



# Oscine serenade

---

PIERRE DEVICHE AND HIS COLLEAGUES STUDY THE INTERACTIONS BETWEEN HORMONES, BRAINS, AND REPRODUCTIVE BEHAVIOR IN SONGBIRDS. THEIR FINDINGS ARE PROVIDING NEW CLUES TO BETTER UNDERSTANDING HUMAN NEUROBIOLOGY.

by **Diane Boudreau**

## Crooning like a tiny Barry White with wings,

the finch approaches his object of desire. He opens his beak and begins his serenade. While other birds warble and tweet around her, the female finch responds only to her male counterpart's song.

Okay, the little bird might not be belting out "Can't Get Enough of Your Love Baby," but his purpose is the same as any serenader's—to get the girl. In fact, scientists studying bird brains and mating behavior have found that birds are remarkably complex, and share many characteristics with humans.

Pierre Deviche studies a group of perching birds called Oscines. Oscines include common songbirds such as finches and sparrows. While some birds are hard-wired at birth to sing a particular song, Oscines learn their songs as they develop, much like humans learn language. "We learn to speak from our parents. If we were raised in isolation, we just couldn't speak," says Deviche, an assistant professor of biology at Arizona State University. "People have raised these birds in isolation, where they never hear the song of their species. They never learn to sing like other birds."

Deviche and his colleagues study interactions between hormones, brains, and reproductive behavior. Their work is helping scientists to understand more about bird mating behavior. The findings also offer new clues about human neurobiology. Birds may not have the intelligence of people, but their brains develop in many similar ways.

In earlier studies, scientists raised Oscines in isolation and then exposed them to songs of other species. The birds can learn another species' song to some extent, much like humans can learn whatever language they are exposed to when young. "If you were raised in China, you'd speak Chinese. Birds are a little more limited, but it's a similar process," explains Deviche.

In addition, Oscines can only learn their songs at a certain age. There is a window of opportunity in which they must learn to sing. Human brains are similar—it is much easier to learn language as a young child than as an adult. "Like me," says Deviche, a native of Belgium. "I started learning English when I was 12 or 13. I will always have an accent. My children, however, have always lived here and speak perfect English."

Unlike human speech, birdsongs are strictly a reproductive function. All birds make sounds, but typically only the males produce actual songs, and only during breeding season. Scientists have found that singing is triggered by testosterone. Taking a male bird outside of breeding season and treating him with testosterone can induce singing. Taking a female bird that normally doesn't sing, and treating her with testosterone, also induces singing in some species.

**Bird songs** are controlled by four main regions of the brain. Scientists label these areas as MAN, HVC, Area X, and RA. Together, these areas are known as the vocal control regions, or VCRs. They are involved with perceiving and expressing sounds. Scientists were recently stunned to learn that the VCRs actually increase in size during the breeding season.

"This was a big finding—revolutionary," Deviche explains. "Prior to this discovery, we thought that the brain was very plastic in young birds, but not in adults. Now we find this is not limited to early life."

Deviche wanted to know what caused this change in VCR size. In his laboratory, he castrated male birds so that they stopped producing testosterone. The VCRs in these birds became smaller. When he treated the birds with testosterone, their VCRs grew again.

But what exactly was happening to the brain to make it grow? The size changes could be attributed to a number of possible causes. "Are there more cells? Bigger cells? Does the space between the cells expand?

Or is it a combination of these? It turns out, at least in the HVC, that these changes are due to more neurons," says Deviche.

"This was sort of a second revolution. Until about 15 years ago, people thought you were born with all the neurons you would get for life. You only lose these cells, not gain them. New connections form as you learn, but not new neurons."

Birds, however, are making new neurons all the time. Deviche is able to see new brain cells by injecting birds with a chemical that mimics thymine, one of the four nucleotides that make up DNA. When the brain cells divide, some of this chemical gets taken up as part of the new cell's DNA. The researchers can stain brain sections to identify the compound and find new cells.

If birds can regenerate neurons, what about humans? For a long time, scientists studying mammals showed no interest in bird neural regeneration, says Deviche. "They said, 'That's nice, but mammals don't do it so why should we care?' But recently we've learned that mammals, including humans, do indeed regenerate neurons in some circumstances," he explains.

Although neural regeneration in adult mammals is extremely rare, scientists like Deviche believe that birds may offer some clues on how to induce the process in humans who have, for instance, suffered brain damage. "Bird and human brain cells look essentially the same. But something about birds allows these cells to really regenerate in adulthood," Deviche says. "What makes that possible? Do birds produce some different chemical? Or larger amounts? These are the questions I'm really excited about."

