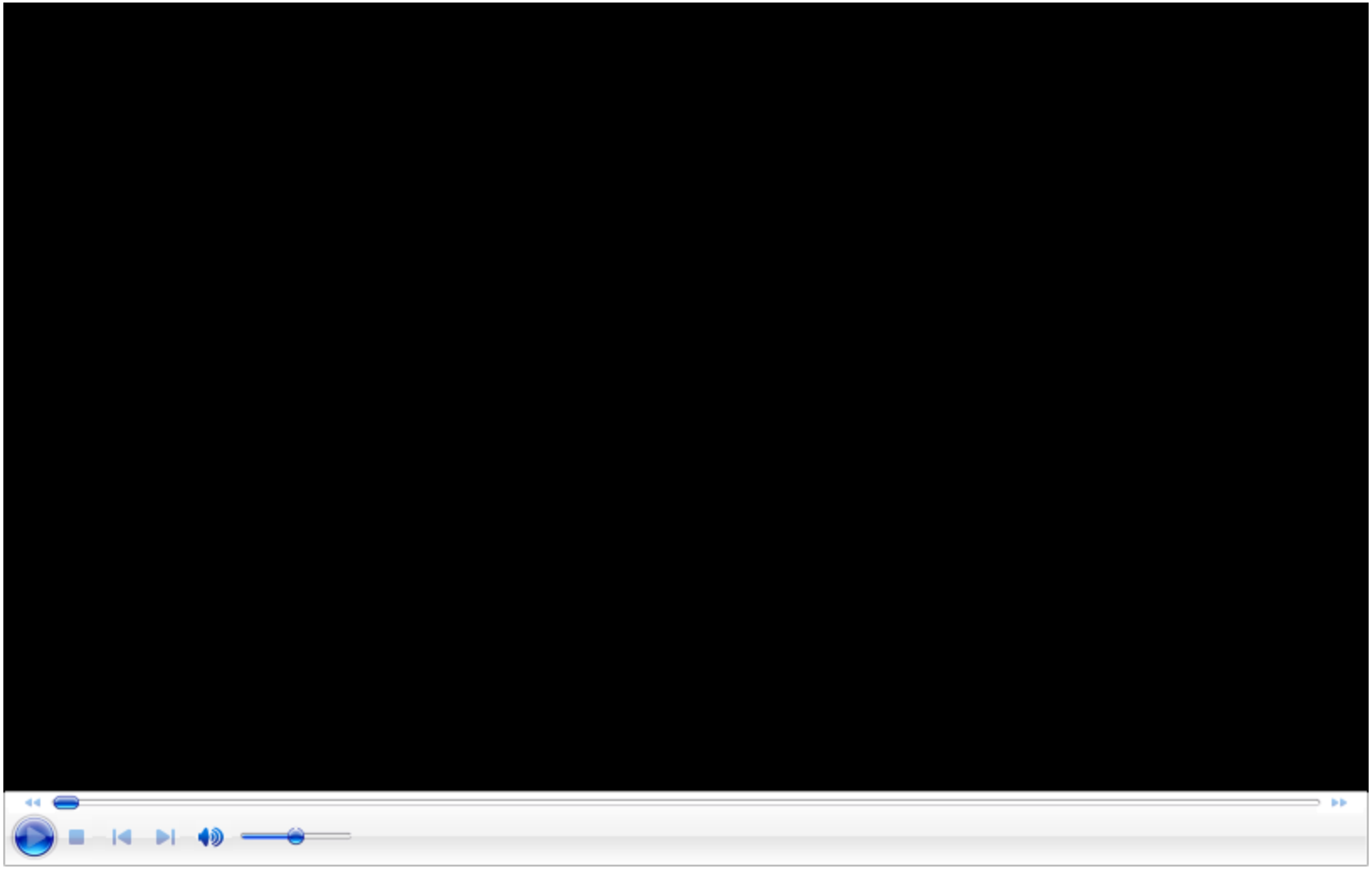
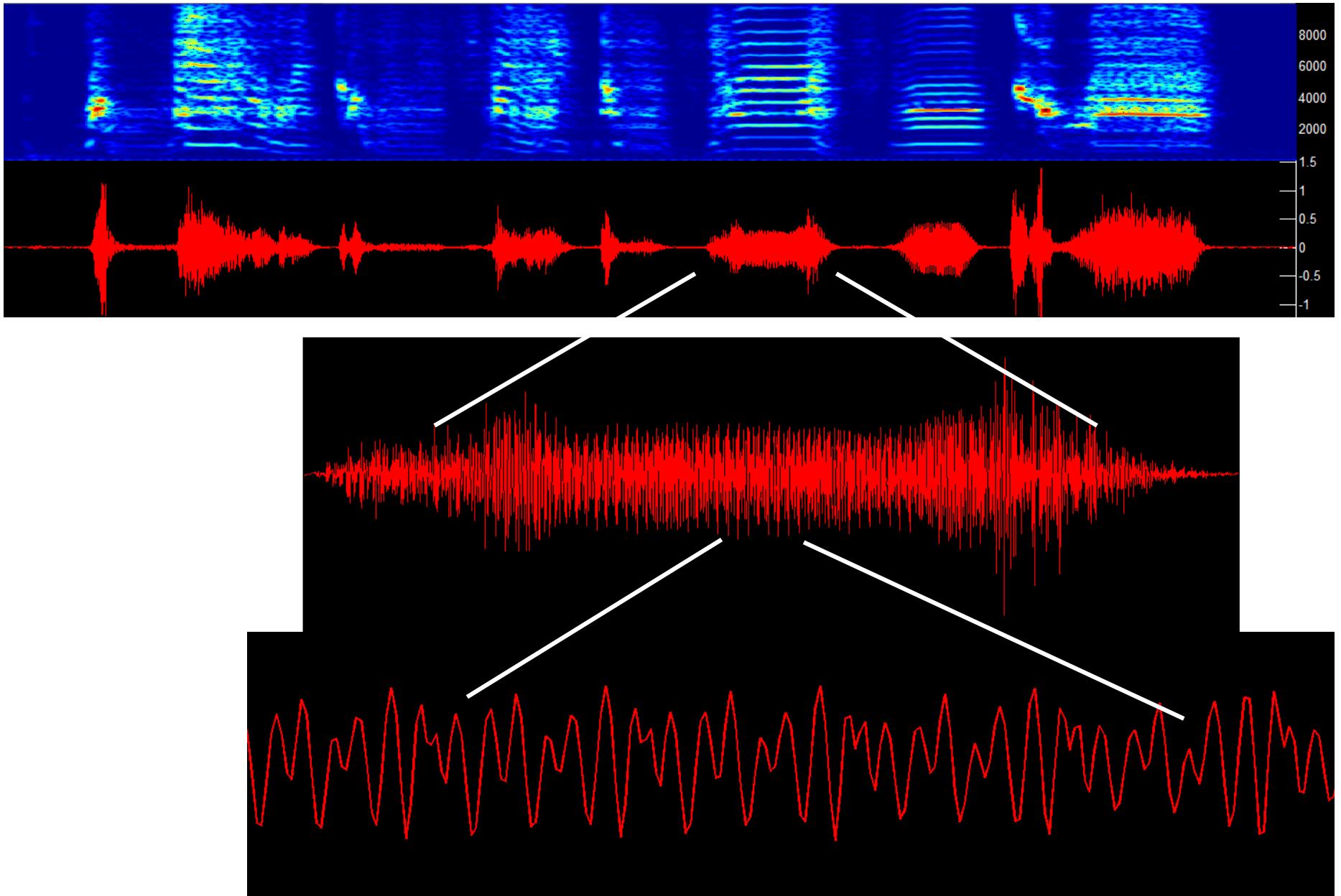
# Neurophysics 2015

