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The Evolution of Marsupials and Related Bionic Applications

——Taking Kangaroos as an Example

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Abstract:

As a typical marsupial, kangaroos have a unique reproductive structure, the pouch, which has great research and application value. Many studies have focused on the structure and function of kangaroo pouches and related applications. However, there are still controversies regarding evolutionary theory and so on. This article analyzes kangaroo pouches' physiological characteristics, evolution, and application. It aims to delve into the characteristics and functions of this distinctive structure, exploring its unique structure and its pivotal role in developing kangaroo joeys. Additionally, it delves into the evolutionary origins of the pouch, dissecting the mechanisms potentially responsible for this extraordinary feature's development. Understanding the evolutionary pathways behind the pouch not only sheds light on biodiversity's shaping but also offers practical applications and insights, helping people have a new view of mother care and giving scholars inspiration for the reproduction of kangaroos, marsupial animals, and mammals.

Keywords: Evolution; kangaroo; pouch.

1. Introduction

Like koalas and wombats, Kangaroos belong to the marsupial family and are known for their unique abdominal pouch. However, kangaroos stand out as one of Australia‘s most recognizable symbols, appearing on the country‘s emblem and in many areas in Australia [1]. Over the years, kangaroo pouches have piqued the curiosity of scientists and science enthusiasts, leading to extensive research in various aspects, including the internal structure of the pouch, the developmental stages of kangaroo joeys within, and the benefits of the pouch for kangaroo development.

Studies on the internal structure of kangaroo pouches have delved into the unique muscles and tissues that make up this remarkable feature. Scientists have been keen to understand how the pouch provides an ideal environment for the growth and development of joeys. This article will offer valuable insights into its physical attributes based on an analysis of the progress made in the pouch‘s environment.

The developmental cycle of kangaroo joeys within the pouch has also been a subject of profound investigation. Researchers have explored the timing of birth, the process of suckling, the stages of growth, and the critical moment when joeys leave the pouch. One of the key aspects of research focuses on the advantages the pouch offers to kangaroo development. This includes physical protection, temperature regulation, and the unique bonding and interaction between mothers and their offspring. These aspects contribute significantly to the survival and well-being of kangaroo joeys. Through a study of the benefits of pouches, the fascination with kangaroos and their pouches has not been limited to biology. Kangaroo‘s pouch has also inspired practical applications, most notably in neonatology. As shown in Figure, the concept of „kangaroo care,“ drawing from the natural phenomenon of kangaroo pouches, has been adapted for human neonatology, leading to practices such as Kangaroo Mother Care (KMC) (Figure 1). This emphasizes the importance of touch and close contact in infant care, akin to how kangaroos utilize their pouches, greatly enhancing the survival rates of premature infants [2]. These studies have satisfied people‘s curiosity about this iconic Australian species and have advanced the fields of animal behavior and evolutionary biology, introducing more intriguing and in-depth topics for exploration.

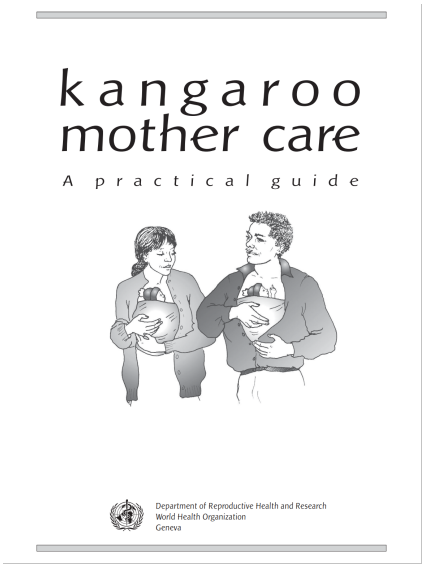

Fig. 1 What KMC is [3]?

