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PERSPECTIVES

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BIOLOGY AND MUSIC: Enhanced: The Music of Nature and the Nature of Music

Patricia M. Gray, Bernie Krause, Jelle Atema, Roger Payne, Carol Krumhansl, Luis Baptista [HN27] *

Our world is filled with innumerable natural sounds, and from the earliest times humans have been intrigued and inspired by this "soundscape." People who live close to nature perceive a wider range of sounds than those of us living in industrialized societies, who rely heavily on advances in sound technology. The sounds of whales in the ocean, for example, were first recorded in the 1940s, yet the Tlingit, Inuit, and other seafaring tribes have been hearing them through the hulls of their boats for millennia. Similarly, the ultralow frequency communications of elephants [HN1] have only just been recorded even though the Hutu and Tutsi tribes of central East Africa have incorporated these sounds into their songs and stories for centuries.

It is said that every known human culture has music. Music has been defined as patterns of sound varying in pitch and time produced for emotional, social, cultural, and cognitive purposes (1). Is music-making in humans defined by our genes? [HN2] Do other species show musical language and expression? If they do, what kinds of behavior invoke music-making in these animals? Is there evidence in the animal kingdom for the ability to create and recreate a musical language with established musical sounds? How are musical sounds used to communicate within and between species? Do musical sounds in nature reveal a profound bond between all living things?

The Music of Nature

Whales. The undersea songs of humpback whales [HN3] are similar in structure to bird and human songs and prove that these marine mammals are inveterate composers. If songs can be defined as "any rhythmic repeated utterance, whether by a bird, a frog, an insect, a whale or a human being" (2), then humpback whale songs [HN4] are constructed according to laws that are strikingly similar to those adopted by human composers.

· Singing humpbacks use rhythms similar to those in our own music, yet they could just as easily formulate free-form, arrhythmic sounds.

· They use phrases of a similar length to ours--a few seconds--and create themes out of several phrases before singing the next theme. Their songs could easily "grow" organically without the need for repetition but, like human composers, these marine mammals prefer to reiterate their material.

· Whale songs fall between the length of a modern ballad and that of a movement of a symphony. Perhaps they have chosen the same length of performance as we have because, with their large cerebral cortex, they have a similar attention span to humans.

· Even though they are capable of singing over a range of at least seven octaves, humpbacks use musical intervals between their notes that are similar to or the same as the intervals in our scales.

· Whales mix percussive or noisy elements in their songs with relatively pure tones, and do so in a ratio similar to that used by humans in Western symphonic music.

· In some whale songs, the overall song structure is similar to human compositions: a statement of theme, a section in which it is elaborated, and then a return to a slightly modified version of the original theme (that is, the ABA form) [HN5].

· The tone and timbre of many whale notes are similar to human musical sounds. With an infinitude of possible sounds to choose from, whales could easily prefer to make sounds that we would deem unpleasant (roars, stutters, grunts).

· Most surprisingly, humpback songs contain repeating refrains that form rhymes. This suggests that whales use rhyme in the same way that we do: as a mnemonic device to help them remember complex material (2).

The fact that whale and human music have so much in common even though our evolutionary paths have not intersected for 60 million years, suggests that music may predate humans--that rather than being the inventors of music, we are latecomers to the musical scene.

Birds. Advances in audio technology allowed the late Luis Baptista [HN6] to draw fascinating parallels between bird song [HN7] and human music (3). For instance, when birds compose songs they often use the same rhythmic variations, pitch relationships, permutations, and combinations of notes as human composers. Thus, some bird songs resemble musical compositions; for example, the canyon wren's [HN8] trill cascades down the musical scale like the opening of Chopin's "Revolutionary" Etude [HN9].

