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Why can some monkeys live high in the mountains?

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Abstract

Geladas are an unusual primate. They eat mostly grass instead of fruit or meat. They are known as "bleeding heart monkeys" for the bright red patch of skin on their chests. They also live high in the mountains instead of in the jungle or the savanna. The air is thinner high in the mountains, so it is harder to get enough oxygen. How can geladas thrive in that environment? That's what we wanted to find out. We studied the DNA of wild geladas. We found a surprising difference in how DNA is packaged between geladas from two different regions of Ethiopia. Also, we know that some animals react to low oxygen by increasing the amount of hemoglobin in their blood. But we learned that geladas don't do that. Instead, they might have evolved to have larger lungs to help them get more oxygen with each breath.

Introduction

What comes to mind when you think of mountaintops? Rocks, small plants, cold temperatures, thin air? What about monkeys? You may be surprised to learn that not all monkeys live in the jungle or the savanna. Monkeys live in many habitats, and a few **species** even thrive at high **altitudes**.

One such mountain-dweller is the gelada. Geladas live high on the Ethiopian Plateau in eastern Africa. They are one of the only primate species on Earth who can live so high up!

Living at the top of the mountains means there aren't many predators. But it also means there isn't as much food. It can get cold up there, too. Plus, the air is thin, making it harder to get enough oxygen. Geladas have long hair to keep them warm. And unlike any other monkey, they eat grass, which is plentiful there. But what about the thin air?

Animals that live at high altitudes often adapt to avoid **hypoxia**, or a lack of oxygen. Hypoxia is dangerous for animals that aren't equipped for it. Geladas have lived high in the mountains for millions of years. What kind of **adaptation** could help them get enough oxygen from thin mountain air?

To try to answer this question, we looked at

- geladas' **genes**,
- their **hemoglobin** (the protein in blood that carries oxygen), and
- their body shape.

Male gelada in the Simien Mountains.
Photo: © India Schneider-Crease

Methods

We took measurements and **samples** from wild geladas from northern and central Ethiopia (Figure 1). We did the same with central Ethiopian geladas that live in zoos. With the help of veterinarians, we sedated wild geladas using a blow dart. We measured each gelada's size and weight and took a small amount of blood and tissue. Then, veterinarians made sure the geladas woke up safely and rejoined their groups. We also used measurements from other studies whenever we could.

We then used two **DNA**-reading tools to put together a **reference genome** of a wild adult female gelada. A reference genome is a detailed map of an organism's DNA.

We measured the amount of hemoglobin in the geladas' blood. We also measured how easily gelada hemoglobin absorbed oxygen.

We wanted to know if geladas' body shapes have adapted to help them breathe. If geladas evolved to have bigger lungs, they could get more oxygen with each breath. But measuring the exact **volume** of an animal's lungs is very difficult. So we checked the **circumference** of their chest and waist to get an idea of how big their lungs could be.

Figure 1:
Geladas live in the northern, central, and southern Ethiopian highlands in the areas marked on the map. Most of the wild geladas in our study came from the Simien Mountains in the north. Most of the zoo geladas or their ancestors originally came from the central region.

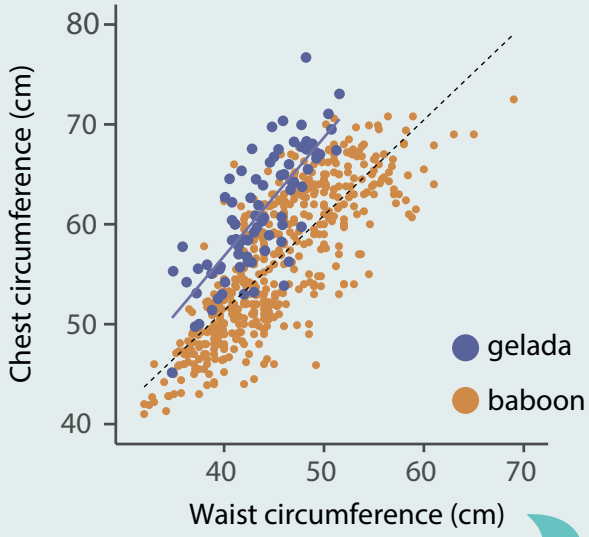
Results

We compared the gelada's genome to other species in the same **clade**. Related species like baboons and macaques have 21 **chromosome** pairs. We were surprised that the gelada genome we sequenced had 22 chromosome pairs! We found that chromosome 7 had split into two. We looked at the chromosomes in 15 individuals. We only found the split chromosome in geladas from the north of Ethiopia.

