When Animals Dream

The Hidden World of Animal Consciousness

David M. Peña-Guzmán

PUBLISHED BY PRINCETON UNIVERSITY PRESS
41 William Street, Princeton, New Jersey 08540
99 Banbury Road, Oxford OX2 6JX

press.princeton.edu

Library of Congress Cataloging-in-Publication Data

Names: Peña-Guzmán, David M., author.
Title: When animals dream : the hidden world of animal consciousness / David M. Peña-Guzmán.
Description: Princeton : Princeton University Press, [2022] | Includes bibliographical references and index.
Identifiers: LCCN 2021050401 | ISBN 9780691220093 (hardback) | ISBN 9780691220109 (ebook)
Subjects: LCSH: Consciousness in animals. | Animal rights—Moral and ethical aspects. | BISAC: PHILOSOPHY / Ethics & Moral Philosophy | SCIENCE / Life Sciences / Zoology / Ethology (Animal Behavior)
Classification: LCC QL785.25 .P46 2022 | DDC 156/.3—dc23/eng/20211208
LC record available at https://lccn.loc.gov/2021050401

Version 1.0

British Library Cataloging-in-Publication Data is available

Editorial: Matt Rohal
Production Editorial: Ali Parrington
Jacket and Text Design: Chris Ferrante
Production: Erin Suydam
Publicity: Matthew Taylor & Carmen Jimenez
Copyeditor: Michele Rosen

Jacket art: *Muusoctopus levis,* Enteroctopodidae. Plate LXXIX from *Die Cephalopoden* by Carl Chun, 1915.

CONTENTS

ACKNOWLEDGMENTS

Even if only my name appears on the cover, this book is the offspring of what the feminist science scholar Karen Barad calls an "agential network," which refers to complex structures whose effects are best understood as emerging from the convergence of multiple factors rather than the conscious intent of any one individual. In these networks, agency is decentralized and distributed such that even the most centrally located of nodes can never claim to be more than that—a node, one among many.

I want to express my gratitude to the many nodes that have made this book possible, beginning with two people who, without their knowledge, put me on the path that would culminate in me writing these words. The first is Tanya Augsburg, whose invitation to speak at the 2018 meeting of The Animal Union marked my first public mention of my interest in the nightly experiences of other species—even if, at the time, this interest was little more than a nebulous idea in the back of my mind. The second is Marjolein Oele, who invited me to give a talk at the University of San Francisco a few weeks later, in April 2018. I used this opportunity to dig more seriously into the science and philosophy of dreaming and sculpt my still ill-defined interest into something resembling a coherent philosophical thesis. This talk was well received by students and faculty alike, which is how I started toying with the idea of writing a book.

Having never done such a thing, however, the thought filled me with dread and made me ooze more insecurities than I care to admit—about my writing style, about my authorial voice, about my research skills, and, of course, about being found out as the impostor that I obviously was. Fear grabbed hold of me, and I decided to simply let the project fall by the wayside.

It was Rabih Hage who changed my mind and convinced me not to flee from the challenge. It was him who, with the skill of a seasoned therapist, assuaged my fears and encouraged me to write, even when I got my first real taste of writer's block. It was also him who, with the generosity of a partner but the rigor of an expert, answered all my questions about neuroscience while pressing me with tough questions of his own about the philosophical use I intended to make of it. Sadly, this kindness backfired on him since it was him, too, who endured more rants about

animals and their dreams in a single year than anyone should in an entire lifetime—a suffering he bore with the patience of a saint. Throughout this process, he has been it all: my lover, my friend, my interlocutor, my editor, my confidant, my critic. This book has been made better by him, as have I. I dedicate this book to him, my partner in all things.

Writing can be an unbearably lonely activity, and most of the writing for this book was done under conditions of intense isolation: during confinement in Paris, France, in 2020. These were difficult times that I braved by holding on for dear life to my partner, family, and friends. My daily interactions with my partner anchored and sustained me. My phone calls with my mother, my brother, and my extended family in Mexico drew me out of myself and gave me perspective. My friendships renewed and restored me.