2. The Structure of Pouch

The pouch of marsupials serves as a crucial and unique developmental environment for their young, though marsupials‘ pouch structures vary with species. Although the structure of marsupial pouches varies from species to species, their role for the young is the same, providing a crucial and unique developmental environment for their growth. Inside the pouch is essentially a hairless, warm, and slightly perspiring cavity with a soft skin lining and four teats that release milk for the joey (Figure 2) [4].

Fig. 2 The Baby Kangaroo in its mother’s pouch [5]

3. The Role the Pouch Plays in Joey’s Development

Firstly, reproduction is essential when knowing pouch. The conception process of kangaroo is akin to that of placental mammals, involving the release of an egg from the ovary and its subsequent journey down the fallopian tube. If fertilization occurs upon encountering sperm, the egg implants itself into the mother‘s uterine wall [6]. Gestation periods in kangaroos are significantly shorter than those of placental mammals, typically ranging from 25 to 35 days, and the developing embryo relies solely on its yolk for sustenance, a process reminiscent of the way a bird egg develops until all available nutrients are depleted. Kangaroo joeys are born in a highly underdeveloped state, often weighing less than 1 gram and in an embryonic development stage. This early birth is due to the relatively short gestation period [7].

To protect these fragile joeys, the pouch serves as their primary physical shield. As mentioned earlier, joeys are enveloped by the skin of the pouch, providing them with a warm and comfortable environment [4]. However, the role of the pouch extends beyond mere physical protection. There are four teats, each producing milk with different chemical compositions to cater to the baby‘s growing needs, which leads to a strong and intimate bond between mother and offspring. The milk produced in the pouch‘s teats holds significant functions pivotal for the young. It serves as the optimal nutrition source, fostering newborn growth. Moreover, this milk delivers various bioactive compounds, potentially triggering the young one‘s development. Additionally, it can remodel the mammary gland, stimulating growth or signaling cell death. Lastly, the milk acts as a protective shield, guarding against infections and inflammation during vulnerable phases of the mammary gland. Also, the pouch fosters a deep connection through the close touch and skin-to-skin contact between the mother and Joey. This relationship ensures Joey‘s survival and development. The concept of kangaroo care, derived from the natural phenomenon of kangaroos‘ pouches, has been applied to human neonatology, as KMC mentioned before, highlighting the importance of touch and close contact in infant care [2].

4. An Evolutionary Perspective on Pouch Formation

4.1 Five Mechanisms of Evolution

Natural selection is when certain traits or characteristics of an organism become more or less common in a population over time. It happens because advantageous traits individuals carry are more likely to survive and pass on

those traits to their offspring, like diving mammals‘ ability to store and effectively utilize oxygen in their muscles, particularly through the protein myoglobin [8]. As a result, these advantageous traits become more widespread in the population, while less helpful traits become less common since organisms with them are more likely to be out. Selection is the only mechanism that can lead to evolution and adaptation.

Genetic drift refers to the random changes in the frequency of specific traits or alleles within a population over time, and it tends to have more chances to happen in a smaller population. For example, in the book The Beak of the Finch, written by Jonathan Weiner, genetic drift happens when fluctuations in food availability lead to changes in the frequency of specific traits in finch populations.

Mutation means a change in DNA that leads to a change in allele frequencies, which is rare. For example, the mutation of a gene called CNGB3 leads to the colorblindness of humans, causing people to not distinguish between some particular colors [9].

Migration, also called gene flow, refers to the movement of alleles between populations, significantly impacting small populations. The example of migration in the book The Beak of the Finch is that many finches migrate to the nearby island of Santa Cruz, where the conditions are more suitable and food is more abundant.

