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The Prediction of Evolutionary Trend for Coloration of Mammals under the Influence of Climate Change

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Abstract. Like humans getting tanned after sunbath, mammals around the world may also change their coloration according to the dynamic environment. Such changes primarily aim for better camouflage, but it also comes with some linked physiological changes for mammals to potentially have better fitness. The article predicts the overall evolutionary trend of mammal coloration using case studies across different species in distinct geographical locations. The article focuses on the explanation of animal coloration mechanism and the comparison between the potential fitness of the same species of mammals with different colorations. As demonstrated by most case studies, the evolutionary trend of mammal coloration is to become darker. Such an evolutionary trend is promoted in which darker coloration brings better fitness for the mammal for the purpose of better camouflage and more adapted physiology to the environment under the influence of climate change.

Keywords: melanin, climate change, mammal physiology

1. Introduction

The influence of human activity on global climate has been exponentially increasing in recent years. Although some people are trying to undo or reduce the damage, it is undeniable that the climate on Earth has changed. Such change can be reflected in the rising sea level due to the melting of icecap, an increase in global temperature, and more frequent droughts or floods [1]. Climate change pushes terrestrial mammals to evolve in various ways such as size, behaviors, and population distribution. Among those, the change in coloration is one of the most obvious traits for us to observe. However, the change in coloration is not merely a change in pigment expression but also indicates changes in other related traits for example the physiology of the animal.

There are established studies on both ectotherm and endotherm vertebrates for their adaptation to the dynamic environment under the influence of climate change. However, in most cases, the study is about the specific change one species experienced. While the change in coloration, never mentions the physiology and ecological meanings behind the change, is rarely discussed in depth. For those that cover the changes of coloration, they are mostly based on Gloger’s theory or thermal melanism theory alone depending on whether the case animal is endotherm or ectotherm. In this article, many cases of endotherm mammals are compared among one of them, Gloger’s rules do not describe the general trend as fit as thermal melanism theory. Therefore, the general trend of evolution for coloration of mammals can be concluded, and can also be partially further justified through the comparison with cases where the contradictory theory applies.

Although the change in coloration of mammals may seem irrelevant to society. It can serve as an indication of the changes human activities have caused to the global climate and environment. The change in coloration also indicates the change in the physiology of the animal itself. This can lead to more unpredictable animal behaviors which can influence the life of humans through direct interactions such as animal attacks or indirect interactions such as invading farmlands. Studying those changes can help with policymaking toward both the animal themselves and the environment and the community they live with.

2. Coloration of animals

The coloration of the animals is mostly evolved purposely for functions instead of beauty as humans intuitively recognize. The purpose of the coloration includes heat regulation, camouflage, and an indication of some physiological state. Heat regulation is relatively self-explanatory which darker the coloration the broader spectrum of light is absorbed, therefore more heat can be received by the animal and it can spend less time and effort to gain essential body temperature. The camouflage can be classified into different categories, such as crypsis, masquerade, and motion dazzle. Although the coloration of animals affects all kinds of camouflage, crypsis is the most affected type which by definition is the range of strategies animals use to prevent detection by other animals [2]. The potential change in coloration has a profound effect on the effect of crypsis. For example, a change in coloration can influence the effectiveness of background matching and even the fitness of the animal. As seen in the example of the pepper moth, the morph with lighter coloration has a dramatic reduction in population density as they are easily predated due to the defect in their background matching. This, as a result, lead to an evolutionary trend for darker-colored moth [3]. Furthermore, the surface coloration displayed by mammals is controlled via the secretion of the pigment melanin which may also link to the secretion of other chemicals. To discuss this, it is essential to understand the mechanism of melanin secretion.