Many of these friendships directly aided and abetted in the writing of this book. Jessica Locke, Osman Nemli, and I formed a writing accountability group that met weekly during the pandemic. I benefitted tremendously from these encounters, which gave me structure, kept me on track, and kept me honest. I thank both for their constructive and critical feedback on various chapters. I also thank Rebecca Longtin, Joel M. Reynolds, Alex Feldman, Michael Sano, and Deborah Goldgaber, all of whom also lent their support. Their observations, critiques, and recommendations had a meaningful impact on my thinking and writing. Special thanks to Rebekah F. Spera, who put together the book's index and edited the manuscript from top to bottom, saving readers from some of my less honorable writing habits along the way.

I also would like to thank the members of two scholarly communities at San Francisco State University that helped me process my ideas in a welcoming and collaborative environment: the "Historicity of Consciousness" reading group that I co-founded with Arezoo Islami, and the STS HUB run by Laura Mamo, Martha Kenney, and Martha Lincoln. Also deserving of mention are my colleagues in the School of Humanities and Liberal Studies: Cristina Ruotolo, Tanya Augsburg, Jose Acacio de Barros, Denise Battista, Sean Connelly, Karen Coopman, Brad Erickson, Mariana Ferreira, Judith Fraschella, Laura Garcia-Moreno, Logan Hennessy, George Leonard, Sarah Marinelli, Marie McNaughton, Peter Richardson, Steve Savage, Mary Scott, Nick Sousanis, Christopher Sterba, Shawn Taylor, Rob Thomas, and Stacey Zupan. I could not have finished this book without the material support of the George and Judy Marcus Fund for Excellence in the Liberal Arts, which financed my sabbatical leave in the spring of 2020.

Finally, I take my hat off to the very competent team at Princeton University Press. Matt Rohal has been an efficient, wonderful, and caring editor who believed in this project even when I still harbored serious doubts about its viability. He saw its potential and nudged me to make it accessible to a general audience, something that doesn't come naturally to people in my line of work (academic philosophy). Michele Rosen proved an excellent copyeditor whose eagle eye for detail improved

the manuscript greatly. Ali Parrington saw the manuscript through copyediting and the successive production stages, ensuring that all the deadlines were met by all the relevant nodes. Chris Ferrante designed the stunning cover, while Emma Burns took charge of the in-chapter illustrations under the coordination of Dimitri Karetnikov. Their artistic talent has added an entire dimension of meaning to the book for which I take no credit.

Like me, each of these individuals is a node in the network that begat the book you now hold in your hands. Still, any errors unearthed in the book are through no one's fault but my own.

INTRODUCTION

In the Trenches of Sleep

I can hear little clicks inside my dream.
Night drips its silver tap
down the back. At 4 A.M. I wake. Thinking

—ANNE CARSON[1]

HEIDI'S DREAM

Season thirty-eight, episode one of the PBS series *Nature*, "Octopus: Making Contact,"[2] promised viewers a rare journey into the inner lives of octopuses, billed as "the closest we may get to meeting an alien." The star of the one-hour documentary is Heidi, a female day octopus (*Octopus cyanea*) who lives with the narrator, David Scheel, a biologist at Alaska Pacific University. Unlike most captive octopuses, Heidi lives neither in an aquarium nor in a laboratory, but in Scheel's private residence in Anchorage—a charming mix of roommate, companion animal, and research assistant.

"Octopus: Making Contact" tells a tale of octopuses not as "stupid creatures," which is how the Greek philosopher Aristotle described them in 355 BCE, but as intelligent and naturally curious beings who have unique personalities, recognize others of the same species, and solve complex problems. From start to finish, octopuses are presented as conscious agents who know when they are being observed and who, more importantly, do not hesitate to observe in return. "When you look at them," says Scheel, "you feel like they're looking back. That's not an illusion. They *are* looking back."