Lecture 3: Vocal learning and single neuron computations

# Vocal learning: who does it?



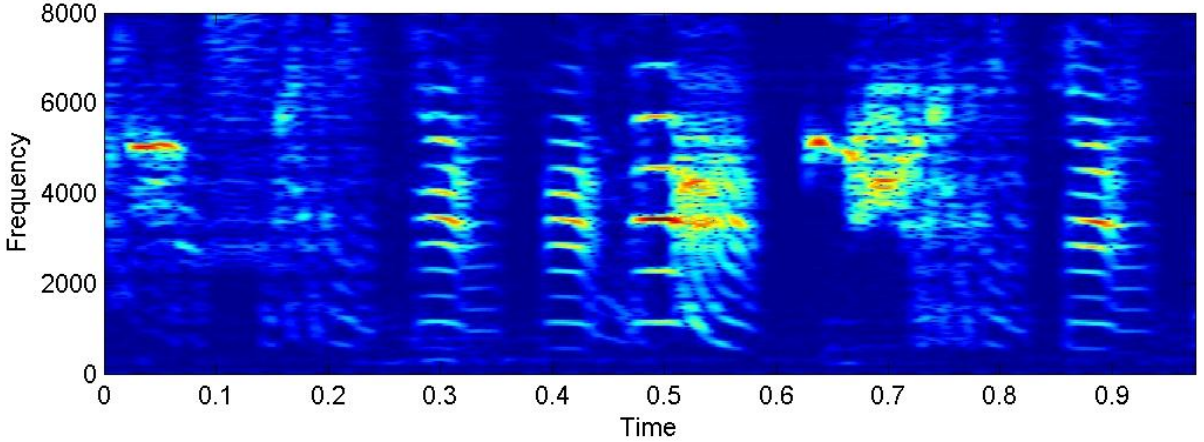
# Spectrograms