3. Melanin based coloration of mammals

The expression of the pigment melanin has a major role in determining the dark color of an animal's skin and hair. The secretion of such pigment is controlled by messenger melanocortin peptides such as a-, b-, c-melanin stimulating hormone (MSH) produced by proopiomelanocortin gene (POMC) as shown in figure 1. There are 5 highly conservative types of POMC, and each of them is responsible for different functions. Signaling peptides such as a-, b-MSH, and Adrenocorticotropic hormone (ACTH) can stimulate the melanocortin receptor 1 (MC1R) which links to agouti-signaling protein (ASIP) in skin cells and as a result produce black pigment. [4] As a direct result, the coloration of the skin or hair of animals can appear to be darker. However, those signaling molecules can also target other receptors such as MC3R which not only links to ASIP in the skin but also agouti-related protein (AGRP) located in the brain. When AGRP binds to its agonist melanocortin peptides, it can reduce food intake while increasing cardiovascular and anti-inflammatory responses [5]. The MSHs produced by POMC have other functions such as increased libido, aggressiveness, and HPA stress response. An example of those derived changes induced by darker coloration is the increase in sexual motivation in animals with a darker color, and as suggested in the study “a more sexually aggressive personality” [6].

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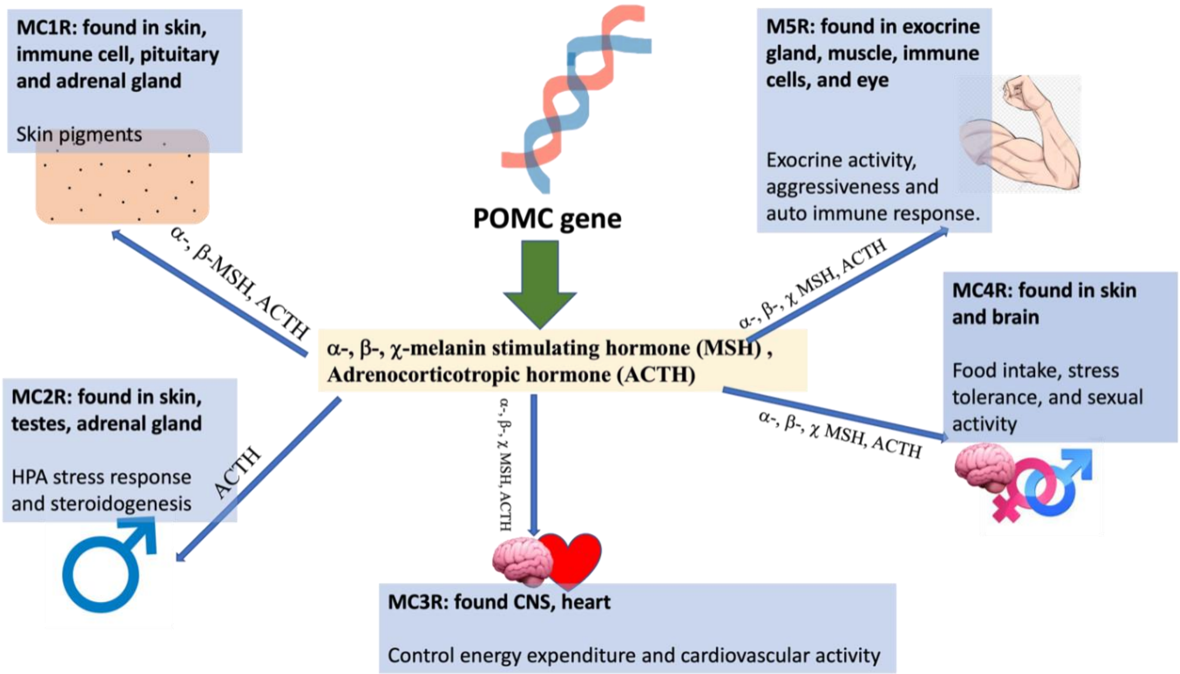

Figure 1. Functions of POMC gene on animal physiology.

4.Thermal melanism theory

It is rather common knowledge that darker coloration absorbs more heat which can be demonstrated by comparing the temperature inside the same type of car with different colored paint. A similar theory applies to animals as well. As suggested by [7], animals with darker coloration tend to have advantages in cooler climates since they can raise their body temperature faster, while animals tend to have lighter coloration in warmer climates to reduce the chance of overheating. This theory is known as Thermal melanism theory. This theory was originally designed for an ectotherm. [8] Although the established research and evidence on thermal melanism theory for mammals are lacking, the heating mechanism for different coloration potentially applies as well. As suggested by studies by American Naturalists, birds as a type of endotherm in some areas that are becoming warmer and drier tend to have lighter coloration compared to birds in the same family Furnariidae [9]. A similar result is reflected by the study on bird feathers by the Journal of Royal Society [8].