Near the end of the documentary, as Heidi is shown sleeping in her tank, Scheel reports: "Last night, I witnessed something I've never seen recorded before." What follows is a breathtaking one-minute-long shot. In it, Heidi is at first peacefully restful, but after a few seconds her skin lights up, displaying a sequence of dramatic, multicolored patterns, each one more mesmerizing than the last. The "something" Scheel is referring to may be an *octopus dream*.

His voice then walks the viewer through each of Heidi's arresting displays, noting, "you could almost just narrate the body changes and narrate the dream."

DISPLAY 1

Heidi changes from a smooth and consistent alabaster white to a flashing yellow with blotches of mandarin orange. "So here she's asleep, she sees a crab, and her color starts to change a little bit."

DISPLAY 2

From these splendid shades of yellow and orange, Heidi changes to a dark and piercing purple, a purple so deep that for a fraction of a second, we cannot tell where her body ends and the dark blue background begins. "Octopuses will do that when they leave the bottom," usually after a successful kill, Scheel explains.

DISPLAY 3

Heidi then changes into a series of light grays and yellows, except this time the colors are crisscrossed by a disordered topology of ridges and spiky horns, the textured byproduct of the contractions of the papillae on her skin. "This is a camouflage, like she's just subdued a crab and she's just going to sit there and eat it, and she doesn't want anyone to notice her."[3]

The camera then turns to Scheel himself, who says with noticeable elation: "This really is fascinating [...] If she's dreaming, *that's* the dream."

Heidi became a viral sensation overnight. Within days, thousands of people shared the video of her dream on social media, and major news outlets rushed to cover the story. Viewers were simultaneously fascinated and stupefied. Her sleep displays were stunning, a veritable kaleidoscope of flesh. But what did they mean? And beneath this procession of color and texture, what was Heidi herself thinking or feeling? As Elizabeth Preston put it in the *New York Times*, "[A]n octopus is almost nothing like a person. So how much can anyone really say with accuracy about what Heidi was doing?"

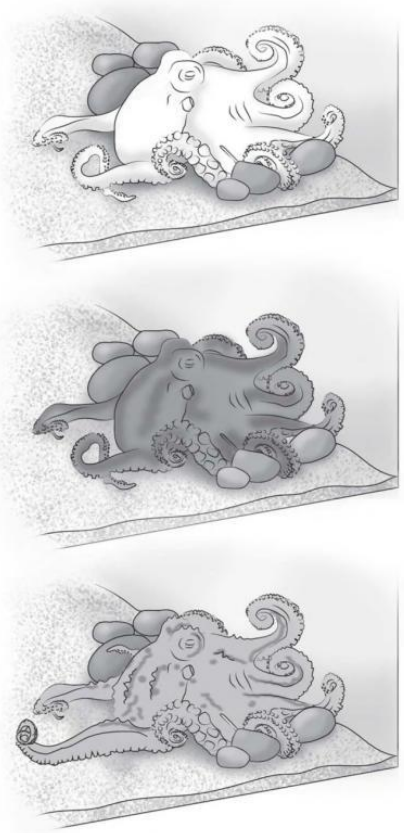

FIGURE 1. Heidi displays three separate chromatic patterns in a row while asleep, probably on account of experiencing a dream in which she is hunting and eating prey.

Pan out and the bigger question becomes: What goes on in the minds of nonhuman animals when they sleep, or, as the poet Anne Carson says, when "night drips its silver tap"? Do they experience those penetrating nightly visions that humans do, which Shakespeare described as "the children of an idle brain"? Or do their minds simply plummet into a psychic void in which no conscious experience takes root? Can other animals—not just octopuses, but parrots, lizards, elephants, owls, zebras, fish, marmosets, dogs, and so on—truly dream? If so, what does this tell us about who these creatures are and how they dwell in this world? And if not, does this mean that dreaming may be the cognitive Rubicon that separates us from the other animals? Are humans "the dreaming animal," as the Spanish philosopher George Santayana believed?[4]

This book is about these questions.