The ASU biologist wants to know the exact mechanisms through which hormones are affecting brain cells, thus affecting behavior. Research suggests that testosterone's effect on the brain might be indirect, occurring through a chemical called brain-derived neurotrophic factor (BDNF). Testosterone increases BDNF production in the brain. In addition, giving BDNF to birds instead of testosterone produces the same brain growth as giving testosterone directly. Deviche hopes to take this research one step further by observing whether BDNF induces singing the way testosterone does.

**Birds only sing** their mating songs during the breeding season—generally in the spring. The VCRs in their brains grow before and during this period, and become smaller during the rest of the year. Birds do not carry calendars; so how do they know when it's time to sing?

The results of earlier studies have shown that day length is the cue that prompts birds to churn out the testosterone that enlarges the VCR and induces singing. "It makes sense," explains Deviche. "Day length is just about the most consistent cue out there." Length of daylight changes predictably over the seasons, year after year, unlike factors such as temperature or food availability.

Birds do not receive this cue through their eyes, as might be expected. They catch the cue through cells in the brain that are directly sensitive to light. While light could never pass through a human skull, bird skulls are extremely thin. The bird skull is made up of two thin layers of bone connected by little pillars. The structure keeps the skull lightweight for flying. Light can easily penetrate a bird's skull to reach its brain.

In laboratory tests, exposing birds to artificially long days activates their reproductive systems and produces hormonal changes. However, after about 70 of these long, summer-like days, most Oscines become desensitized to the light. Hormone production shuts down, and the VCR becomes smaller. This reversal is called "photorefractoriness."

2 sec

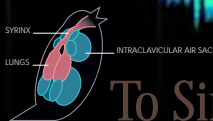
3 sec

4 sec

5 sec

1 sec

2 sec



## To Sing a Song

The most powerful human singing voice can shatter glass. But no opera star can match the range and complexity of a common songbird.

Birds have the greatest sound-producing ability of all vertebrates. They have the ability to produce harmonics—multiple tones of different frequencies. They can even produce two different, complex songs simultaneously.

Some birds can sound special alarm calls that alert their kin to predators without giving away the caller's location. Others sing duets that are so well coordinated they seem to be produced by a single bird. A few birds, such as mynahs, can even mimic human speech.

Birds owe their vocal prowess to a unique organ called the syrinx. Unlike humans, birds do not have vocal cords located in the larynx. The syrinx lies lower inside the bird's body. This difference was discovered in a rather gruesome manner about 400 years ago, when Italian naturalist Ulyssis Aldrovandus observed that ducks and chickens continued to call after their heads were chopped off.

The syrinx is located just beneath the bird's trachea. It branches into independent halves at the junction of the bronchial tubes.

Birds exhale air forcefully through the syrinx. The air causes thin membranes in the syrinx—called tympaniform membranes—to vibrate. These vibrations produce sound. The characteristics of these sounds depend on several factors. Syringeal muscles change the tension of the tympaniform membrane to produce different tones. Think of plucking on a rubber band—the more you stretch the band, the higher the pitch of the sound.

The respiratory system of birds includes a set of air sacs that extend throughout the body cavity. These sacs are also found in the wing and leg bones. The air sacs help provide a continuous airflow through the lungs. They have other functions as well. The air sacs help to regulate body temperature and protect delicate organs during flight.

Within the syrinx itself, a structure called the interclavicular air sac plays a role in sound quality. Pressure in the interclavicular air sac pushes the tympaniform membrane into the bronchial air space. This protrusion changes the diameter of the air passageway and affects sound characteristics.

When the tympaniform membrane vibrates freely, the bird produces a whistled song without harmonics. Harmonics occur when the membrane's movement is distorted. Scientists do not yet know the exact cause of these distortions.

The force at which the bird expels air through the syrinx can affect the volume of its song. In addition, rhythmic activity from the respiratory and syringeal muscles allow for a variety of trills and warbles.

Scientists marvel at the efficiency of the syrinx. How efficient is it? Consider that humans use only about 2 percent of the air passing through the larynx to make sound. Birds use 100 percent of the air that passes through the syrinx. *Diane Boudreau*

**"Bird and human** BRAIN CELLS LOOK ESSENTIALLY THE SAME. BUT SOMETHING ABOUT BIRDS ALLOWS THESE CELLS TO REALLY REGENERATE IN ADULTHOOD," SAYS PIERRE DEVICHE.