Springbok (Antidorcas marsupialis), as a mammal, is an example of which thermal melanism theory applies. The study has shown that the distribution of the paler morph and black morph is influenced by the temperature of the habitat. Further up the latitude, the lower the temperature and higher the proportion of black morph. This is because the black morph utilizes solar radiation to raise body temperature better than the paler morph. This reduces the metabolic requirement for the black morph which can spend less energy and time foraging for food compared to the paler morph. As the temperature increases gradually due to global warming, the paler morph has become more and more dominant since higher temperature means the requirement for solar radiation to raise body temperature is no longer necessary. Furthermore, black morph may even suffer from overheating due to the absorption of solar radiation in warm weather [10].

5. Gloger's rule

In contrast to thermal melanism theory, scientists such as Constantin W.L. Gloger came up with a theory through the study of sparrows which suggests that as the climate gets warmer, the coloration of animals tends to get darker. This theory is mainly based on the crypsis purpose of the dark coloration due to the darker background environment in a warmer climate.

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Many habitats around the globe are pushing the animals to evolve their coloration following Gloger's rule. Evidence shows that the vegetation in tropical areas such as jungles in Australia has increased due to an increase in precipitation as well as temperature [11]. As mentioned before, one of the purposes of the change in coloration of animals is to conduct camouflage such as background matching. By doing this they can avoid predation or be spotted by prey which both increases their rate of survival and potentially their fitness. Such an example can be seen in the American gray wolf (Canis lupus) near Yellowstone national park where the number of wolves with gray or black coats has taken a larger proportion of the population in recent years in most habitats except taiga. From a genetic point of view, such change can also be indicated by the increase in the frequency Kb gene carriers in recent decades. The Kb gene is suggested to have a strong linkage with the darker coat color where all black Canis lupus and all forest gray wolves carry the gene (a subspecies of C.lupus). More than 80% of all gray wolves observed near the Yellowstone national park carry the gene as well. Such change might be a result of climate change since the tundra biome where the wolf with a white coat shows better fitness due to better camouflage is decreasing in size around the world due to global warming in recent decades [12].

Another canine, arctic fox, has experienced similar changes in its habitat recently. The recent rise in temperature and shorter winter has led to a decrease in the area and duration of the snowy environment. Arctic fox (Vulpes lagopus) has multiple phenotypes in their coat color and although almost all foxes are able to shed coat in summer and winter, some of them cannot dramatically change their coat color from darker summer color to snow white winter color. For those that remained darker gray/blue colors, they are predominately found in more heavily vegetated areas [13]. This has led to a potential speciation effect with the different colored foxes. The darker coat color is caused by a dominant mutation in MC1R in which the glycine residue is substituted by cysteine. With this mutation, the blue arctic fox cannot change their coat color to snow white in winter but instead only gray. Without an effective background matching camouflage, the blue arctic fox has to compete with other predators active in forestry areas since they are easily spotted in the snowy areas in the winter. As mentioned before, blue color is dominant to white coloration. As the snowy area shrinks and increase the rate of mating between the two morphs. The darker-colored blue morph can become the dominant type of fox due to climate change. This change can also be seen on the arctic hare due to a similar reason but instead of dominant [14].