An examination of bird song reveals every elementary rhythmic effect found in human music (4). There are interval inversions, simple harmonic relations, and retention of melody with change of key [HN10]. Many birds regularly transpose motifs to different keys (5). Some birds pitch their songs to the same scale as Western music, one possible reason for human attraction to these sounds. For example, notes in the song of the wood thrush (*Catharus mustelina*) [HN11] are pitched such that they follow our musical scale very accurately (6). The interval between the first and second parts of the song of a ruby-crowned kinglet (*Regulus calendula*) [HN12] is often a full octave. The canyon wren sings in the chromatic scale (which divides the octave into 12 semitones) (7) and the hermit thrush (*Catharus guttatus*) [HN13] in the pentatonic scale (which consists of five different tones within the octave) [HN14] (8).

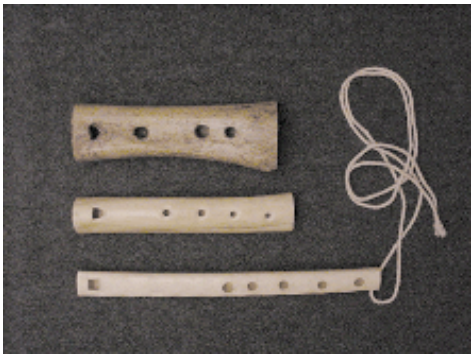
The simple melodic canon [HN15], a frequent device in human composition based on imitation, is reminiscent of the matched countersinging of many bird species.

The Socorro mockingbird (*Mimodes graysoni*) [HN16] of Mexico sings a long series of short themes and its immediate neighbor will then respond to each theme with the identical theme (9). The Californian marsh wren (*Cistothorus palustris*) [HN17] may sing as many as 120 different themes in a fixed sequence. Each theme is matched by its neighbor in a leader-follower sequence (in music this is known as the call-response pattern) (10).

Not all bird sounds emanate from the vocal tract--some are produced with "instruments" such as special feather structures, others by the bird pounding on an object with a "preferred" resonance. Perhaps the most remarkable example of a bird using an instrument to produce sound is that of the palm cockatoo (*Probosciger aterrimus*) [HN18] of Northern Australia and New Guinea (11). Each male breaks a twig from a tree, then shapes it into a drumstick. The bird selects a hollow log with a preferred resonance and then, holding the stick with its foot, drums on the log as part of its courtship ritual.

Humans. Human music-making may vary dramatically between cultures, but the fact that it is found in all cultures suggests that there is a deep human need to create, perform, and listen to music.

It appears that our Cro-Magnon and Neanderthal ancestors [HN19] were as fond of music as we are. The discovery of prehistoric flutes [HN20] made of animal bone in France and Slovenia, ranging in age from 4000 to 53,000 years old, demonstrates that ancient civilizations devoted considerable time and skill to constructing complicated musical instruments (see the figure, below). Reconstructions of these prehistoric flutes suggest that they resemble today's recorders [HN21] (12). It is possible that these ancient instruments even had a sound-producing plug (a fipple), making them easier to play but more difficult to make. Remarkably, many different types of scales can be played on reconstructed prehistoric flutes, and the sounds are pure and haunting. Given the sophistication of these 50,000-year-old instruments, it is quite possible that humans have been making music for several hundred thousand years.



No bones about Neanderthal music. Reconstructions of (**top**) a 53,000-year-old Neanderthal flute made of bear bone found in Slovenia (possibly recorder type), (**middle**) a 30,000-year-old French deer bone flute (most likely recorder type), and (**bottom**) a 4000-year-old French vulture bone flute (definitely recorder type).

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The oral tradition of the Sami--the indigenous people of the northern Scandinavian Peninsula and the Kola Peninsula of present-day Russia--is contained in exclusively vocal songs called yoiks [HN22] (13). Yoiks--consisting of short repeated cycles of nonsense syllables without linguistic meaning--describe everyday life and always carry personal meaning for the yoiker. Although not

described in words, the topic of a yoik may be a person, livelihood, an animal, a place, or an aspect of nature. It is believed that musical knowledge is acquired in part by the internalizing of frequently repeated patterns in a particular musical style, thereby enabling listeners to abstract recurring commonalities from the music that they hear (13). The ability to memorize and recognize musical patterns thereby creates learned oral traditions that are passed on to subsequent generations.

