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BIRDS AND THEIR EXTRAORDINARY SENSE OF SMELL

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Smell is one of the five senses we use to experience the world. It allows humans and other animals to find their food, avoid danger, and even recognize family members. Animals detect smells with olfactory receptors, special proteins that sit on the surface of the nose cells. These interact with odor molecules (small particles that have a smell) and send signals to the brain so the animal can perceive the smell. We know mammals have hundreds of olfactory receptors and can detect tens of thousands of smells, but what about birds? For decades, many people thought that birds did not use smell in their daily lives, but recent studies have shown that birds respond to smell. We show that many birds have a large number of olfactory receptors similar

to mammals, strengthening the case for smell playing an important role in the life of birds.

WHAT IS SMELL?

Smell is one of the five senses that we use to perceive the world. An ancient sense shared by all animals, smell is a key way animals receive information about their environments. Animals detect and interpret odors using the **olfactory system**, which consists of the nose and the nasal cavities [1].

OLFACTORY SYSTEM

Body parts that are used for smell. Olfactory receptors are a crucial part of this system.

How does the olfactory system work? Imagine this scenario: you have been toiling away at your homework for 5 h. Exhausted, you lean back in your chair, keen on taking a break, when the promising smell of freshly oven-baked pizza wafts across your nose. Identifying the pizza via its smell seems like second nature to your famished self, but how did your brain do this in the first place? First the pizza smell is taken in by the nose. In the nose, there are proteins called **olfactory receptors** that detect odors [2]. Olfactory receptors come in various shapes, allowing each receptor to match to and detect its own unique set of smells. For example, you can differentiate the smell of pizza from pancakes because the pizza odor molecule interacts with a different receptor than that of a pancake. Each receptor's shape is determined by a unique DNA sequence or a "code". DNA codes for olfactory receptors can be found within an organism's entire set of genes, which is called the **genome**.

OLFACTORY RECEPTORS

Proteins on the cell surface that directly attach to odor molecules. After attaching, the receptor sends signals to the brain, which then interprets the odor.

GENOME

The full genetic material of an organism, containing the "code" that makes up all of the organism's genes.

Different species have many different olfactory receptors in their noses [3]. Humans have about 400 and other mammals have hundreds of olfactory receptors, too. Some mammals, such as elephants, can have over two thousand different kinds of olfactory receptors! This makes olfactory receptors the most numerous group of genes in all of vertebrates [3]. Most studies of olfactory receptors have been done in mammals, like mice and humans. However, what about in other animals?

DO BIRDS HAVE A SENSE OF SMELL?

For a long time, it was thought that most birds could not smell many odors [4]. After all, birds are colorful, are often active during daylight hours, and some species sing beautiful songs. Therefore, people thought that birds do not use smell but instead have better vision and hearing. Early experiments on bird behavior agreed with this idea. For example, the famous **ornithologist** John James Audubon conducted an experiment on turkey vultures and concluded they could not smell meat. Increasingly though, we are learning the opposite: birds may use smell. For example, finches preferred the smell of their own egg instead of the egg of another finch, hinting that birds may use

ORNITHOLOGIST

A scientist who studies birds. The study of birds is called ornithology.

smell to recognize family members [5]. Similarly, other birds showed a preference for vanilla-scented nesting materials, showing that birds may use smell as a guide when building nests [6]. When scientists placed food for albatrosses in the ocean, the albatrosses successfully navigated many miles across the ocean directly to the source of the food, suggesting that birds use smell while foraging [7]. Why did Audubon's vultures seem to not be able to smell, then? The meat Audubon used may have been too rotten to be appealing to the vultures.

Adding to the evidence that birds can smell, birds were also discovered to have olfactory receptors [3]. Previous research found few olfactory receptors in birds—in a study of 48 bird species, it was found that 45 species had fewer than 75 olfactory receptors [8]. However, given that birds engage in many behaviors involving smell, the question remains: how can birds do so if they have so few olfactory receptors?