We found that hemoglobin in geladas is shaped differently than in humans and baboons. But despite the different shape, gelada hemoglobin molecules don't carry more oxygen. Geladas living at high altitude also did not have more hemoglobin in their blood than geladas living at low altitude.

We compared chest circumferences in geladas to chest circumferences in five baboon species that don't live at high altitudes. We found geladas have a larger chest circumference for their weights and waist sizes (Figure 2). So geladas with larger lungs might have better adapted to the thin mountain air!

Figure 2:
We compared the chest circumference to the waist circumference for geladas and for five different baboon species. For their size, geladas usually have larger chest circumferences than the other species. That might mean that they have larger lungs, which would let them get more oxygen from each breath.



What do you notice about the pattern made by the geladas data (darker dots) compared to the pattern made by the data from the baboon species?

Discussion

How can you tell whether two groups of animals are the same species? One species can include individuals with big differences in size, shape, and color. (Think of all the different kinds of house cat, or *Felis catus*!) To answer this question, biologists ask

- Do the groups ever interact with each other?
- Can an animal with one parent from each group also have children?

Scientists think of northern geladas and central geladas as two **subspecies** of *Theropithecus gelada*. Subspecies are groups of animals of the same species that live in different places. They have some differences in body shape or color. In zoos, northern and central geladas can mate. And geladas with both northern and central parents can have children. But the gelada DNA didn't show any evidence that northern and central geladas ever mate in the wild. The split chromosome we found only appeared in:

- northern geladas in the wild and
- geladas in zoos with some northern gelada ancestors.

This could mean that northern geladas and central geladas are on their way to becoming different species!

Conclusion

Humans living at high altitude can get altitude sickness. Some diseases can make it harder for people to breathe. When there isn't as much oxygen as we're used to, our bodies sometimes react by making extra hemoglobin. This helps carry extra oxygen. But the extra hemoglobin also makes it harder for blood to move through the body, making us feel sick. Knowing how animals like geladas survive low-oxygen environments can help scientists find new medicines and treatments. Think of your favorite animal. What secrets are they waiting to tell you?

Glossary of Key Terms

Adaptation – traits or behaviors that help a living thing survive.

Altitude – the height of something compared to sea level.

Chromosome – long, threadlike strands of DNA.

Circumference – the distance around an object.

Clade – a group of organisms that share a common ancestor.

DNA – material found in the cells of all living organisms that carries information about how they look and function.

Gene – small sections of DNA.

Genome – the complete set of chromosomes in an organism.

Hemoglobin – a molecule in blood that carries oxygen throughout the body.

Hypoxia – condition in which not enough oxygen reaches the body's tissues.

Sample – a representative part of something. In our study, we took small amounts of blood from geladas.

Species – a group of organisms with similar characteristics that are capable of sharing DNA and reproducing.

Subspecies – groups of organisms that live in a different place than other groups of the same species. A subspecies usually has some differences in appearance.

Volume – the amount of space that an object fills.

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Check your understanding

1. What makes living at high altitudes challenging?

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2. What result was surprising to us? Why?

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3. We were careful to say that our results show that it's possible that geladas evolved to have bigger lungs, but that our results don't prove it. Can you think of an alternative hypothesis for why geladas have larger chest circumferences?

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4. Describe the place where you live. For example, is it hot during summer? Is it usually dry or wet? Does it have a cold or a mild winter? What adaptations would an animal need to be comfortable there?

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5. Think of a favorite animal. Where does it live, and how is it well adapted to its environment? What is it good at? What could you learn from this animal?

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