Non-random mating means an organism does not choose its mates entirely by chance. One form of non-random mating is inbreeding, or between close relatives, and another extreme form is selfing. Take kangaroos as an example. Female kangaroos choose male kangaroos according to their age and size and exhibit preferences for larger and more dominant males. These preferences are likely rooted in the desire for healthier and more viable offspring. The social structure of kangaroo groups, especially in species like the red kangaroo, leads to non-random mating patterns. In these groups, a dominant male mates with multiple females, emphasizing non-randomly mating based on social dominance. Geographical factors can also influence mate selection, as the availability of suitable mates in a particular area may lead to non-random mating based on distance and environmental considerations [10].

4.2 Discussion on the Evolution of the Pouch of Kangaroos

The pouch of kangaroos is a remarkable trait in the process of kangaroos‘ evolution. Firstly, the pouch is a complex trait. As mentioned before, the pouch involves a pocket of specialized skin and musculature that have evolved to uniquely protect and nurture the underdeveloped joeys. It is not a simple, single-gene trait but a combination of special functions and structures. Secondly, natural selection has played a crucial role in the evolution of the kangaroo‘s pouch, or we can say that it makes evolution happen. The mammals have a common ancestry of egg-laying animals, but they finally took different reproductive paths, splitting into two main categories: eutherians and marsupials. Eutherians have placenta, but the marsupials do not [11]. As a marsupial, the kangaroo must develop a particular way to give birth, which is using pouches. As a result, those kangaroos with this unique pouch structure had an advantage in rearing their young (Figure 3). The pouch provided a safe and nurturing environment for the underdeveloped joeys, increasing their chances of survival. Kangaroos with better pouches were more likely to pass on their genes, leading to the preservation and refinement of this complex trait.

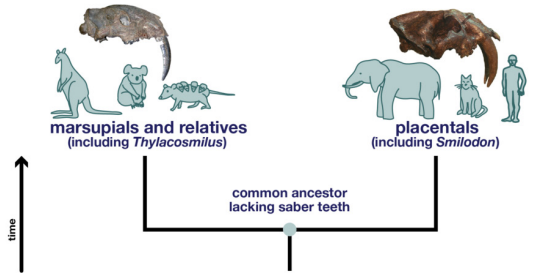

Fig. 3 Homology & Convergent Evolution [12]

Thirdly, genetic drift might not have a significant effect on the evolution of the pouch. Genetic drift tends to be more pronounced in smaller populations. Still, Kangaroo populations are generally not small, and the evolution of the pouch seems to be primarily driven by natural selection rather than random genetic changes.

The biological or genetic constraints on the kangaroo pouch limit the range of variation because of its uniqueness and importance. The pouch serves a very specific purpose in protecting and nurturing the developing joeys, and any deviation from its current structure might be less effective or even detrimental to the survival of the young.

Finally, since the primary function of the pouch is related to maternal care and protection, it‘s possible that sexual or kin selection could also be acting on this trait. Female kangaroos may select mates based on their ability to provide better care for their offspring, like whether the males can provide enough food and are strong enough to protect the joeys and territory. As I mentioned previously, social structure is also an element in selecting mates. To use evidence to demonstrate that sexual and kin selection plays a role in a kangaroo‘s pouch, research and data are needed. For example, one of the evidence showing increased muscularity in male kangaroos could serve as a signal to attract females or deter other males [13].

5. Conclusion

The article primarily summarizes the structure, functions, and critical role of the kangaroo‘s pouch in joey development. It emphasizes the pouch‘s significance in the kangaroo‘s reproductive strategy, mother-offspring interaction, and the joey‘s growth process. It also highlights potential human medicine applications, such as KMC, indicating interdisciplinary implications for future studies in zoology and medicine.

While the article delves into the pouch‘s structure and functions, it does not extensively explore the gene of pouch development or potential variations among different kangaroo populations. Future research avenues could encompass a deeper understanding of the genetic mechanisms driving pouch development and genetic variations among kangaroo populations. Further exploration also includes the pouch‘s impact on joey behavior and health, and it could broaden insights. Moreover, extending pouch research to a wider range of species could offer more comprehensive insights into the nurturing strategies of other marsupials.

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