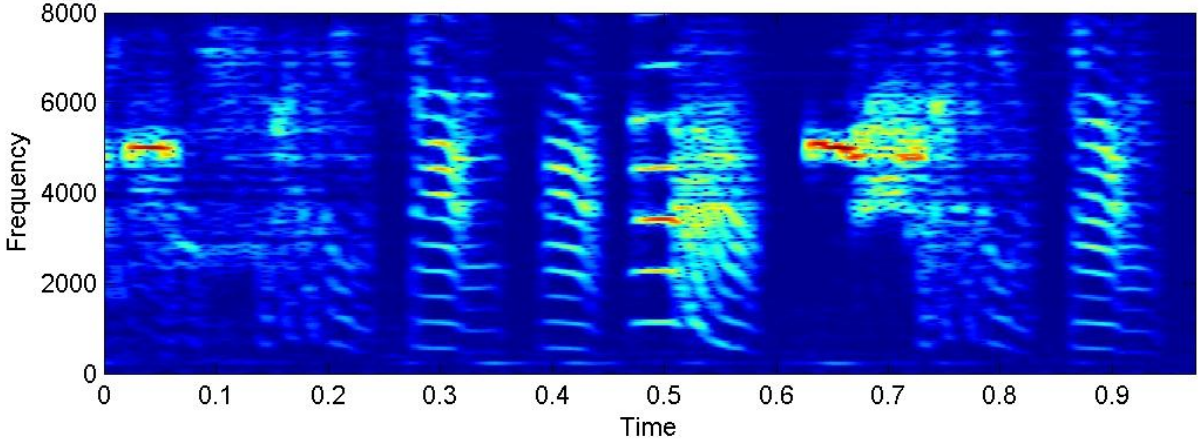


# Song is stereotyped

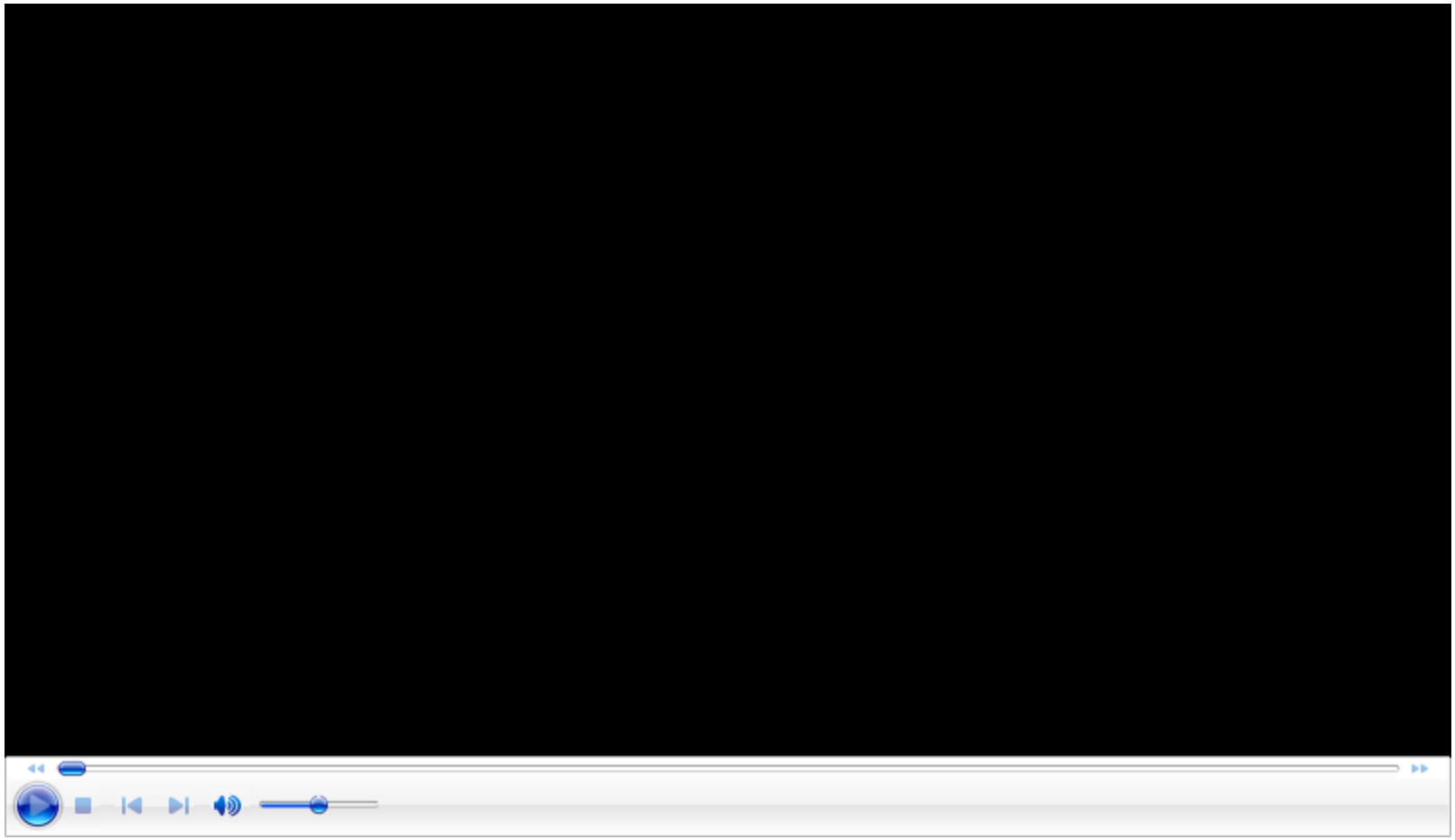




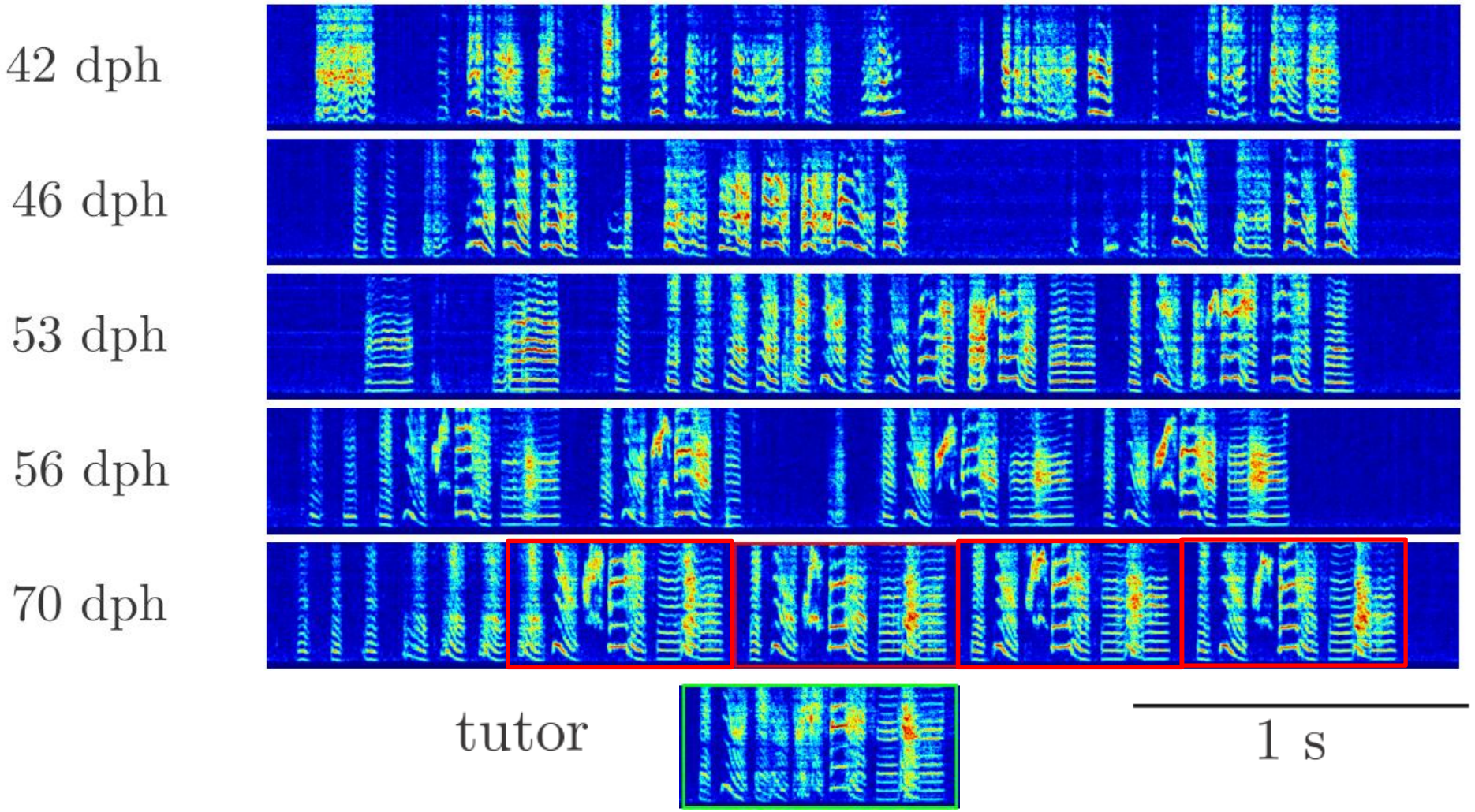