ANIMAL INTERIORITY

Even though humans have been fascinated by the possible dreamworlds of other animals for millennia,[5] the first modern scientific publication devoted to animal dreaming appeared in 2020. In an article published in the *Journal of Comparative*

Neurology under the title "Do All Mammals Dream?," the biologists Paul Manger and Jerome Siegel express doubt that only humans experience dream sequences during sleep, and they wonder whether dreaming—that curious mental happening that the sociologist Eugene Halton describes as "the mind's nightly ritual of inner icons"[6]—may be a universal feature of mammalian life, something we share with all other species whose young feed from the mother's mammary glands. I will come back to this mammalocentric hypothesis in chapter 1, but for now I want to emphasize that this article stands out within the field of animal sleep research as a genuine anomaly: the only publication in a scientific journal to use the terms "dream" and "dreaming" explicitly in connection to animals other than *Homo sapiens*.[7]

To be clear, this is not the only publication to shed light on what goes on inside the minds and bodies of animals during sleep. Far from it. Over the last century, biologists, psychologists, and neuroscientists have made significant strides in cracking the code of animal sleep, giving us a fuller picture of the imperatives of animal experience across the great sleep-wake divide. Nevertheless, these same experts have historically shied away from describing their findings using the language of dreams. Instead, they have opted for more phenomenologically ambivalent terms, such as "oneiric behavior"[8] and "mental replay,"[9] that allow them to talk at great length about the mechanics of animal sleep—the biological processes that regulate it, the physiological changes that prompt it, the neurochemical changes it occasions, and so on—without needing to take a stance on whether any of the animals under study actually experience anything subjectively at any point during the cycle of sleep. Because of their intrinsic agnosticism, these terms end up blotting out some of the most philosophically stimulating questions raised by the possibility of animal dreaming, especially questions concerning consciousness, intentionality, and subjectivity.

In this book, I build on contemporary animal sleep research to show that what scientists refer to as "oneiric behaviors" and "mental replay" in sleeping animals should be interpreted as the result of internally generated dream sequences that animals experience—even if only momentarily—as their very reality. Rejecting this phenomenological interpretation, I argue, would require holding two conflicting beliefs at once: first, that many animals display the same patterns of motor and neural activity during sleep that are widely accepted as indices of dreaming in humans; and second, that while this bustle is going on inside them, these same animals sense, feel, and think nothing. It would almost require believing that the minds of animals magically disappear into the ether the moment animals drift off into sleep; that, immediately upon entering the kingdom of Hypnos, a gaping abyss opens up beneath them and swallows them whole. While this position is not necessarily illogical, a close reading of the empirical data reveals it to be untenable. Even if scientists are reluctant to talk about the dreams of animals (say, for reasons of scientific humility), their findings point in precisely that direction.

My concern is that, aside from betraying a problematic double standard,[10] this reluctance to talk about animal dreaming feeds a larger cultural prejudice that rationalizes our appalling treatment of animals. In a seminal article on animal consciousness, the father of cognitive ethology, Donald Griffin, called this prejudice "mentophobia"—the fear of viewing animals as creatures with minds of their own.[11] This fear leads us to see animals as food to be consumed, reservoirs of labor power to be exploited, resources to be used, and specimens to be cultured and dissected—as anything, that is, except creatures who live, feel, and think on their own terms. While mentophobia affects all areas of social life, Griffin recognized that it exerts an exceptionally strong pressure on the scientific community, a pressure that is most conspicuously on display whenever scientists resist attributing complex mental states to the animals they study even when there is ample support for it. It is because of mentophobia that most of us continue to see animals, in the now infamous words of the philosopher Normal Malcolm, as "thoughtless brutes"; that is, as creatures who eat, sleep, and die, but who never develop a meaningful cognitive, emotional, or existential bond with the world.[12] Once animals are pigeonholed into this category, their fate is sealed. There are simply too many things one cannot expect from a thoughtless brute.

