• Keep asking great questions!

• During lectures, please *turn off* and *put away*
  • phones
  • laptops
  • tablets

• Please do not arrive late.

• Actively participate in class
Proximate Mechanisms: Immediate Causes

- Songbirds have a circuit of brain nuclei (clusters of neurons) that controls the learning and production of song.
Neural song circuit

- **Motor control.** Song output is patterned in **HVC**, which projects to **RA**, which then projects to neurons in the brainstem (**nXIIIts**) that control muscles of the **syrinx** (vocal organ).

- **Learning.** Auditory information is sent to nuclei in the anterior forebrain (**IMAN & Area X**) that are involved in song learning. Tutor song and the bird’s own song are compared here. These forebrain centers are connected to **HVC** – to influence motor control.
Neuroplasticity in the song circuit during development

- **Sex differences.** In some species, during development, the song circuit becomes different between males and females (nuclei size; number of neurons in song nuclei, connections between nuclei). *Overall brain size is the same.*

Adult male zebra finches learn to sing; adult female zebra finches do not sing
Dramatic sex differences in zebra finch song circuit

Adult male

Adult female

Nissl stain
Development of sex differences in HVC

From Nissl-stained sections

Number of neurons in HVC ($\times 10^4$)

Age (days after hatching)
Hormone-Induced Sexual Differentiation of Brain and Behavior in Zebra Finches

Mark E. Gurney; Masakazu Konishi


Fig. 1. Effect of various hormone treatments on the volume of HVC, RA, and DM. Mean volumes with ranges are plotted on the ordinate in cubic millimeters (9). Below each column is the number (N) of birds used and the hormone treatment given to that group; $E_2$, $DHT$, and $T$ designate, respectively, 17β-estradiol, 5α-dihydrotestosterone, and testosterone. Bars denote no treatment.
Gene expression in song circuit

messenger RNA = mRNA

DNA → mRNA → protein

Songbird genome project

What genes are involved in learning songs?
Gene expression in song circuit

Also: The gene FoxP2 is expressed in Area X at 20-30 days
Gene expression in song circuit

- Inhibited expression of FoxP2 gene in Area X of 23 day-old male zebra finches.
- Control group(s)?
- Experimental animals were unable to copy the song of their social tutors and produced more variable vocal output, compared to controls.
Stimuli included forward playback of all of the BOS types …stimuli also included reverse song type playback.

Other stimuli included other conspecific (swamp sparrow) and heterospecific (song sparrow) songs.
Ultimate Mechanisms: Phylogeny

phylogeny → function → development → cause

ancestral species' evol. history → species' evol. history → individual's lifetime → now

ultimate

proximate
Vocal learning in birds

- Birds (Class Aves): 23 Orders, ~9200 species
- Passeriformes: contains ~5000 species, of which ~4000 are oscines (true songbirds, which learn vocalizations).
Phylogeny of song learning

- Cuckoos
- Parrots
- Swifts
- Hummingbirds
- Turacos
- Owls
- Doves
- Cranes
- Shorebirds
- Suboscines
- Oscine songbirds

Legend:
- Blue: Vocal learners
- Orange: Vocal non-learners
- Red: Suspected vocal non-learners
Ultimate Mechanisms: Function

• *Adaptationist hypotheses* suggest that song learning has evolved by natural selection. That is, song learning increases reproductive success (fitness).

• Song learning may repel intruders or attract mates.
Are dialects adaptive?

- Perhaps dialects serve a function in male-male territorial encounters - for instance, being known as an “insider” rather than the stranger.

- Perhaps there are regional differences in female preferences for dialects.
Hypothesis: song repels intruders

- Male white-throated sparrows were removed from their territories.
- On some territories, taped song was played (playback); control territories were silent.
Song sparrow males share songs with neighbors

- Juvenile male song sparrows (after dispersal) learn songs from neighbors

- During a territorial dispute, if the neighbor sings, a song sparrow can:
  - Type match
  - Repertoire match
  - Unshared song

s = shared song type
Song matching & communication of aggressive intent

Aggressiveness of response

More

Less

Focal bird

Neighbor

Focal bird

Sings shared song

Sings repertoire match

Sings unshared song

Stays on same type and responds aggressively

Sings type match

Switches to a different song
Hypothesis: songs attract mates

WCSP females are attracted to the songs of male WCSP
Discuss with your neighbor:

How to test whether females respond more strongly to natal dialect songs?

Use a **within-subjects** design.
Within their species, why would females prefer some songs over others?

- Songs may tell females about the health or genetic quality of males.

- Preferred songs may be associated with greater parasite resistance, better parental ability, or better health during development.
Nutritional stress early in life

(A) Swamp sparrow

(B) Graph showing HVC volume and song copy quality score for control and experimental treatment groups.
Pre-copulatory displays given by female sparrows

http://www.youtube.com/watch?v=9spWPH-wT38