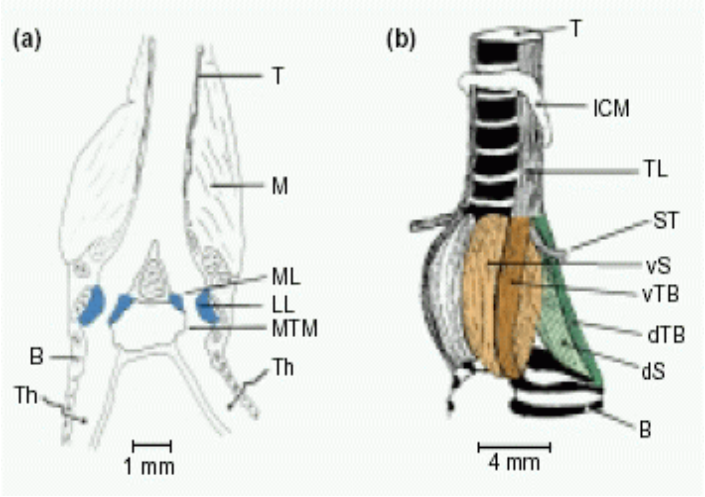
# 3 times slower

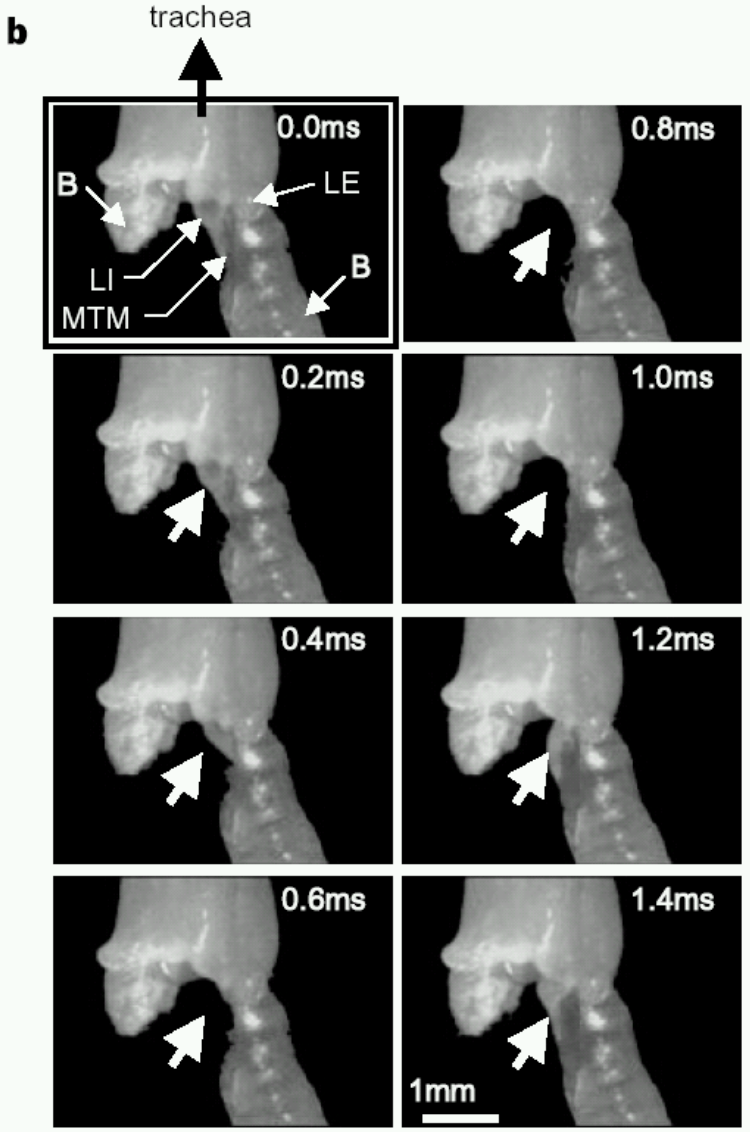


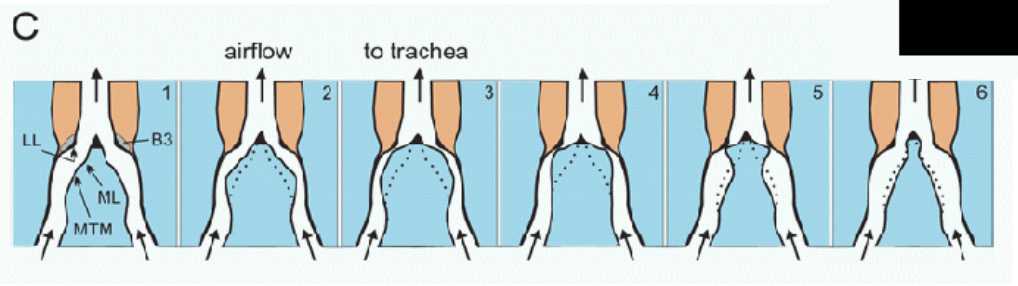
# Song development (spectrograms)



