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Study on the Effect of Temperature on Epigenetic Marks in Mice

Zhenni Lu
Hangzhou Luohuashi Biotechnology Co., Ltd, Hangzhou, 310000, China
Corresponding author email: 1348509309@qq.com

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Abstract This study reviews studies on the effects of temperature on epigenetic marks in mice. As an important experimental model, mice achieve adaptive changes in physiological functions by regulating epigenetic marks when adapting to changes in environmental temperature. This study first introduces the physiological characteristics and temperature adaptation mechanism of mice, and then provides a systematic overview of the basic knowledge of epigenetics, including DNA methylation, histone modifications, and non-coding RNA. This study also explored in detail the effect of temperature on epigenetic marks in mice, including its regulatory effects on DNA methylation, histone modifications and non-coding RNAs. The association mechanism between epigenetic marks and temperature adaptation in mice was further analyzed, and its clinical significance and application prospects in related diseases were explored. This study provides an outlook on future research directions and application prospects, and emphasizes the importance of in-depth study of the relationship between temperature adaptive regulation and epigenetic marks in mice to understand the adaptation mechanism of organisms to environmental changes and the pathogenesis of diseases.

Keywords Mice; Temperature adaptation; Epigenetic marks; DNA methylation; Histone modification; Non-coding RNA

In the field of biology, epigenetics, as an emerging research field, has gradually received widespread attention (Wang et al., 2024). The research objects of epigenetics include DNA methylation, histone modification, non-coding RNA and a series of genetic information transmission methods that do not involve changes in DNA sequence. These epigenetic marks play important roles in regulating gene expression, cell differentiation, development, and disease development. Environmental factors play a crucial role in the growth and development of organisms, and temperature is one of the most basic factors that directly affects the physiological functions of organisms. Temperature changes can cause a series of physiological responses in organisms, including metabolic regulation, gene expression changes, and cell signaling (Somero, 2020). Past research has shown that temperature also has a clear impact on an organism's epigenetic marks. For example, temperature can affect DNA methylation levels, change histone modification patterns, and regulate the expression levels of non-coding RNAs, thereby affecting gene expression and cellular function.

As a commonly used experimental model organism, mice play an important role in the study of epigenetics and biological temperature adaptation. Mice have high biological and genetic similarities, and their physiological mechanisms and genomic information have been extensively studied and understood (Rosshart et al., 2019). Therefore, by studying the epigenetic mark response of mice to temperature changes, we can better understand the adaptation mechanism of organisms to environmental temperature, and provide an important reference for human health and disease treatment.

This study aims to review the effects of temperature on epigenetic marks in mice, explore its mechanism in biological temperature adaptation regulation, and look forward to its potential applications in clinical treatment and disease prevention. By systematically reviewing relevant research progress, this study hopes to comprehensively understand the impact of temperature on epigenetic marks in mice and its possible biological significance, and provide new ideas and directions for future research.

1 Physiological and Temperature Adaptability of Mice

1.1 Living habits and physiological characteristics of mice

Mice (*Mus musculus)* are a widespread rodent found in a variety of environments, from cities to rural areas and even wilderness. They are usually active at night and have well-developed senses of hearing and smell, making them prime prey for predators such as cats. The relatively small size of mice allows them to find food and build nests in a variety of environments. It has strong fecundity, can quickly adapt to environmental changes, and rapidly increase its population size.

The physiological characteristics of mice are highly adaptable, allowing them to survive in various temperature conditions. They have the ability to self-regulate their body temperature and adapt to different environmental temperatures by changing their metabolic rate and behavior. The density and color of a mouse's fur can also affect its adaptability to temperature to a certain extent.

1.2 Effect of temperature on physiological functions of mice

Temperature has a significant impact on the physiological functions of mice (Zhu et al., 2023). In a low-temperature environment, the metabolic rate of mice increases to produce more heat to maintain body temperature. This may result in increased food intake to meet energy needs or fat storage in response to long-term cold exposure. On the other hand, in high-temperature environments, the metabolic rate of mice may decrease to reduce heat production and maintain body temperature stability by dissipating heat through the mouth, skin, and breathing.