6. Physiological explanation of darker coloration evolutionary trend

Melanin is the pigment responsible for the darker coloration in mammalian coats or skin. The secretion of it is linked with the secretion of other hormones as mentioned before. With a rise in the frequency of extreme weather events including intense heat waves, floods, and abrupt temperature shifts, the ecosystem has grown increasingly unstable. For example, for African lions (Panthera leo) whose habitat is experiencing more frequent extreme weather events such as drought which has occurred more and more frequently in recent decades [15]. For mammals, there is a tendency to increase the rate and urges of reproduction under stressful environments [16]. The mane of male lions has a profound influence on sexual selection. Darker the mane, indicates the lion has higher food intake, older age, and higher testosterone level. This is explained previously as the production of pigment melanin is linked with the production of other MCR-related hormones which includes testosterone. To put this into a more practical way of explanation is that those lions with darker mane are more likely to survive and succussed defending the pride after conflicts with other male lions. Thus, more likely to have access to female lions and more likely to mate. With a more stressful environment, lions with such adaptation can be more advantaged over male lions with a more yellowish mane. Due to the potential more frequent reproduction of lions with darker manes, this can lead to an evolutionary trend toward lions with darker manes [17].

Not only the mammal themselves are under stress in climate change, the environment they rely on can also suffer from it, which also influences the food available to them. This may allow mammals with better usage of energy, less food intake, and more aggressiveness to be advantageous over the others since this can potentially increase the chances for them to obtain food and territory. Studies on the fancy mouse have shown that black mice are more aggressive and secrete more adrenaline than agouti mice.

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Meanwhile, the black mice also have a relatively smaller food intake. [18] Those traits mentioned are linked with the expression of proopiomelanocortin gene (POMC) can be beneficial for animals. MC3R is also influenced by the MSH which may be primarily secreted to darken the coat or skin color. When MC3R is stimulated, chemicals such as d-trp is secreted and it influences the sensitivity towards insulin. This can reduce food intake but increase the utilization of energy. This is because individuals injected with MC3R agonists show an increase in appetite but are less vulnerable to obesity due to higher metabolic rates [19].

7. Reflection and potential controversy

As suggested in many cases, it is an evolutionary trend for mammals to become darker in color. However, this conclusion has a major controversy. As mentioned in the explanation of thermal melanism theory, the darker the color, the more heat the animal absorbs from solar radiation. In many cases mentioned, the animals develop a darker coloration to better match the darkening background environment due to heavier vegetation. One of the major contributors to denser vegetation is rising temperature. Darker coloration can potentially cause the animal to be overheated. If not overheated, mammals may need to maintain their body temperature in a regular range with the cost of extra water loss since evaporation is one of the major ways of lowering the temperature for many mammals such as humans (Homo Sapiens). Without considering the original assumption of Gloger's rule for denser vegetation that comes with warmer vegetation, the situation can be worse. Drought and high temperature heatwaves as extreme weather events happened more and more regularly in recent years [1] In many environments, the solar radiation has become stronger which increases the chances for mammals with darker coloration to be overheated as demonstrated in the example of springbok. The water expenditure can be higher in a such warm environment, and with more and more regular drought, it is not only overheating that is problematic but also dehydration.

Although overheating due to darker coloration can be an issue. Darker coloration can also transform the more harmful UV radiation into heat which prevents the damage of UV radiation to DNA and prevents cancer as shown in the example of sheep in Brazil [20]. For those cases that strictly follow Gloger's rule which can be found living in humid, heavily vegetated environments. Their darker coloration may not absorb more heat since the light penetrating through the canopy is already reduced. Since heavy vegetation requires a large amount of water to support, in this case, dehydration may not be a problem as well.

8. Conclusion

Animals have better fitness with darker coloration in many cases, and mammal is included in those cases. With some controversy, there is an overall evolutionary trend for mammals to evolve darker coloration. Mammals that are both herbivores and carnivores show an overall evolutionary trend towards darker coloration. Crypsis is the major driving force for the evolution of the body color of animals. As mentioned before, in many areas around the globe, darker coloration better matches the background with heavier vegetation. However, from a physiological point of view, developing darker coloration may also be beneficial since the traits derived from melanin secretion are very advantageous in the environment influenced by climate change. Climate change caused the environment to be more stressful for almost all mammals around the globe. Examples of such influences are unstable habitats, insufficient food, habitat loss, and extreme weather. Traits linked with melanin secretion such as an increase in the secretion of sex-driving hormones and adrenaline, as well as better sensitivity towards insulin potentially have better fitness in such an environment.

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