# The syrinx

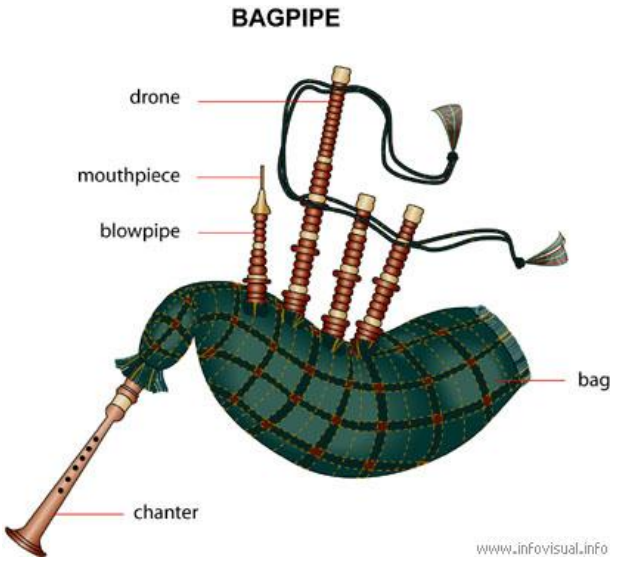

(a)
T
M
ML
LL
MTM
B
Th
Th
1 mm
(b)
T
ICM
TL
ST
vS
vTB
dTB
dS
B
4 mm

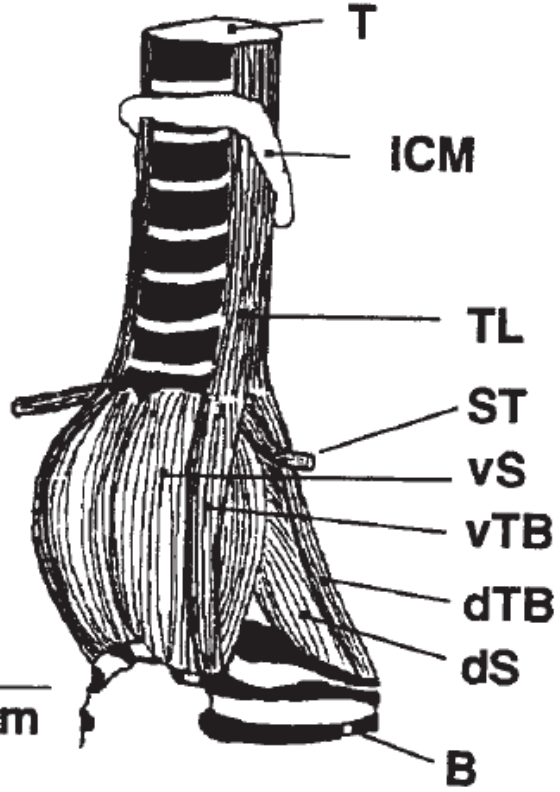

b
trachea
0.0ms
B
LE
LI
MTM
B
0.8ms
0.2ms
1.0ms
0.4ms
1.2ms
0.6ms
1.4ms
1mm


C
airflow
to trachea
1
2
3
4
5
6
LL
B3
ML
MTM

# The syrinx

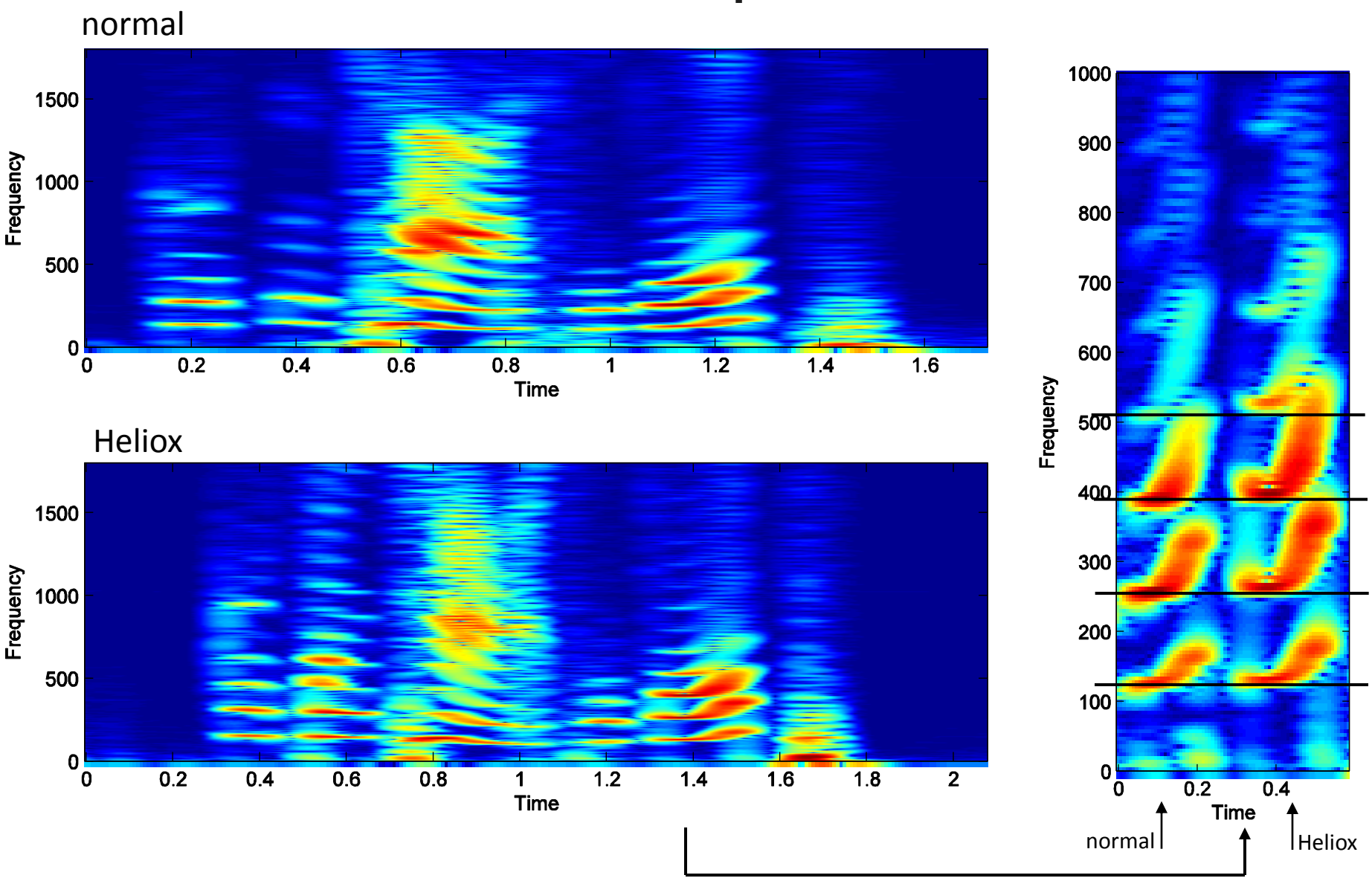
?