NEW FINDINGS IN BIRD OLFACTORY RECEPTORS

In our investigation, we tested the accuracy of previously reported olfactory receptor counts in birds. Olfactory receptor counts are generated by scanning the complete bird genome. However, laboratory machines cannot get the code of an entire genome at once, so researchers get the DNA code in puzzle-like pieces, then build it back together. In so-called **short read genomes**, each puzzle piece is small, and in **long read genomes**, each piece is much larger. While short read genomes are less expensive to build, they are also more difficult to build. For example, imagine a puzzle with many small pieces compared to a puzzle with a few large pieces. The puzzle with a few large pieces would be easier to complete than the puzzle with many small pieces.

Pretend you are in class and your teacher gives you an assignment in which you must identify the number of unique dogs in a puzzle. She gives full dog images to one half of the class. Then she cuts up the rest of the images into smaller pieces and gives them to the other half, including you. Excited for a challenge, you begin assembling the pieces, only to quickly realize that several fragments seem **redundant** and look like they belong to the same dog. You end up assembling two dogs (Figure 1A) while the other half of the class, with the more complete pictures, easily identifies four dogs (Figure 1B). This illustrates one of the shortcomings of a short read genome vs. a long read genome: with very similar small puzzle pieces, a short read genome cannot distinguish between two similar DNA segments. On the other hand, in long read genomes, puzzle pieces are larger and have a greater number of distinct features, so they can be identified more easily. The long read genome enables scientists to better identify that two DNA segments are unique sequences and not redundant, like

SHORT READ GENOME

The full genetic material of an organism, put together from small pieces. Two small pieces that are very similar may be difficult to distinguish from one another.

LONG READ GENOME

The full genetic material of an organism, put together from larger pieces. Two large pieces have enough unique qualities to be distinguished from each other and labeled as unique.

REDUNDANT

An item or object that is unnecessary because it is already present. An extra copy of something, where the extra copy does not provide any additional value.

how four dogs instead of two could be identified in the puzzle when the images were whole.

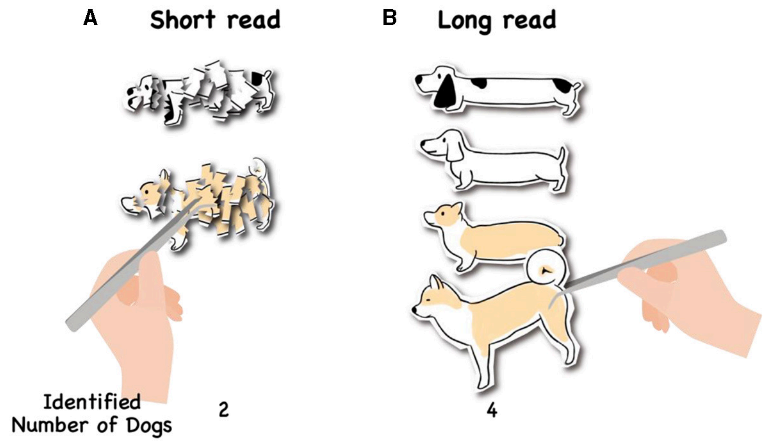

Figure 1

Figure 1

(A) In short read genomes, DNA segments are short, and so similar sequences may appear identical. In this example, fragments of a dog puzzle that are the same color are extremely difficult to tell apart, so only two dogs are detected in the sample. **(B)** In long read genomes, DNA segments are longer, allowing for more distinct features to be seen. Here, the dog puzzle pieces are larger and mostly complete, and we can detect four different kinds of dogs.

In the previous study reporting fewer than 75 olfactory receptors in 45 bird genomes, all 45 of the bird genomes were short read genomes [8]. Olfactory receptors have many similar sequences to each other and are often found right next to each other in the genome puzzle. The very problem described above arises: since small puzzle pieces could be mistakenly identified as redundant in short read genomes, could they be affecting the olfactory receptor counts found in birds?