One of them is the capacity to dream.[13]

And yet: watching the displays of Alaska's most famous cephalopod feels very much like witnessing the collision of two subjective realities—one human, one not. It is almost as if Heidi's flamboyant metamorphoses bring within the reach of our human, all-too-human senses that alluring yet inscrutable realm of reality from which every human observer has been barred from time immemorial: the inner world of another animal. Perhaps a phenomenology of animal dreaming can explain why. If, while watching Heidi's displays, we feel that we are coming face-to-face with another subjective reality that is recognizable and alien at once, this may be because the band of colors marching rhythmically on the surface of her skin bespeaks a dream, a dream that—much like the dreams of the myriad other animals we will encounter throughout this book—is itself an irrefutable sign that *there exist, alongside ours, endless other worlds—utterly "Other," inhuman worlds. Enigmatic, foreign, hidden animal worlds.*

Worlds without human contours.

Worlds with nonhuman centers.

AN INTEGRATIVE APPROACH

There are experts who worry that attributing dreams to animals anthropomorphizes them by projecting a uniquely human ability onto them. In their view, animal researchers should stick to what the philosopher of science Peter Winch calls

"external descriptions" of behavior, leaving considerations of animal interiority to their colleagues from across the quad: the philosophers.[14] In defense of this division of intellectual labor, they offer a host of arguments. Sometimes, they invoke the authority of "Morgan's canon," which says we must opt for the simplest possible explanation of animal behavior.[15] Sometimes, they appeal to the philosophical "problem of other minds," which maintains that we cannot say that animals have an interior life because we lack direct access to their first-person experience of the world.[16] At other times, however, they hint at the problem of language. In the absence of a shared language, they say, we cannot make empirically meaningful claims about how, when, or why—or even whether—other animals dream, let alone about the nature, structure, and quality of their putative dream experiences. What are dreams, after all, if not unobservable mental happenings whose existence we can infer only on the basis of subjective verbal reports—reports that animals cannot provide?

However appealing, this view relies on the conceit that the scientific study of dreams depends solely or mostly on the compilation, analysis, and interpretation of dream reports. Surely, dream scientists have learned, and continue to learn, a great deal from the verbal reports of human dreamers about what our minds and bodies do when we go "offline." But the bulk of dream research since the 1980s has not been exclusively (or even primarily) based on the analysis of linguistic reports. It has been based on the investigation of the neural and behavioral correlates of dream experiences, which is to the say, the brain activity and bodily behaviors that correspond with the subjective experience of dreaming. A brief survey of contemporary human dream research reveals a vast, interdisciplinary, and rapidly evolving field in which experts concentrate on spotting the neural signatures (e.g., ponto-geniculo-occipital, or "PGO," waves)[17] and behavioral markers (e.g., rapid eye movements or "REMs") of human dream phenomenology.[18]

While our inability to speak with other animals certainly limits what we can know about their dream experiences, it does not prevent us from making meaningful and empirically educated claims about their capacity to dream, or even from ruminating about the possible implications of this capacity for ongoing scholarly debates about animal consciousness, animal emotion, and animal ethics.[19] Indeed, throughout this book I use an *integrative method* to advance several such claims. In essence, this method involves:

1. surveying the empirical literature on animal sleep for findings that might point to dream experiences in other animals; and,
2. interpreting these findings through a philosophical lens that combines conceptual tools and resources from such fields as phenomenology, the philosophy of consciousness, and the philosophy of animal cognition.

FIGURE 2. While linguistic reports remain a valuable tool in dream science, much contemporary dream research relies on the use of electroencephalography (EEG), functional magnetic resonance imaging (fMRI), and positron emission tomography (PET) to isolate the neural circuits involved in dreaming. Here, a woman wears an EEG headset in preparation for a study.