Musical Commonalities

The ability to memorize and recognize musical patterns is also central to whale and bird music-making. These learning patterns may be vertical traditions (when a behavior is passed from parent to offspring), oblique traditions (when adults who are not blood-related pass the culture to younger generations), or horizontal traditions (when peers learn from each other).

Vertical musical tradition, such as the Sami yoik, is found in all human cultures and in several finch species, including the zebra finch (*Taeniopygia castanostis*) and the Northern bullfinch (*Pyrrhula pyrrhula*) [HN23]. Oblique musical tradition is the central component of every music lesson and is probably the most widespread mode of learning songs among birds (14). Horizontal musical tradition is found on every children's playground, in hand-raised juvenile chaffinches (*Fringilla coelebs*) [HN24], white-crowned sparrows (*Zonotrichia leucophrys*) [HN25], and in Anna's hummingbirds (*Calypte anna*) [HN26], which when raised together develop very similar songs (14). Horizontal transfer of songs is also found among humpbacks--every whale in the same breeding area sings the same song and the song slowly evolves from year to year (2), but whales from different oceans sing completely different songs. By comparing any given whale song with a collection of song tapes, the year and the ocean from which the songs came can be identified. A recent report documented the extraordinary finding that the arrival of a few humpbacks from the Indian Ocean (Australia's west coast) to the Pacific Ocean (Australia's east coast) resulted in the resident Pacific whales ditching their own song in favor of the newcomer's ditty, a transformation that was complete within 3 years (15).

Universal Music

Ambient sound is a central component of natural habitats. Abstracting the voice of a single creature from a habitat and trying to understand it out of context is a little like trying to comprehend an elephant by examining only a single hair at the tip of its tail (before cloning, of course). The ambient sound of an environment mimics a modern-day orchestra: the voice of each creature has its own frequency, amplitude, timbre, and duration, and occupies a unique niche among the other musicians (16). This "animal orchestra" or biophony represents a unique sound grouping for any given biome and sends a clear acoustical message.

Musical sounds form an exciting, natural conduit between members of our own species, between our species and others, and between the arts and sciences. By looking at musical commonalities, our understanding of music is enlarging, and by viewing musical sounds as an intuitive, nonverbal form of communication, we can better understand our own development in a biodiverse world.

It has been postulated that there is an unproven (and probably unprovable) concept called mathematical Platonism, which supposes that there is a universal mathematics awaiting discovery. Is there a universal music awaiting discovery, or is all music just a construct of whatever mind is making it--human, bird, whale? The similarities among human music, bird song, and whale song tempt one to speculate that the Platonic alternative may exist--that there is a universal music awaiting discovery.

It is not known when the ancient art of making music first began. But, if it is as ancient as some believe, this could explain why we find so much meaning and emotion in music even though we cannot explain why it makes us feel the way it does. Such an impenetrable vagueness about this most basic of human creations seems to signal that the roots of music lie closer to our ancient lizard brain than to our more recent reasoning cortex, that music has a more ancient origin even than human language.