Temperature can also affect the behavior and living habits of mice. In cold environments, mice are more likely to seek out secluded nests or more food to increase energy intake. In hot environments, they may choose to rest more in the shade and move less to prevent overheating.

1.3 Mechanism of temperature adaptation in mice

The temperature adaptation mechanism of mice involves multiple aspects, including adaptive changes at the physiological, behavioral and molecular levels (Figure 1). Physiologically, mice adapt to different temperature environments by adjusting their metabolic rate, changing breathing patterns, and using body hair to regulate heat dissipation. Mice can also avoid the effects of extreme temperatures by changing their activity patterns and finding suitable habitats.

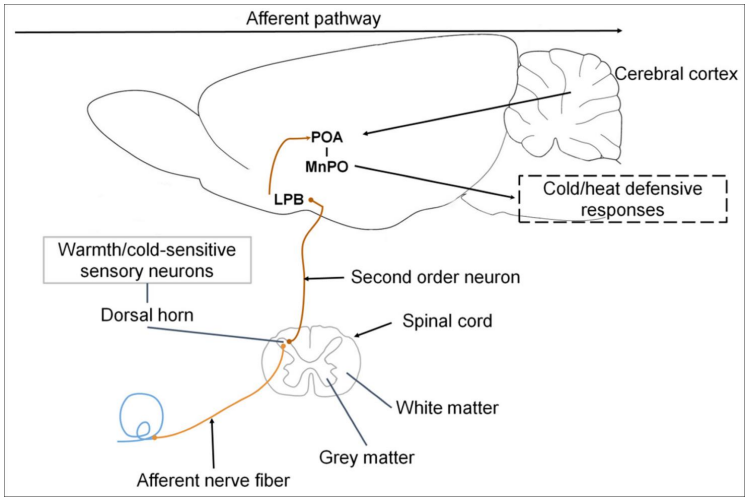

Figure 1 General mechanism of physiological thermoregulation in mammals (Mota-Rojas et al., 2021)

At the molecular level, mice adapt to temperature by regulating gene expression and epigenetic marks. For example, some genes are related to temperature sensitivity, and their expression levels may change at different temperatures to regulate related physiological processes. At the same time, temperature may also affect epigenetic marks in mice, such as DNA methylation and histone modifications, thereby regulating gene expression patterns to adapt to different temperature environments.

Mice are able to adapt to different temperature environments through a variety of physiological and molecular mechanisms. The study of these mechanisms helps researchers better understand the adaptability of organisms to environmental changes and provides new ideas and methods for the prevention and treatment of related diseases.

2 Basic Knowledge of Epigenetics

Epigenetics is a discipline that studies genetic changes that do not involve changes in DNA sequence during the transmission of genetic information in cells (Inbar-Feigenberg et al., 2013). Compared with traditional genetic research, which focuses on changes in DNA sequence, epigenetics pays more attention to the regulation mechanism of gene expression and its impact on individual phenotype and function.

2.1 Overview of epigenetics

Epigenetics involves a series of genetic changes that can be inherited but are not caused by changes in DNA sequence, mainly including DNA methylation, histone modifications, non-coding RNA, etc. These genetic changes can affect cell function and individual phenotypes by regulating gene expression levels. Epigenetics plays an important role in development, disease, and environmental adaptation.

2.2 Types and functions of epigenetic marks

DNA methylation is the earliest discovered epigenetic mark, which regulates the transcriptional activity of genes by adding methyl groups to DNA molecules. DNA methylation plays an important role in genome stability, gene silencing, and genomic imprinting.

Histone modification. Histone is the main structural protein of chromatin. Chemical modification of amino acids on histone, such as methylation, acetylation, etc., can regulate the tightness of chromatin, thereby affecting the accessibility genes and transcriptional activity.

