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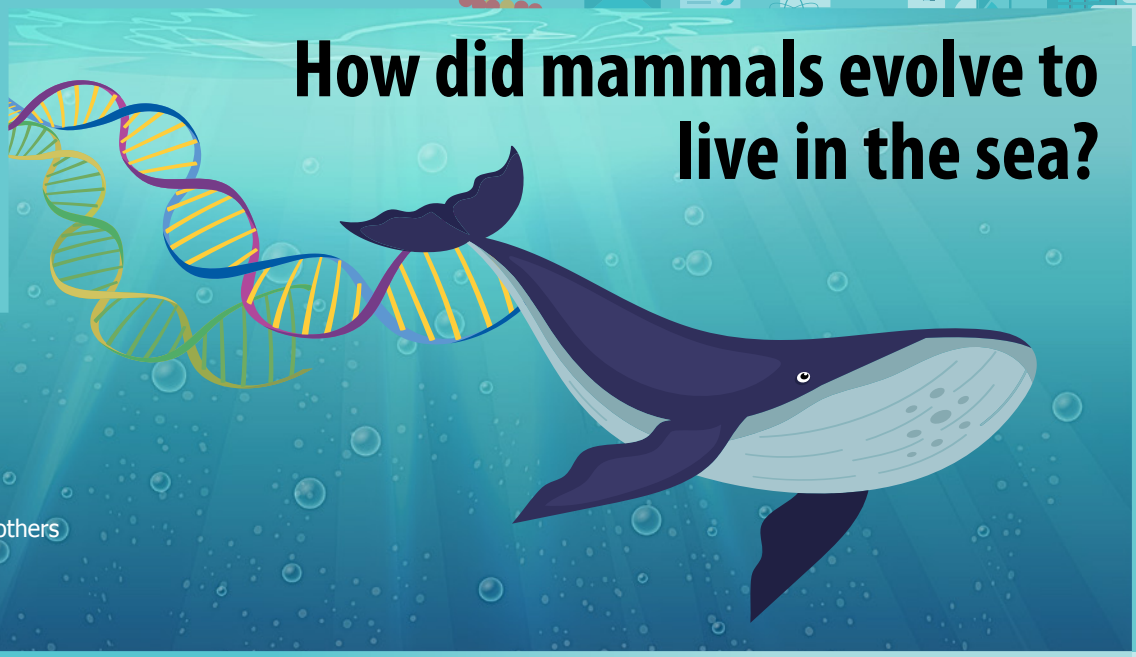
How did mammals evolve to live in the sea?



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Abstract

Marine mammals are well adapted to living in the sea. For example, whales and dolphins are excellent divers, hold their breath for long periods, and can sleep underwater. However, this was not always the case. In fact, whales and dolphins (collectively known as cetaceans) evolved from mammals that once lived on land! How did cetaceans develop these abilities to live underwater? A group of chemicals called neuropeptides may hold the answer. These chemicals play important roles in numerous bodily processes including sleep, feeding and the maintenance of blood pressure.

We compared the neuropeptides found in cetaceans with those found in land mammals. We wanted to see how they are different. We found that marine mammals have lost the ability to make many of the neuropeptides that land mammals still have. So, differences in neuropeptides may explain how cetaceans adapted to live in a marine environment.

Introduction

Did you know that **cetaceans** (whales, dolphins, and porpoises) are mammals? About 50 million years ago, their ancestors lived on land. They later evolved to live in marine environments. Such an extreme habitat transition required many **adaptations**.

One remarkable example is how cetaceans sleep: one half of their brain rests, while the other half remains active! This **unihemispheric sleep** ensures cetaceans are always watching out for predators and food. Other adaptations helped cetaceans hunt their prey underwater. For example, reduced oxygen demands allowed them to dive for longer and control their blood pressure at great depths. Thick layers of fat also helped insulate them from cold waters.