References and Notes

1. The BioMusic Program is a program of National Musical Arts (NMA), the resident ensemble of the National Academy of Sciences. The program emerged from NMA's involvement in the National Forum on BioDiversity conference co-hosted by the National Academy of Sciences and the Smithsonian Institution in 1986. It now serves as a think tank for a diverse group of scientists and musicians. The BioMusic Program is a unique conduit between art and science, as it seeks to examine music in all species and to explore and understand its powerful role in all living things. This Perspective summarizes presentations at the BioMusic Symposium held as part of the American Association for the Advancement of Science Annual Meeting (17 to 22 February 2000, Washington, DC). We dedicate this Perspective to our colleague Dr. Luis Baptista (deceased July 2000) **[AAAS meeting program]** .
2. R. Payne, *Whale Songs: Musicality or Mantra?* BioMusic Symposium, AAAS Annual Meeting, 2000.
3. L. F. Baptista, R. Keister, *Why Bird Song Is Sometimes Like Music*, BioMusic Symposium, AAAS Annual Meeting, 2000.
4. C. Hartshorne, *Born to Sing* (Indiana Univ. Press, Bloomington, IN, 1973).
5. E. A. Armstrong, *A Study of Bird Song* (Oxford Univ. Press, London, 1963).
6. D. J. Borror, C. R. Reese, *Ohio J. Sci.* **56**, 177 (1956).
7. C. Hartshorne, personal communication.
8. L. Wing, *Auk* **68**, 189 (1951).
9. J. E. Martinez-Gomez, L. F. Baptista, in preparation.
10. J. Verner, *Living Bird* **14**, 263 (1975); D. E. Kroodsma, *Auk* **103**, 189 (1979).
11. G. A. Wood, *Corolla* **8**, 94 (1984).
12. J. Atema, *Old Bone Flutes: Tracing the Origins of Human Music*, BioMusic Symposium, AAAS Annual Meeting, 2000.
13. C. L. Krumhansl *et al.*, *Music Percept.* **17**, 151 (1999); C. L. Krumhansl *et al.*, *Cognition* **75**, 13 (2000) **[Medline]**.
14. L. F. Baptista, S. L. L. Gaunt, in *Social Influences on Vocal Development,* M. Hausberger, C. Snowdon, Eds. (Cambridge Univ. Press, Cambridge, 1997), pp. 23-40; L. F. Baptista *et al.*, *Neth. J. Zool.* **43**, 17 (1993) **[publisher's information]** .
15. M. J. Noad *et al.*, *Nature* **408**, 537 (2000) **[Medline]**.
16. B. Krause, *The Niche Hypothesis: How Animals Taught Us to Dance and Sing*, BioMusic Symposium, AAAS Annual Meeting, 2000

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HyperNotes

Related Resources on the World Wide Web

GENERAL HYPERNOTES

Also in this issue is a related Enhanced Perspective by M. Tramo titled "Music of the hemispheres."

The Internet Resource Guide for Zoology from BIOSIS includes a section of links to animal behavior resources.

Guide to Animal Sounds on the Net provides links to Internet resources.

The Animal Bioacoustics Committee of the Acoustical Society of America provides an introduction to bioacoustics and links to Internet resources for bioacoustics.

Links2Go provides links to Internet resources on ethnomusicology.

E. Mercado, Center for Molecular and Behavioral Neuroscience, Rutgers University, maintains a directory of scientists interested in animal bioacoustics.

WhaleNet, an educational Web site focused on whales and marine research, is sponsored by Wheelock College, Boston, with support from the National Science Foundation. A resource page for sounds and bio-acoustics information and links is included.

The Cetacean Society International provides a photo gallery and a collection of Internet links.

The Office of Protected Resources of NOAA's National Marine Fisheries Service provides information about whales, dolphins, and porpoises. A section on humpback whales is included.

WhaleLink, a presentation of the Vancouver Aquarium Marine Science Centre, presents Orca FM with recordings of killer whale communications. Information about humpback whale song is also provided.

BIRDNET, a service of the Ornithological Council, provides information resources and Web links related to the scientific study of birds.

OWL (Ornithological Web Library) provides classified lists of Internet avian resources. A collection of links to sound and image resources for birds is included.

Bird Links to the World is a compendium of Internet resources provided by Bird Studies Canada.

The Patuxent Wildlife Research Center of the U.S. Geological Survey makes available the Patuxent Bird Identification InfoCenter, a guide to birds with audio files of birdsongs.

The Cornell Laboratory of Ornithology (CLO) offers an online bird guide with sound files and sounds of the week from the Macaulay Library of Natural Sounds; an audio of the musician wren (*Cyphorhinus arada*) is included. The CLO's Bioacoustics Research Program develops and applies new techniques for recording and analyzing animal sounds; information about whale, bird, and elephant communication research is provided.

R. Irwin, Department of Biological Science, University of Tennessee at Martin, provides lecture notes for an ornithology course. Lecture notes on song are included.

B. Sinervo, Department of Biology, University of California, Santa Cruz, provides lecture notes for a course on behavioral ecology. A presentation on sensory

systems and communication is included.