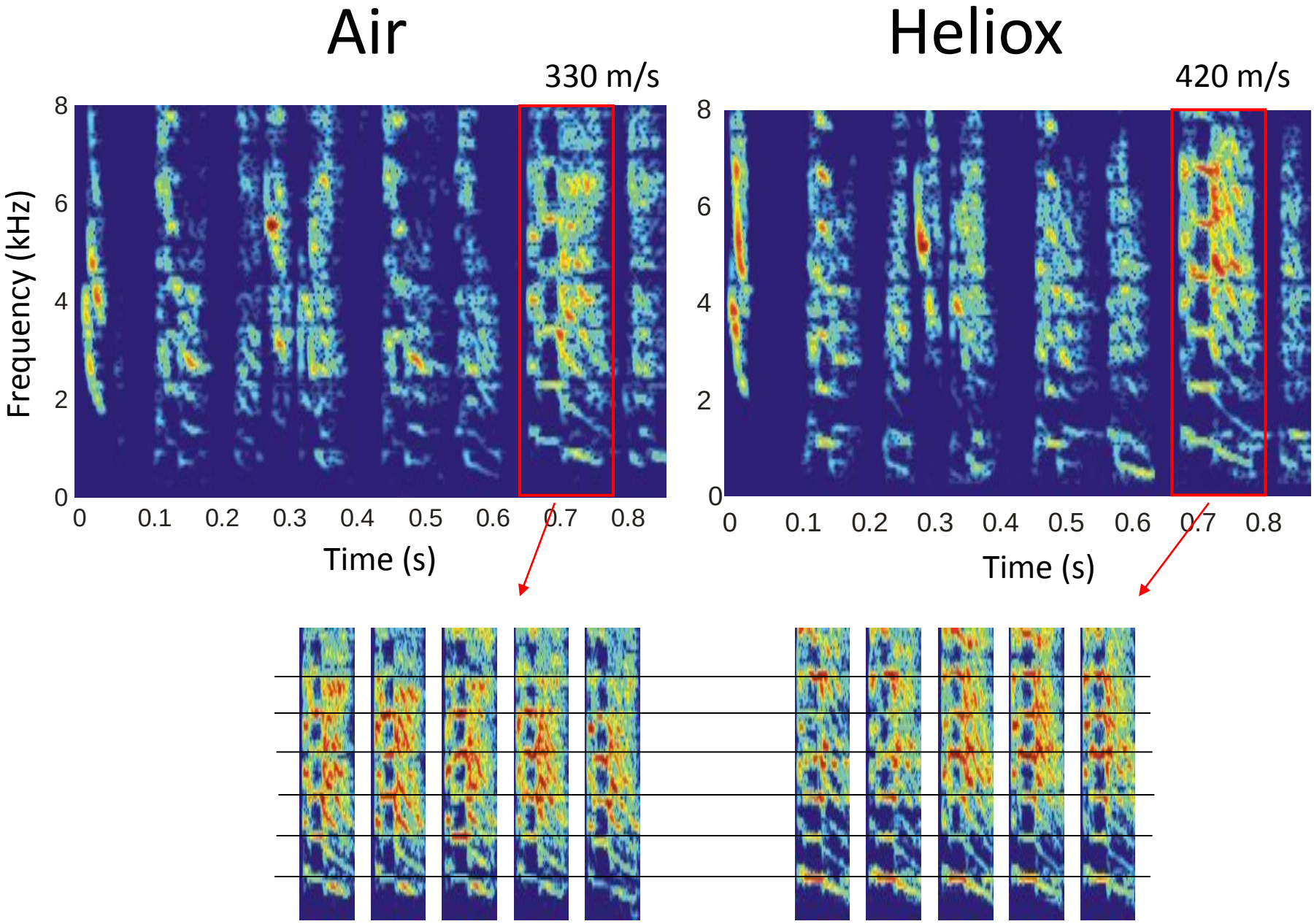

BAGPIPE
drone
mouthpiece
blowpipe
bag
chanter


T
ICM
TL
ST
vS
vTB
dTB
dS
B
www.infovisual.info
4 mm

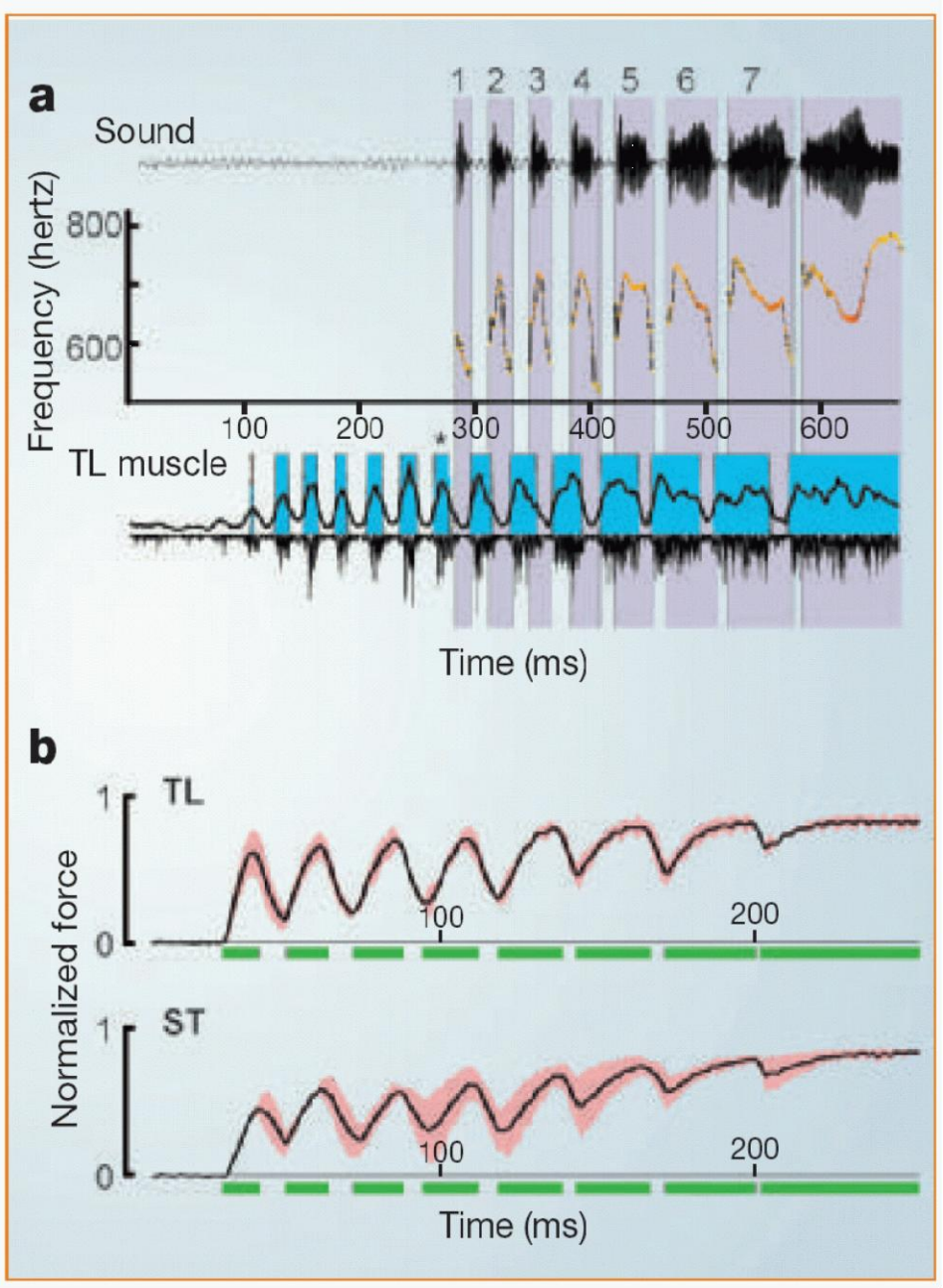
?