Using this method, I can take the empirical data seriously while asking vital philosophical questions about what this data means. For, as we shall see, its meaning *is* up for grabs.[20]

THE BOOK—STRUCTURE AND AIMS

People who interact with animals as part of their everyday life—animal lovers, farmers, veterinarians, animal activists, and so on—may be tickled by the thought that someone would write an entire book about something that strikes them as obvious: that we share the ability to dream with many other critters. But holding this belief is one thing; defending it on scientific grounds is another; and teasing apart its philosophical implications is yet another. In the chapters that follow, I do all three.[21]

In chapter 1, "The Science of Animal Dreams," I turn to animal sleep research to catalog evidence that animals run "reality simulations" during key phases of their sleep cycles. Even taking certain methodological and conceptual limitations into account, the preponderance of this evidence supports the conclusion that humans are not the only dreamers on earth.

In chapter 2, "Animal Dreams and Consciousness," I consider the philosophical significance of the evidence laid out in chapter 1. Here, I introduce the "SAM" model of consciousness, which distinguishes three types of self-awareness: "S" for subjective (being at the center of a phenomenal field of experience), "A" for affective (experiencing events as emotionally shaded), and "M" for metaconscious (having the ability to reflect upon one's own mental life). Guided by phenomenological theories of dreaming, I assert that all animals who dream are necessarily *subjectively conscious*, that most (if not all) are also *affectively conscious*, and that a select few may be *metaconscious* as well.

In chapter 3, "A Zoology of the Imagination," I take the discussion of animal consciousness to a higher level by accentuating the imaginative character of dreams. Given that dreams hinge on the generation of sensory (visual, tactile, auditory, and so on) imagery, creatures who dream must possess what the philosopher of mind Jonathan Ichikawa calls "imaginative capacities," such as creativity, fantasy, and make-believe. I explore how these capacities congeal in dreams while presenting dreams as part of a larger spectrum of imagination that includes, inter alia, hallucinations, daydreams, and mind-wanderings.

In chapter 4, "The Value of Animal Consciousness," I tackle the ethical dimension. Do the dreams of animals matter from an ethical standpoint? Under most ethical frameworks, the answer to that would be yes, as consciousness is thought to determine which entities have moral status and which do not. Here, I use the philosopher Ned Block's famous theory of consciousness as a jumping-off point for articulating a novel account of why dreams are pregnant with what I call "moral force." On this account, dreams are morally significant because they reveal animals to be both carriers and sources of moral value, which is to say, beings who matter and *for whom* things matter.

The book closes with a short epilogue, "Animal Subjects, World Builders," in which I offer some final thoughts about the subjectivity of other animals and about what binds us to and cleaves us from them. It is in this tension between sameness and difference, between conjunction and disjunction, that the heart of this book lies. If inhabited correctly, I argue, this tension can open up contemporary debates about animal minds and animal experience and make us question some of our more disturbing assumptions about our nonhuman comrades, so that we can begin the task of collectively learning to see animals truly anew—no longer as the evolutionarily, cognitively, metaphysically, or even spiritually impoverished versions of us that we have historically taken them to be, but as the fully realized, inviolable, sacred versions of themselves that they already are and always have been.

Sanctis conducted with breeders, farmers, hunters, and circus trainers about the dreams of "superior animals" such as dogs, horses, and birds.[10]

Animal dreams may have been deeply ingrained in the cultural and scientific imaginaries of the nineteenth century, but the tide eventually turned. Due to several developments, especially the rise of behaviorist psychology, what began in the 1870s as a wave of support for the complexity of animals' minds morphed over the span of only a few decades into a pervasive skepticism about animal cognition of any kind.[11] After the turn of the century, the life sciences adopted a new attitude—a colder, more distant attitude—that led new generations of scientists to distance themselves from their predecessors and to accuse them of projecting human abilities onto animals.[12] By the 1930s, many of the topics that had galvanized nineteenth century naturalists—animal reasoning, animal language, animal emotions, animal play, and, of course, animal dreaming—had fallen into scientific ill repute, and most of them remained there for a long time. I call the period stretching from the 1900s to the 1980s "the silent century" because, during this time, discussions of animal consciousness came to a standstill from which our scientific culture is still trying to break free.