R. Huber, Department of Biological Sciences, Bowling Green State University, provides lecture notes for an animal behavior course. A presentation on bird song learning is included.

S. Beshers, Integrative Biology Program, School of Life Sciences, University of Illinois, provides lecture notes for a course on animal behavior.

The Music of Sound is a presentation of the Why Files: Science Behind the News from the University of Wisconsin.

The Summer 2000 issue of the *Animal Welfare Institute Quarterly* had an article about the BioMusic Symposium at the AAAS annual meeting.

NUMBERED HYPERNOTES

1. The **Oakland Zoo** provides an **introduction** (with a sound file) to the African elephant. The **Elephant Information Repository** offers an introduction to **elephant senses**. CLO's **Bioacoustics Research Program** offers an introduction to the **elephant infrasound research** of K. Payne. **ABC News** offers a 1998 **feature** on Payne's elephant research titled "Listening to elephants: Animals communicate infrasonically."

2. **ABC News** makes available an **article** by M. Crenson titled "Born to sing? Scientists debate whether there is a music gene."

3. NOAA's **National Marine Mammal Laboratory** provides an introduction to **whales, dolphins, and porpoises**; a presentation on **humpback whales** is included. **Animal Diversity Web**, maintained by the **Museum of Zoology** of the University of Michigan, provides information about the **humpback whale**. **Wildfacts** from the **BBC Online** has an entry for the **humpback whale**. The **Hawaii Whale Research Foundation** provides information about **humpback whale natural history**. **Earthtrust**, Kailua, HI, offers a presentation on **humpback whales**. The **Island Marine Institute Whale Resource Center**, Lahaina, Maui, HI, offers information on the **behavior of humpback whales**. **Virtual Whales** from Simon Fraser University, Burnaby, BC, is a visualization project to develop animation and sounds to assist in interpreting the foraging behaviors of Pacific humpback whales.

4. The **National Geographic Society** makes available a National Public Radio presentation on **humpback whales and their songs**; included are an **excerpt and audio** from the January 1979 *National Geographic* article "Humpbacks: Their mysterious songs." The **Newfoundland and Labrador** Web Site offers a presentation (with audio files) about **humpback whales**. The **Whale Center of New England** provides information about **humpback whales** and **audio files** of humpback whale calls. The **Whale Acoustics Project** is a joint study of the **National Marine Mammal Laboratory** and the **Pacific Marine Environmental Laboratory**; an overview of the **humpback whale** and a selection of **humpback whale vocalizations** is offered. CLO's **Bioacoustics Research Program** offers a presentation on **whale vocalizations**. ***Nature*** provides a 5 November 1999 **Science Update** by P. Ball titled "Sounding out the science of whale song."

5. The ***Grove Concise Dictionary of Music***, available on the Web from the **xrefer** Web site, defines the **ternary (ABA) form**; a **definition** is also provided in xrefer's ***Penguin Dictionary of Music***.

6. The **California Academy of Sciences** provides a profile of **Luis Baptista**. National Public Radio's **Living on Earth** had an **appreciation** of Baptista by L.

Gravitz titled "Birds and Beethoven" as part of the **28 July 2000 broadcast**. The WhyFiles **Music of Sound** includes a section about **Baptista's presentation** on the science of music and natural sound at the February 2000 AAAS annual meeting. **BIRDNET** offers an **obituary** of Baptista.

7. **Bird Song Files of Selected Species**, maintained by **S. Hopp**, Department of Ecology and Evolutionary Biology, University of Arizona, provides links to bird song resources on the Internet. The **Amazing World of Birds** offers presentations on **birds and hearing** and **bird sounds**. **T. L. George**, Department of Wildlife, Humboldt State University, Arcata, CA, offers lecture notes on **bird song** for an **ornithology course**. **C. Evans**, Animal Behaviour Laboratory, Macquarie University, Sydney, Australia, offers a presentation on **song learning** as part of a series of **animal behavior lectures**. **G. Jacobs**, Department of Cell Biology and Neuroscience, Montana State University, Bozeman, provides **lecture notes** on birdsong as a model system for language for a **neuroethology course**; lecture notes on the **physiology of the song system** are also provided. **M. van Staaden**, Department of Biological Sciences, Bowling Green State University, offers **lecture notes** (and **part two**) on bird song for a **neuroethology course**. The August–September 1996 issue of ***National Wildlife*** had an **article about bird song** by P. Nelson titled "A song for every occasion."