# Human speech

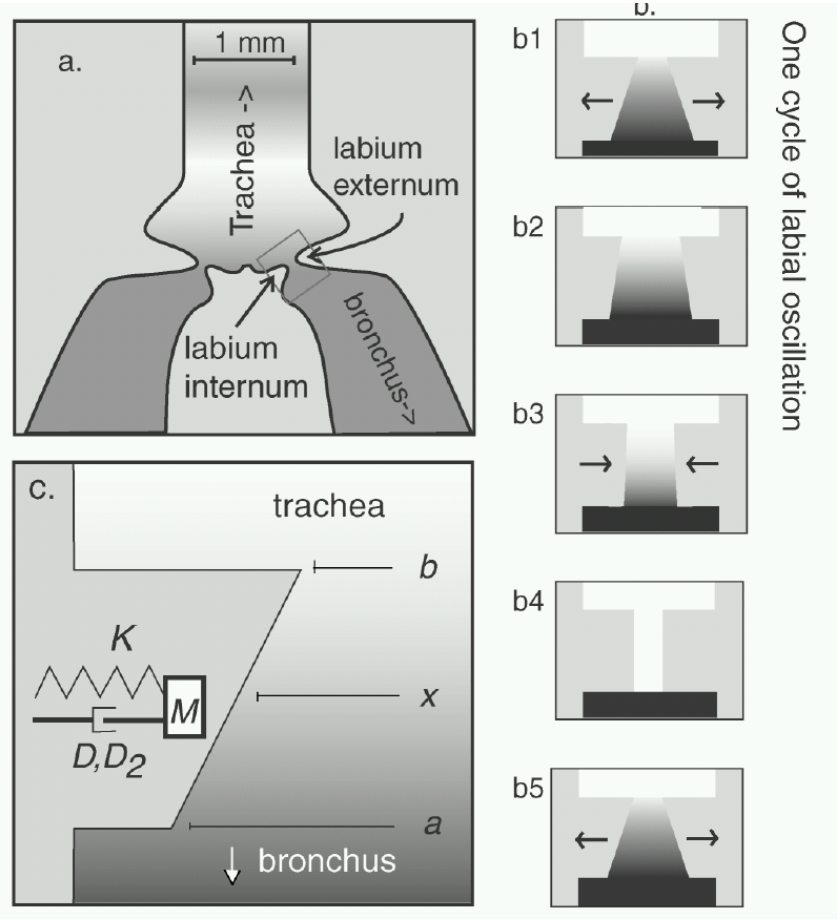


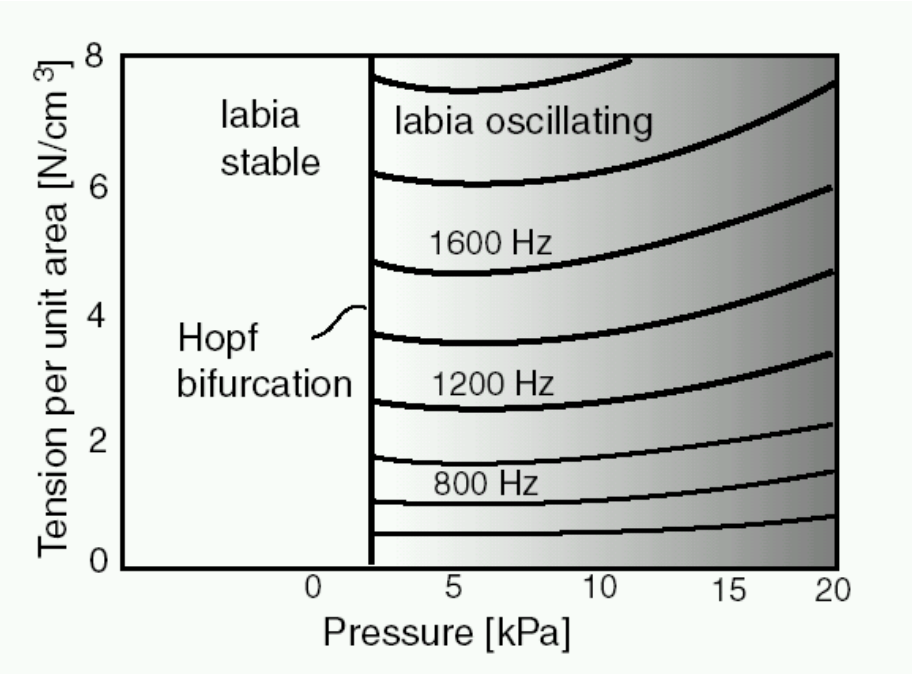

Air
330 m/s
Heliox
420 m/s
Frequency (kHz)
0
2
4
6
8
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Time (s)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Time (s)