Non-coding RNA, this type of RNA molecules does not participate in protein coding, but can affect gene expression by regulating transcription, splicing, translation and other processes. including microRNA (miRNA), long non-coding RNA (lncRNA), etc., which play an important role in the regulation of gene expression and cell function.

2.3 Current status of research on epigenetic markers in mice

In mice, important progress has been made in the study of epigenetic marks. Mice are a commonly used experimental animal model. Their genome structure is highly similar to humans, so they are widely used to study epigenetics. The main research directions include DNA methylation, histone modification, non-coding RNA, etc.

In recent years, researchers have conducted in-depth studies on DNA methylation in the mouse genome, revealing its important role in development, disease, and environmental adaptation. By measuring the methylation levels of mice in different tissues and under different physiological states, the complex mechanism of DNA methylation in the regulation of mouse gene expression was revealed. Histone modifications in the mouse genome have also received much attention. Studies have found that there are significant differences in histone modification patterns in different tissues, different developmental stages and different environmental conditions in mice, and changes in these modification patterns are closely related to gene expression regulation. Research on non-coding RNAs in mice is also continuing. Researchers have discovered that there are a large number of non-coding RNAs such as miRNA and lncRNA in the mouse genome, which are involved in regulating physiological processes such as mouse development, immune response, and metabolism.

Mice, as important experimental model animals, play an important role in the study of epigenetic markers, providing important clues for researchers with an in-depth understanding of the basic principles of epigenetics and their functions in life activities.

3 Effects of Temperature on Epigenetic Marks in Mice

Temperature is an important environmental factor in the survival and development of organisms, and has a significant impact on the physiological and ecological adaptation of mammals such as mice (Li and Yin, 2023).

Recent studies have shown that temperature not only affects the physiological functions of mice, but may also affect the genetic expression and adaptability of mice by affecting the formation and regulation of epigenetic marks.

3.1 Effect of temperature on DNA methylation

DNA methylation is an important epigenetic mark that plays an important role in the regulation of gene expression in mammals. Recent studies have found that temperature can affect DNA methylation levels in mice, thereby affecting gene expression patterns. Some experiments have shown that rising temperature can lead to a decrease in DNA methylation levels in mice and changes in the methylation status of specific genes, thus affecting the expression levels and functions of related genes.

Temperature also affects the activity of DNA methylation modification enzymes. Studies have found that the activity of certain DNA methylation modification enzymes is regulated by temperature, leading to abnormalities in the DNA methylation process, which in turn affects gene expression regulation and physiological functions in mice.

3.2 Effect of temperature on histone modifications

Histone modification is another important epigenetic mark. By regulating the modification status of histones, it can affect the structure and function of chromatin, thereby affecting the expression pattern of genes. Recent studies have shown that temperature has a significant impact on the status of histone modifications in mice.

Changes in temperature can affect the activity and specificity of histone-modifying enzymes, leading to changes in the modification pattern of chromatin. This change may affect the tightness and accessibility of chromatin, thereby affecting the transcriptional activity and expression levels of genes. Temperature changes may also affect the interaction of histone-modifying enzymes with other regulatory factors, further regulating chromatin structure and gene expression.

3.3 Effect of temperature on non-coding RNA

Non-coding RNA is a type of RNA molecules that do not encode proteins in cells. They play an important role in the regulation of gene expression and cell function (Panni et al., 2020). Recent studies have found that temperature changes can affect the expression levels and functions of non-coding RNAs in mice.

Experimental results show that increasing or decreasing temperature can cause changes in the expression pattern of non-coding RNA in mice. The expression levels of some non-coding RNAs are positively or negatively correlated with temperature, indicating that temperature changes may affect gene transcription and translation by regulating the expression of non-coding RNAs. Temperature may also affect the spatial structure and function of non-coding RNA, further regulating its mode of action and effect in cells.