8. **Animal Diversity Web** provides information (with sound files) about the **canyon wren**. The online **field guide to birds** available from **eNature.com** has an entry (with a sound file) for the **canyon wren**. **Southern California Natural History**, a multimedia textbook provided by **H. Towner**, Department of Biology, Loyola Marymount University, Los Angeles, includes information (with a sound file) about the **canyon wren**.

9. The **ChopinFiles** Web site provides information about Chopin's **Revolutionary Etude** and an audio excerpt of the music. J. Smeet's **Classical Composers Database** provides a biography of **Frédéric Chopin** with links to Internet resources.

10. The ***Oxford Dictionary of Music***, available from **xrefer**, provides definitions of **interval** and **key**; **harmonics** and **melody** are defined in xrefer's ***Grove Dictionary of Music***.

11. The **Patuxent Bird InfoCenter** has an entry (with a sound file) for the **wood thrush**. The **Cornell online bird guide** includes an entry (with a sound file) for the **wood thrush**. The eNature.com **field guide to birds** has an entry (with a sound file) for the **wood thrush**.

12. An entry (with a sound file) for the **ruby-crowned kinglet** is included in the **Patuxent Bird InfoCenter**. The eNature.com **field guide to birds** has an entry for the **ruby-crowned kinglet**. **Animal Diversity Web** provides sound recordings of the **ruby-crowned kinglet**.

13. The **Patuxent Bird InfoCenter** provides information (with a sound file) about the **hermit thrush**. The **Cornell online bird guide** has an entry (with a sound file) for the **hermit thrush**. The eNature.com **field guide to birds** has an entry (with sound file) for the **hermit thrush**. **Animal Diversity Web** provides **sound recordings** of the hermit thrush.

14. The ***Penguin Dictionary of Music***, available from **xrefer**, defines **chromatic** and **pentatonic** scales. **Britannica. com** provides an *Encyclopædia Britannica* overview of **scales** and introductions to the **diatonic**, **chromatic,** and **pentatonic** scales.

15. The *Penguin Dictionary of Music* defines **canon**.

16. **J. Martínez-Gómez**, Department of Biology, University of Missouri, offers information about the **Socorro mockingbird**.

17. The **Patuxent Bird InfoCenter** has an entry (with a sound file) for the **marsh wren.** The eNature.com **field guide to birds** has an entry (with sound file) for the **marsh wren**. **Animal Diversity Web** provides a photo and sound recording of the **marsh wren**.

18. **About.com Birding/Wild Birds** offers a presentation on the **palm cockatoo**. The **Smithsonian National Zoological Park** offers a presentation on the **palm cockatoo**. The **Riverbanks Zoo and Botanical Garden**, Columbia, SC, provides information about the **palm cockatoo**. **Earthwatch Radio** from the University of Wisconsin presents a **feature** on palm cockatoo drumming.

19. The *Encyclopædia Britannica* article on **human evolution** has sections on **Cro-Magnons** and **Neanderthals**. A collection of links to Internet resources on **Cro-Magnons** is provided by **T. Roufs**, College of Liberal Arts, University of Minnesota, Duluth. **Neanderthals and Modern Humans -- A Regional Guide** is maintained by **S. Brown**. **Neandertals: A Cyber Perspective** is a student Web project by K. Ramanan, Indiana State University; the presentation on **Neanderthal art** includes a section on the flute.

