). According to Fuzeau-Braesch (1972) melanins and pterins are two common classes of insects' pigments. Andersen (2010) suggested that Sclerotisation (hardening) and melanisation (darkening) of insect cuticle can act in conjunction, and the appearance of a colour often is the result of both processes. Polidori *et. al.,* (2017) suggested that the colorations in the bumblebee hairs largely depend on the occurrence of eumelanin and/or pheomelanin, or on the lack of both pigments and melanin is primarily responsible for black and orange/red/brown coloration.

In insects black and brown coloration and the hardness of the cuticle is due to melanin (Arakane *et. al.,* 2016). The insect in order Odonata (dragonflies and damselflies) comprises diverse colors in adult wings and bodies (Okude and Futahashi, 2021). In Odonata, melanins are responsible for the dark wings and epidermis (Hooper *et. al.,* 1999; Stavenga *et. al.,* 2012; Okude *et. al.,* 2017), and also conntribute to the production of structural colors (Stavenga *et. al.,* 2012; Nixon *et. al.,* 2017). Arakane *et. al.,* (2016) suggested that NBAD (N-β-alanyldopamine)-melanin and NADA (N-acetyldopamine)-melanin are involved in red and yellow pigmentation, and in the genus Mnais the orange wing coloration is also due to melanin pigments (Hooper *et. al.,* 1999).

Pigmentation in Amphibians, Reptiles and Fish

In amphibians, reptiles and fish, three main types of chromatophore cell are responsible for integumentary coloration and they are melanophores, xanthophores and iridophores (Bagnara, 1966). Melanophores produce brown/black melanin pigment, xanthophores synthesize yellow to red pteridine and/or carotenoid pigments, and iridophores produce reflective guanine crystals. The arrangement of these cells is in a three layered sandwich type, with xanthophores overlying iridophores, and melanophores in the basal position, forming a "dermal chromatophore unit" (Bagnara *et. al.,* 1968) . In aquarium, fish pigmentation is one of the major qualities and this is due to caratinoid (Das and Biswas, 2016). The colouration in skin of the fish is mainly dependent on chromatophores (melanophores, xanthophores, erythrophores, iridophores, leucophores, and cyanophores) that contain pigments such as melanins, carotenoids (e.g. astaxanthin, canthaxanthin, lutein, zeaxanthin), pteridines, and purines (Das and Biswas, 2016). According to Goodwin (1951) and Withers (1992) fish do not have the ability to synthesize carotenoids. Hata and Hata (1973) show that carotenoid pigmentation of fish results from the pigment present in the diet.

The ink in the cuttlefish is composed by sepiamelanin, a type of melanin. Beside cuttlefish, the ink of octopus, squid, and other cephalopods, also contain meleanin, and forming a granulematerial dispersed in colorless plasma. This melanin is mostly eumelanin, formed by heteropolymer of indole and carboxylated pyrrolic units with associated protein (Pezzella *et. al., 1997*; Nicolaus, 1968).

In animals melanin is considered as a cutaneous pigment. The name "melanin" comes from the ancient Greek language "melanos" which means "dark". According to Solano (2014), the widely used definition of Melanin is "heterogeneous polymer derived by the oxidation of phenols and subsequent polymerization of intermediate phenols and their resulting quinones."

All melanins are formed by two phases. The first phase includes enzymatically-controlled phase, generally a phenolase, and second phase is consist of uncontrolled polymerization of the oxidized intermediates. In second phase, quinones derived from phenol oxidation play a crucial role. All melanins show a protective role, but they are not merely photoprotective pigments against UV sunlight (Solano, 2014).

Pigmentation in Birds

In birds, there are two types of melanin present i.e., black and reddish yellow, and a combination and adjustment of these two types create a variety of coloration and pigment patterns in the body surface (Kaelin *et. al.., 2012*; Mallarino *et. al.., 2016*). In eggshells of chicken and other aves such as Purple heron, Little egret, Buzzard, and Knysna lourie the main pigment is biliverdin (Kennedy and Vevers 1976: Zhao *et. al.,* 2006). Two types of melanin pigments, and a variety of carotenoids, which are present in bird feathers (McGraw *et. al.,* 2004). Feather melanin is generally bound to the keratins forming the protein matrix of the hair and feather, respectively. Feather melanins are a mixture of eu- and pheomelanin, (Brumbaugh, 1968). In Japanese quail, glossy pale blue shell is observed which is due to the presence of *ce* (*celadon*) which resembled the eggshell of the Araucano hen both in the external appearance and pigment content (Ito *et. al.,* 1993).

Pigmentation in Mammals

In Buffalo and calves the dark skin colour is observed. Lerner and Fitzpatrick (1950) suggested that ultra-violet radiation appears to be related with melanin formation and helps to increase pigmentation. According to them increase in cutaneous temperature and oxidation of melanin due to exposure of the skin to solar radiation results in the high intensity of dark colour. Xu and Luo (2014) stated that the white tiger is a rare color morph of the Bengal tiger (*Panthera tigris tigris*). According to them White tigers lack pheomelanin, with minor (or no) change in eumelanin, and have white fur interspersed with sepia-brown stripes. They also suggested that coloration in white tiger is a stable genetic recessive trait.

Skin pigmentation is an important phenotypes among human populations, it was observed that darker skin population are mainly present closer to the equator and lighter pigmentation population observed at high latitudes (Sturm and Duffy, 2012). This variation is due to variable exposure to ultraviolet radiation (UVR) creates opposing selective forces for vitamin D production and folate protection (Chaplin and Jablonski, 2009; Jablonski and Chaplin, 2010). In humans, approximately 15 genes are associated with skin pigmentation variation. (Martin *et. al.,* 2017). In mammals, melanin can be present in some other tissues also, like eye, inner ear, and brain, as in the adipose tissue (Randhawa *et. al., l*2009).

CONCLUSION

Skin pigmentation melanin is not only photoprotective factor, but also functioning as a UV absorbent, has antioxidant and radical scavenging properties (Brenner and Hearing, 2008). In animal kingdom, animals use this coloration for protection from predators and harmful solar radiation. Pigmentation is form of defense mechanism apart from being medium of beauty. Pigmentation also help them to choose mate, provide camouflage/crypsis, defense/warning signaling, thermoregulation, communication, and immunity. Pigmentation is a gift by nature to animal kingdom and a complex biological trait that has evolved over time to serve specific purposes in different species.

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