SONOGRAMS, LIKE THE IMAGES AT TOP, CAN BE USED TO VISUALIZE DIFFERENCES IN BIRD SONGS THAT HUMANS CANNOT HEAR, BUT BIRDS DETECT. THE GRAPHS DEPICT FREQUENCY RANGE AND DURATION OF THE SOUNDS. AT LEFT, ONE SONG OF THE CASSIN'S SPARROW, WITH FREQUENCIES BETWEEN ABOUT 4 AND 8 KHZ. ABOVE, THE RUFOUS-CROWNED SPARROW.



**BIRDS OF NOTE** More than half of all birds on Earth belong to the order *Passeriformes*. Scientists call them passerines. The rest of us know them as perching birds. Most passerines are small or medium-sized birds. The largest passerine species are the ravens (*Corvus corax*). There are two basic types of passerines: the sub-Oscines and the Oscines. The majority of passerines found in North America and Eurasia are Oscines. The Oscines are also known as songbirds, because they produce learned songs. Some of the birds categorized as Oscines include: swallows, martins, larks, wrens, mockingbirds, thrushes, orioles, crows, magpies, and jays. Sub-Oscines are rare in North America, but many species live in tropical regions. This group includes New World flycatchers, phoebes, and kingbirds. Diane Boudreau

EGG IMAGES COURTESY OF THE PROVINCIAL MUSEUM OF ALBERTA, EDMONTON, ALBERTA

The reproductive systems of most birds are activated when day length hits about 12 hours—usually in mid-March. The breeding season ends about 70 days later, in mid- to late June.

A few desert birds, however, buck this trend. These species start breeding when the monsoon rains arrive in June or July, a time when most other birds are finished reproducing. Deviche has studied one of these desert nonconformists, the Rufous-winged Sparrow.

He found that the sparrow responds to day length just like other birds. Unlike other birds, however, the sparrow never becomes photorefractory. In laboratory studies, Deviche has exposed the bird to a full year of long days and the animal never stopped being ready to breed.

The Rufous-winged Sparrow is part of the *Aimophila* genus, a group of sparrows that mostly evolved in Mexico, where water is scarce. It makes sense, then, for these birds to wait for the monsoon rains before breeding.

"In May or June before the monsoon, the desert is a hard place to live. There's little water and few insects. It's not a good time to breed, for some bird species at least. Not many do until the monsoon arrives," says Deviche. "However, these sparrows are sexually ready before the monsoon. Some of them do breed then, but it's rare. Obviously, something else is acting on them. But what is it? Rain? Humidity? Light intensity? Insect availability?"

Deviche was awarded a grant from the National Geographic Society to find an answer to this question.

"We will bring birds into captivity and expose them to various stimuli, like the sight and sound of rain, and the sound of thunder," he says of the upcoming study. The ASU scientist will try to tease out what exactly the birds are responding to, and how it affects them physiologically.

Deviche and his team will study the Rufous-winged Sparrow and two other desert birds of the same genus. He wants to know if the loss of photorefractoriness is an adaptation of desert birds or just a fluke in one species.

**Studying birds in the wild** is important to Deviche, because most research on the brain mechanisms that control singing in Oscines has been limited to only two species: canaries and Zebra finches. "They are selected because they sing a lot and they sing year-round," he says. "We have to keep in mind that both of these species have been bred in captivity for many years. My question is this: To what extent does this research apply to other birds out there?"

He has tried to stay away from the commonly studied species, focusing on animals in the wild. His research shows that many of the early findings on captive birds do apply to wild birds as well.

Deviche has always been an avid birdwatcher. He completed his doctoral work studying how hormones affect the behavior of ducks. "When you start studying behavior, you start to wonder how that behavior is controlled," he says.

Slowly, scientists like Deviche are uncovering the mechanisms that control bird behavior. Perhaps it will provide some insight into how and why birds developed song—and the vocal regions that control it—in the first place.

"For all we know, the closest living relative to birds is the crocodile. If you go into the brain of a crocodile, however, you won't find any of this," Deviche says. "Crocodiles don't sing. What's with these [brain] areas? Did birds develop these areas out of nothing? You don't find them in anything else."

The ASU biologist adds that hummingbirds also learn their songs, just like Oscines, but they are only distantly related on the phylogenetic tree. Deviche wonders, "Did this ability evolve from something more primitive, kept in Oscines and hummingbirds but discarded in other species?"

One question always leads to a series of others. Deviche and his colleagues have plenty of work to find the answers.