20. The **Institute of Archeaology** of the **Scientific Research Centre** of the Slovenian Academy of Sciences and Arts makes available the initial **report** about the Neanderthal flute by I. Turk, J. Dirjec, and B. Kavur titled "The oldest musical instrument in Europe discovered in Slovenia?" The **Exploritorium** in San Francisco offers a 21 February 2000 **dispatch** from the AAAS annual meeting by M. Miller titled "Music of the Neanderthals." **MSNBC.com** offers a 21 February 2000 **feature** by A. Boyle titled "Listening to the sounds of science: From ancient flutes to flame-based music." The 22 March 2000 **Science Update** radio broadcast on the **Neanderthal flute** and related resources is available on the AAAS **Science NetLinks** Web site. The WhyFiles **Music of Sound** includes a section on the **Neanderthal flute**. A musicological analysis of the **Neanderthal flute** is provided by R. Fink; an **update** is included. The September 1997 issue of ***Scientific American*** had a **Science and the Citizen feature** by K. Wong titled "Neanderthal notes: Did ancient humans play modern scales?" **Brookhaven National Laboratory** offers a **presentation** titled "9,000-year-old flutes from Jiahu, Henan Province, China." **ABC News** had a **feature** about this discovery titled "Ancient flute plays on."

21. The **Recorder Home Page** maintained by N. Lander includes a **history of the instrument**. B. Santin's **Wooden Flutes** Web site offers a **historical introduction** to the wooden flute.

22. The **Finnish Music Information Centre** makes available an **article** by H. Laitinen titled "The many faces of the yoik." The **May 1999 issue** of the online magazine ***Folkworld*** had an **article** by U. Länsman titled "Sámi culture and the yoik." The **Sámi of Far Northern Europe** is a collection of links to Internet resources provided on the **Arctic Circle** Web site. The **Euromosaic Report** Web Site offers information about the **Sami** and links to Internet resources.

23. **H. Williams**, Biology Department, Williams College, Williamstown, MA, provides information about the zebra finch and its song on her **Bird Songs and Bird Brains** Web page and offers recordings in the **Zebra Finch Song Archive**. The **Laboratory of Comparative Psychoacoustics**, Department of Psychology, University of Maryland, offers a presentation on the

zebra finch and its vocalizations. **Britannica.com** provides an *Encyclopædia Britannica* introduction to the **bullfinch**. **Animal Diversity Web** offers information about the **Eurasian bullfinch** (also known as the common or Northern bullfinch). The BBC's **Wildfacts** has an entry (with a sound file) for the **bullfinch**. A. Massi's **European Birds: Songs and Sonagrams** has an entry for the song of the **Eurasian bullfinch**.

24. Robinson Research's **World of Knowledge** offers a presentation on the **chaffinch**. The BBC's **Wildfacts** offers an entry (with a sound file) for the **chaffinch**. A. Massi's **European Birds: Songs and Sonagrams** has an entry for the song of the **chaffinch**.

25. The **Cornell online bird guide** includes an entry (with a sound file) for the **white-crowned sparrow**. The eNature.com **field guide to birds** has an entry (with a sound file) for the **white-crowned sparrow**. The Spring 1999 issue of ***California Wild***, published by the **California Academy of Sciences**, had an **article** by L. Baptista about the dialects of the white-crowned sparrow; a Web **presentation** on the white-crowned sparrow and its song is also provided. **D. Nelson**, **Borror Laboratory of Bioacoustics**, Department of Evolution, Ecology and Organismal Biology, Ohio State University, offers a **presentation on song learning** in the white-crowned sparrow.

26. The **Cornell online bird guide** includes an entry (with a sound file) for **Anna's hummingbird**. The eNature.com **field guide to birds** has an entry (with a sound file) for **Anna's hummingbird**.

27. P. Gray is at the **National Musical Arts**, National Academy of Sciences. **B. Krause** is at **Wild Sanctuary, Inc. J. Atema** is in the **Department of Biology**, Boston University, and the **Boston University Marine Program**, Marine Biological Laboratory, Woods Hole, MA. **R. Payne** is at **Ocean Alliance**. **C. Krumhansl** is in the **Department of Psychology**, Cornell University. L. Baptista was in the **Department of Ornithology and Mammalogy**, California Academy of Sciences.

The editors suggest the following Related Resources on *Science* sites:

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