For our study, we looked at bird species that had both short and long read genomes available: the emu, a hummingbird, and a manakin (Figure 2). We chose birds that were different from each other in size, habitat, and diet, to see if we would find similar patterns across such diverse bird lifestyles. Emus are large flightless birds found in Australia. Hummingbirds live in the Americas, are the smallest birds, and hover over flowers to drink their nectar. Manakins are fruit-eating birds found in Central and South America, best known for their elaborate dances. We scanned these genomes and counted the number of olfactory receptors in the short and long read genomes. We found more olfactory receptors in the long read genomes compared to the short read genomes in all three birds (Figure 3). For example, we found 27 olfactory receptors in the short read genome of the hummingbird but 109 in the long read genome. In another example, we found nine olfactory receptors in the short read genomes of the manakin, but 117 olfactory receptors in the long read genome. Likewise, the emu short read genome contained 57 olfactory receptors compared to 296 in the long read genome.

SMELL IS IMPORTANT IN BIRDS!

Our study showed that birds have more olfactory receptors than previously thought. Prior to our findings, scientists thought that most

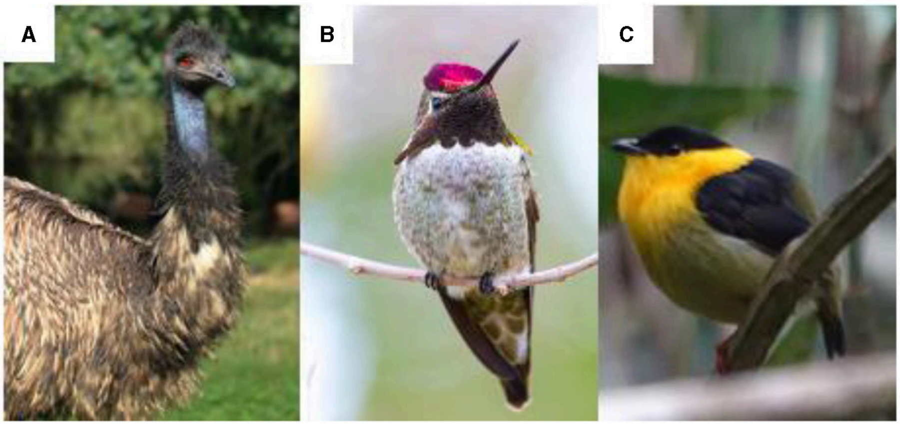

Figure 2

Figure 2

We compared olfactory receptor counts from the short read and long read genomes of three bird species: **(A)** emu, **(B)** hummingbird, and **(C)** manakin [photo credits: **(A)** Niklas Jeromin, **(B)** Joseph Vogel, **(C)** Rudolphous].

Bird species	Long read	Short read
emu	296	57
hummingbird	109	27
manakin	117	9

Figure 3

Figure 3

Olfactory receptor counts in the long read and short read genomes of three kinds of birds. Many more olfactory receptors were found in the long read genomes compared to the short read genomes. This tells us that long read genomes are better for finding and identifying bird olfactory receptors.

birds had fewer than 100 olfactory receptors in their genomes. This is a small number of olfactory receptors compared to other mammals, suggesting that birds may not have enough diversity in their olfactory receptors for smell to be important in their lives. However, recent behavioral studies show that birds may use smell for recognizing family members, nest building, and foraging. We showed that some bird species actually have hundreds of olfactory receptors in their genomes, which is similar to some mammals, including humans. This DNA evidence for bird smell will support future behavioral studies that reveal the exciting possibility that birds use smell in their daily lives, more than scientists had once thought possible. Hopefully, future investigations will test the olfactory receptors to discover which types of odors birds can smell.

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Ranjai loves math, chess, and physics and is especially a big fan of the NASA labs and space explorations.

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Ranvir loves origamy models, reptiles, insects, and every specimen in his biology lab.

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I love playing Minecraft and I enjoy creating different worlds in it. I am very curious. I am also a chatterbox and love asking questions.

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