There are many **molecules** that control **physiological** traits like sleep, blood pressure, and temperature control. Among them, **neuropeptides** are especially important. Neuropeptides are chemical messengers. They relay signals

Pakicetus lived on Earth around 50 million years ago. Scientists think it is one of the first ever cetaceans. Although *Pakicetus* could swim and catch fish, it still mostly lived on land. Its descendants would become increasingly aquatic, eventually evolving into marine mammals like whales and dolphins.

from one nerve cell to another, triggering a physiological change. They can also have more than one role in the body.

Luckily, neuropeptides are found in all mammals. We wanted to know how these neuropeptides changed as mammals evolved. This information can help us understand how mammals adapted to living in the ocean.

Methods

→ **Step 1:** Identifying important neuropeptides

We identified 12 neuropeptides. Previous research has shown they may be related to important traits in cetaceans.

→ **Step 2:** Obtaining DNA sequences for each

Neuropeptides are microscopic, so it is hard to detect differences between them. An easier way to compare neuropeptides is to look at their **DNA** sequences. DNA is like an instruction manual. A specific sequence can build a specific molecule (in this case, a neuropeptide). We got the DNA sequences for our neuropeptides from online databases. We did this for 202 different mammal species. This included 41 species of cetaceans.

→ **Step 3:** Comparing the ability to create neuropeptides

We used a computer program to "build" the neuropeptides based on their DNA sequences. The computer program gave each DNA sequence a score from 0 to 5. A score of 0 meant that the neuropeptide would work. (Think of it as having zero problems!). A score between 2 and 5 meant that the neuropeptide would **not** work. Then we compared the scores for each of the 12 neuropeptides in cetaceans and land mammals.

Results

It turns out cetaceans have lost the ability to make many of the neuropeptides found in land mammals. We found that many cetacean neuropeptides had scores higher than 2. Cetaceans also had fewer DNA sequences that made functional neuropeptides than any other group of mammals. For example, neuropeptide B helps mammals sleep and suppresses hunger. Most cetaceans do not have the correct DNA sequence to build neuropeptide B (Figure 1).