Thankfully, scientists from various fields have started reclaiming some of these topics as legitimate objects of scientific inquiry. Since the 1990s, research on animal emotions has exploded, as has empirical and philosophical work on animal cognition. Unfortunately, the topic of animal dreaming has not been so lucky. As of the time of this book's publication, almost a hundred and fifty years after the publication of Lindsay's *Mind in Lower Animals*, the bulk of the scientific community continues to dismiss the idea that animals dream (let alone that their dreams might be empirically studied) as anthropomorphic, which is to say, as a romantic and non-scientific illusion that misleads us into projecting the traits of the human onto the nonhuman. This is true of many scientists who specialize in dreams, but it is almost universal among experts in animal sleep.[13]

The irony is that over the last three decades, the life sciences have generated a good deal of evidence that our nineteenth century forebearers may have been right about what the minds of animals do, in the words of Jennifer Dumpert, "at the edges of sleep."[14] In this chapter, I catalog and analyze this evidence, dividing it into three categories: electrophysiological, behavioral, and neuroanatomical. When properly interpreted, this evidence shows that our collective error was not that we considered humans and the other animals on a continuum of mental activity during the nineteenth century, but rather that we turned our backs on this continuist perspective in the twentieth and, as a result, our perception of animals changed for the worse. We began seeing their lives as so deficient, so dull, so bare, and so contemptible in comparison to ours that, in an act of collective self-delusion, we convinced ourselves that they could not possibly have what we have: a meaningful inner world. *That* was our mistake.

A Soundless Song

In the year 2000, the biologists Amish Dave and Daniel Margoliash published a report in the journal *Science* describing their research on zebra finches (*Taeniopygia guttata*), which are passerine birds native to Australia. One of the evolutionary challenges these birds face is that they must learn their song from their parents and siblings, since it is not innate.[15] Research on birdsong has historically focused on what these animals do while awake to imitate and memorize their song, but Dave and Margoliash wondered whether sleep might also play a role in song acquisition. Could sleep help juvenile finches internalize the acoustic patterns they hear from their family members and commit them to long-term memory? Could these birds learn their song at least in part by rehearsing it in their minds while asleep?

To test this possibility, Dave and Margoliash performed an experiment in which they mapped the patterns of neural activation elicited in the "birdsong system" (the forebrain nucleus robustus archistriatalis) of a group of juvenile finches while they slept. By analyzing these patterns, they discovered that the brains of zebra finches oscillate between two states during sleep: a state of constant but low-level neural activity in which nothing remarkable happens, and a state marked by spontaneous bursts of high-level neural activity recurring at regular intervals. In itself, this discovery was not particularly groundbreaking, as it merely confirmed previously published work on avian sleep reporting a sleep cycle divided into phases of low and high neural activity (just like mammalian sleep). However, Dave and Margoliash then decided to map the neural pattern that emerged in the same brain region when the finches practiced their song while awake and to compare it to the patterns elicited during sleep. Their findings were astonishing.

They discovered that the pattern elicited by the act of singing while awake was an exact structural replica of the pattern elicited during the period of sleep marked by sudden bursts of high-level neural activity, which was all they needed to realize that the brains of the zebra finches were doing the exact same thing—their neurons were firing in the same organized manner—when the birds sang their song in the middle of the day for the world to hear as when they entered a period of high neural activation during sleep. The match was so perfect that the authors realized they could map these patterns onto one another syllable-by-syllable, nay, *note-by-note*. From this, they concluded that zebra finches learn their song not only by practicing it out loud while awake ("play") but also by mentally replaying it while asleep without making a chirp ("replay"). "Replay," they write, "generates coherent activity throughout the song system that is similar to singing in the absence of actual sound production and perception."[16]