The effect of temperature on epigenetic marks in mice involves many aspects such as DNA methylation, histone modifications and non-coding RNA. These effects may affect the physiological adaptation and ecological adaptability of mice by regulating gene expression and function.. An in-depth understanding of the relationship between temperature and epigenetic marks will help reveal the adaptive mechanisms and strategies of organisms under different environmental conditions, which is of great significance for the protection and utilization of biological resources.

4 Mechanism of Association between Epigenetic Marks and Temperature Adaptability

4.1 Molecular mechanisms by which epigenetic marks regulate temperature adaptability

Epigenetic marks play an important role in regulating temperature adaptability, and their molecular mechanisms involve regulatory processes at multiple levels. First, temperature changes can regulate gene expression by affecting the activity of enzymes that modify epigenetic marks. For example, an increase in temperature may promote the activity of certain histone modification enzymes, leading to changes in certain histone modification patterns of certain genes, thus affecting the expression levels of genes. At the same time, changes in temperature can also directly affect the activity of DNA methylation modification enzymes, which in turn affects the DNA

methylation level of genes, thereby regulating gene expression (He et al., 2021). These regulatory mechanisms work together to enable mice to maintain the stability of gene expression in different temperature environments to adapt to environmental changes.

Epigenetic marks can also influence temperature adaptation by regulating the rate and stability of gene transcription. In a temperature-changing environment, some epigenetic marks can affect the binding of transcription factors and the assembly of transcription initiation complexes by regulating the histone modification patterns in the promoter regions of certain genes, thereby affecting gene transcription. rate. On the other hand, some epigenetic marks can also affect the stability of mRNA by regulating the histone modification pattern in the transcription termination region of certain genes, thereby affecting the expression level of the gene. These regulatory mechanisms work together to enable mice to quickly adjust gene expression levels in different temperature environments to adapt to environmental changes.

4.2 The mechanism of epigenetic marks in temperature adaptation regulation

The mechanism of epigenetic marks in regulating temperature adaptation mainly includes two aspects: one is to regulate the expression level of genes, and the other is to regulate the expression pattern of genes (Pandey et al., 2021).

Epigenetic marks can influence temperature adaptation in mice by regulating the expression levels of certain genes. In a temperature-changing environment, some epigenetic marks can affect the binding of transcription factors and the assembly of transcription initiation complexes by regulating the histone modification patterns in the promoter regions of certain genes, thereby affecting gene transcription. rate. On the other hand, some epigenetic marks can also affect the stability of mRNA by regulating the histone modification pattern in the transcription termination region of certain genes, thereby affecting the expression level of the gene. These regulatory mechanisms work together to enable mice to quickly adjust gene expression levels in different temperature environments to adapt to environmental changes.

Epigenetic marks can also influence temperature adaptation in mice by regulating the expression patterns of certain genes. In an environment where temperature changes, some epigenetic marks can affect the expression pattern of genes by regulating certain histone modification patterns of certain genes. For example, changes in certain histone modification patterns may cause certain genes to Changes in the transcription start site produce different transcription variants, thereby affecting gene function. These regulatory mechanisms work together to enable mice to adjust gene expression patterns in different temperature environments to adapt to environmental changes.

Epigenetic marks regulate the temperature adaptability of mice through multiple mechanisms, including regulating gene expression levels and regulating gene expression patterns. These regulatory mechanisms work together to enable mice to quickly and effectively adjust gene expression in different temperature environments to adapt to environmental changes.

5 Temperature Adaptability and Related Diseases of Mice

5.1 Temperature adaptation and metabolic diseases in mice

There is a strong link between temperature adaptation and metabolic disease in mice. Studies have shown that changes in ambient temperature can directly affect the metabolic rate and fat metabolism process of mice, thereby modulating their susceptibility to metabolic diseases. In a high-temperature environment, the metabolic rate of mice usually increases, and the decomposition rate of fat in the body also accelerates, which may lead to weight loss and increase in blood sugar levels, increasing the risk of obesity, diabetes and other metabolic diseases.