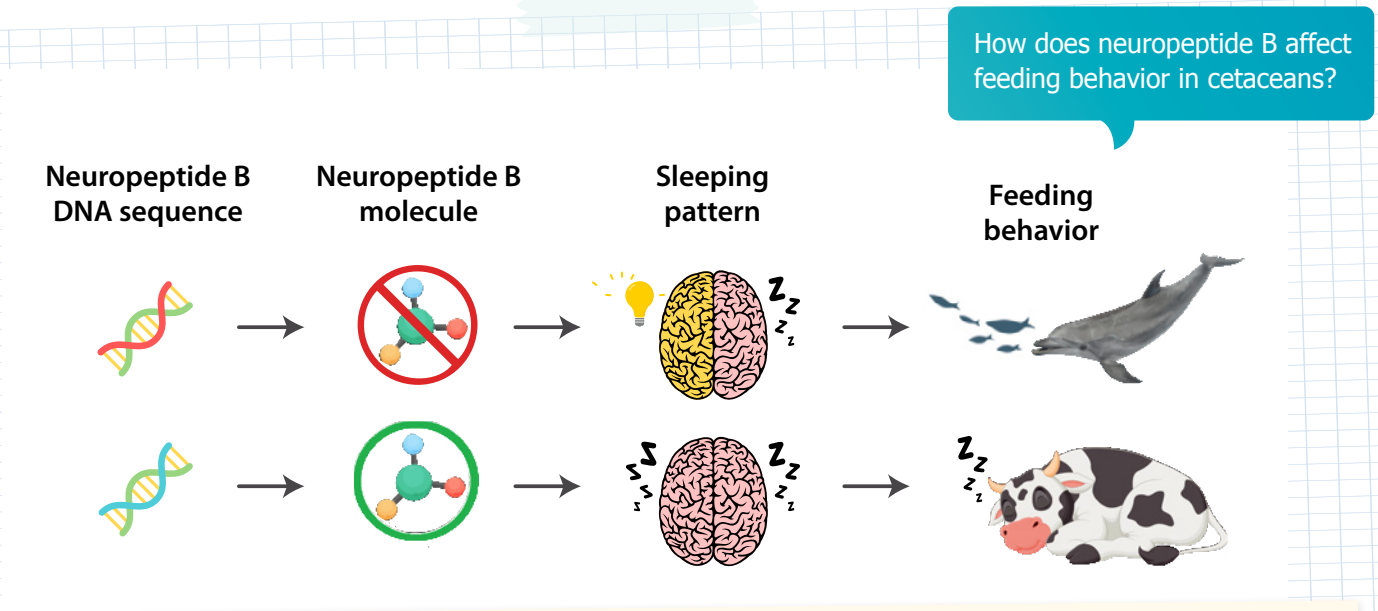

Figure 1: Neuropeptide B in cetaceans has a slightly different DNA sequence than land mammals. This results in a molecule that doesn't function. The loss of neuropeptide B in cetaceans is associated with changes in sleep pattern (one brain hemisphere active, the other resting) and feeding activity (does not suppress appetite).

There were some DNA sequences that created neuropeptides that worked. For example, cetaceans still produce neuropeptide Y. This controls blood pressure, fat storage, and sleep.

Discussion

Why would cetaceans have lost the ability to make many of the neuropeptides that land mammals still have? Over time, DNA can collect **mutations**. Sometimes these mutations create new traits that are beneficial. Sometimes they don't do anything. But at other times they can mess up the instructions the DNA carries. This means that whatever the DNA sequence makes, it won't work properly. This is probably what happened to these neuropeptides.

The ancestors of modern cetaceans probably didn't need a lot of those neuropeptides in their new marine environment. So when the DNA mutated, it didn't matter. They may have even benefited by losing the ability to make specific neuropeptides. For example, they may have lost the ability to make neuropeptide B (which suppresses hunger and induces sleep). This allowed cetaceans to eat lots of food and keep one half of their brain awake. Luckily, most neuropeptides have more than one role. So cetaceans didn't completely lose the ability to sleep or regulate their appetite.

The evolution of cetaceans from land mammals is complex. But it is clear that the loss of working neuropeptides played a role. Their loss allowed early cetaceans to thrive in a marine habitat.

Conclusion

Understanding how cetaceans have adapted to the marine world could help us understand how other mammals have evolved in their new environments. After all, transitioning from land to water is not the only major habitat change mammals have undergone. For example, bats transitioned from climbing trees to flying.

Unfortunately, many animals and plants are facing habitat loss. Find out about local plants and animals in your area and how you can help protect them!

Glossary of Key Terms

Adaptation - traits or behaviors that help an organism survive.

Cetaceans - a group of closely related marine mammals, including whales, dolphins, and porpoises.

DNA - material found in the cells of all living organisms that carries the information to build parts of the body.

Molecules - clusters of atoms that are chemically bonded together.

Mutation - a change in a DNA sequence.

Neuropeptides - a group of neurotransmitter chemicals. Each neuropeptide is coded for by a specific gene. Neuropeptides can have multiple roles in the body.

Physiological - relating to physiology: the way in which organisms or body parts function.

Unihemispheric sleep - a sleep state in which one half of the brain rests while the other remains active.

Check your understanding

1. Give two examples of adaptations that help cetaceans survive in a marine environment. Explain what each adaptation helps them do.

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2. What are neuropeptides? Name one neuropeptide found in cetaceans and the roles it plays.

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3. Why do we think cetaceans have lost the ability to make some neuropeptides?

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4. Our research focused on cetaceans' shift from a land habitat to a marine environment. We mentioned that bats have also undergone a major habitat transition from tree-tops to sky. Can you think of any other animals or plants which have had to evolve to a new environment? What adaptations have made that possible?

REFERENCES

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