Some studies have also found that exposure of mice to cold environments can increase the activity of their brown adipose tissue (Peres Valgas da Silva et al., 2019), thereby promoting fat burning, reducing body fat storage, and improving insulin sensitivity., thereby reducing the incidence of metabolic diseases. These findings suggest the important role of temperature adaptability in mice in regulating the occurrence of metabolic diseases, and provide important clues for further exploring the pathogenesis and treatment of metabolic diseases.

5.2 Temperature adaptation and neurological diseases in mice

Temperature adaptation in mice is also closely associated with neurological diseases. Studies have shown that changes in environmental temperature can affect the function and structure of the nervous system of mice, thereby affecting their susceptibility to neurological diseases. In a high-temperature environment, mice may experience abnormal excitation of neurons and abnormal release of neurotransmitters, which may lead to the occurrence and exacerbation of neurological diseases such as epilepsy and Parkinson's disease.

Some studies have shown that moderate cold stimulation can promote the growth of neurons and the formation of synaptic connections in mice, improve the function of the nervous system, and thereby combat the occurrence and development of neurological diseases. This suggests the potential role of temperature adaptive regulation in preventing and treating neurological diseases, and provides new ideas and methods for the treatment of neurological diseases.

5.3 Mouse temperature adaptability and immune system diseases

Temperature adaptation in mice is also closely related to immune system diseases. Studies have found that changes in environmental temperature can affect the function of the immune system and the activity of immune cells in mice, thereby regulating their resistance to immune system diseases. In cold environments, mice generally have enhanced immune cell activity and increased immune response levels, which help protect against infectious diseases.

However in extreme high temperature environments, the immune function of mice may be suppressed, and the activity of immune cells and immune response levels decrease, which may increase the risk of immune system diseases such as autoimmune diseases (Figure 2). Therefore, temperature adaptive regulation has an important impact on the occurrence and development of immune system diseases and provides new ideas and methods for the prevention and treatment of immune system diseases.

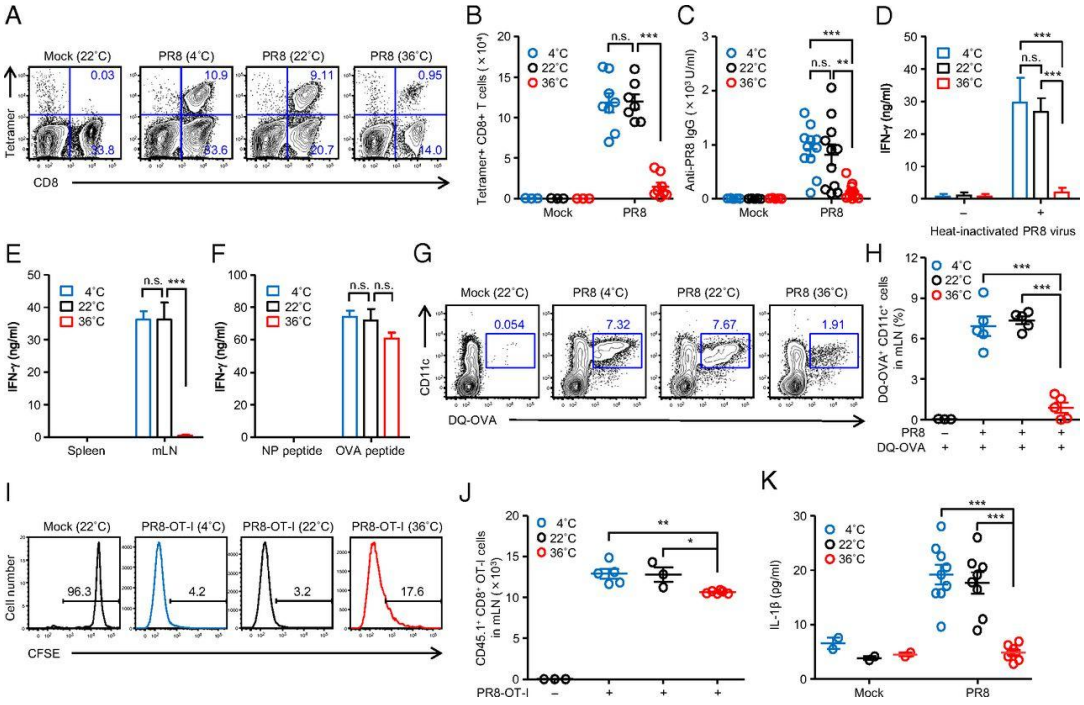

Figure 2 High heat-exposed mice fail to induce adaptive immunity to influenza virus infection (Moriyama and Ichinohe, 2019)

It can be seen from the above that there is a close correlation between temperature adaptability of mice and metabolic diseases, neurological diseases, and immune system diseases. In-depth study of the relationship between temperature adaptability of mice and these diseases will help to deeply understand the pathogenesis of the diseases and provide new ideas and methods for the prevention and treatment of related diseases.

6 Prospects

As an experimental model, mice play an important role in scientific research. The relationship between their temperature adaptive regulation and epigenetic marks is not only of great significance in basic scientific research, but also brings insights to the fields of clinical medicine and biotechnology. New application prospects. Research shows that mice adapt to environmental changes by adjusting epigenetic marks when faced with different environmental temperatures. This discovery provides new ideas for exploring the pathogenesis of the disease. For example, many metabolic diseases such as obesity and type 2 diabetes are closely related to the body's ability to adapt to environmental temperature (Ivanova and Blondin, 2021). Therefore, in-depth study of the epigenetic mark mechanism of temperature adaptive regulation in mice is expected to provide new targets and strategies for the prevention and treatment of related diseases. Research on the adaptive regulation of temperature in mice can also help to understand the pathogenesis of neurological and immune system diseases. Temperature adaptive regulation is closely related to the activity of neurons and the function of immune cells (Angilletta Jr et al., 2019). Therefore, through in-depth study of the temperature adaptive regulation mechanism of mice, it is expected to provide information for the treatment and prevention of related diseases. New ideas and methods.

Based on existing research results, this study can conclude that mice will adjust the patterns and levels of their epigenetic marks when adapting to different temperature environments (Hawkins and Storey, 2020), and this regulation involves DNA methylation, histone modifications and non-coding RNA and other levels. Changes in these epigenetic marks affect gene expression and cellular function, thereby affecting the mice's ability to adapt to environmental temperatures.

Future research can be carried out from the following aspects : in-depth exploration of the mechanism of epigenetic marks in the regulation of temperature adaptation in mice, and further study of the role of epigenetic marks such as DNA methylation, histone modifications and non-coding RNA in mice. The interaction mechanism in the regulation of temperature adaptation in mice reveals its regulatory network and signaling pathways. Explore the potential value of mouse temperature adaptive regulation in clinical applications, combined with mouse model research, explore the clinical application potential of epigenetic mark regulation in metabolic diseases, neurological diseases, immune system diseases and other fields, and develop new treatments Methods and drug targets. To study the long-term effects of environmental factors on epigenetic marks in mice, in addition to temperature, other environmental factors such as diet, light, etc. may also affect epigenetic marks in mice. Future studies could explore the long-term effects of these environmental factors on epigenetic marks in mice, as well as potential effects on mouse health and disease.

The relationship between temperature adaptive regulation and epigenetic marks in mice is a research area that has attracted much attention and is of great significance for understanding the adaptation mechanism of organisms to environmental changes and the pathogenesis of diseases. Future research will further reveal the deep-seated mechanisms in this field and bring new breakthroughs and application prospects to the fields of clinical medicine and biotechnology.

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