# Superfast syringeal muscles

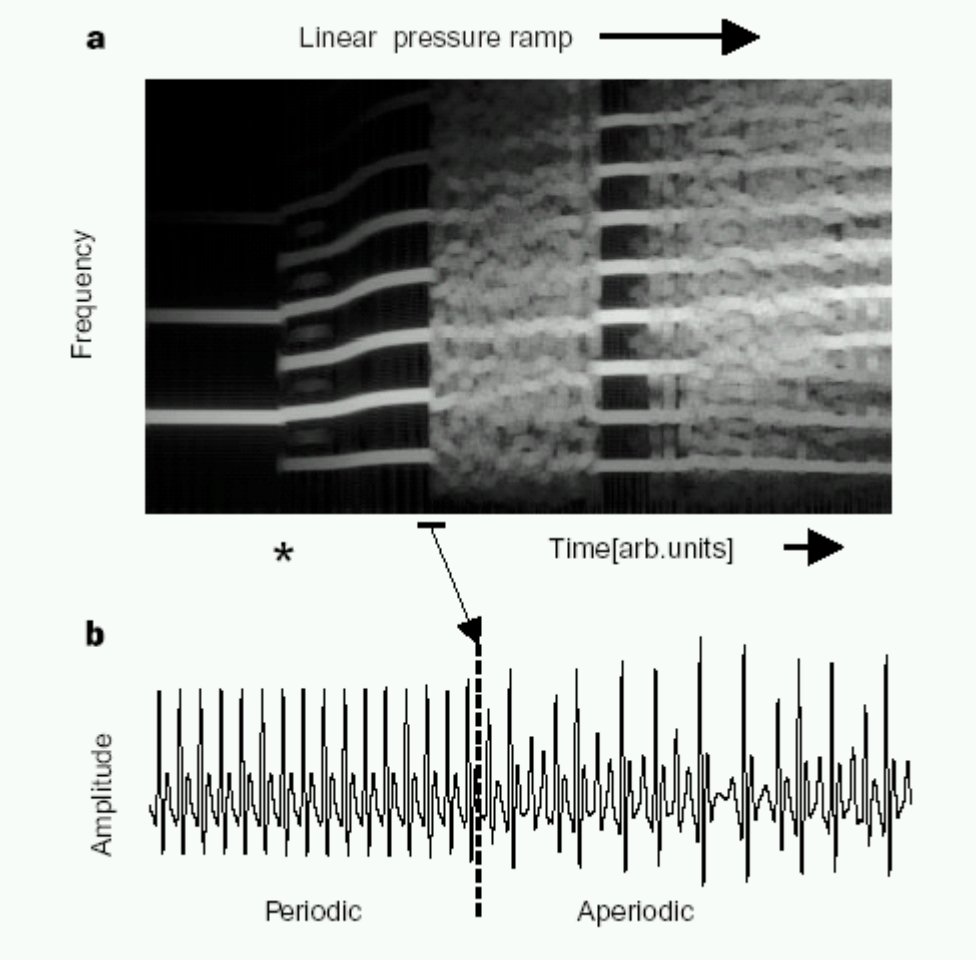


# Model of mechanical properties



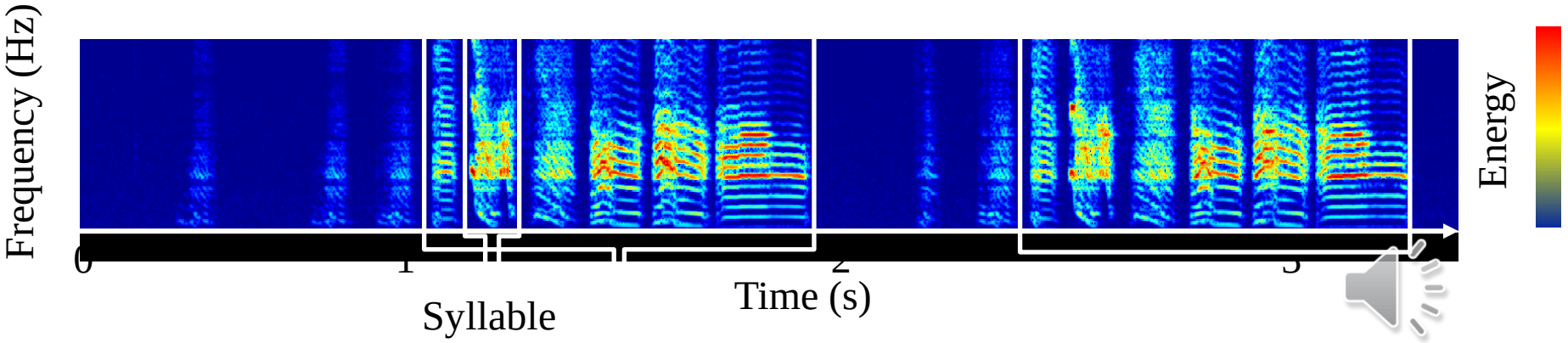
# Mechanical properties of the syrinx



# Different species, different songs

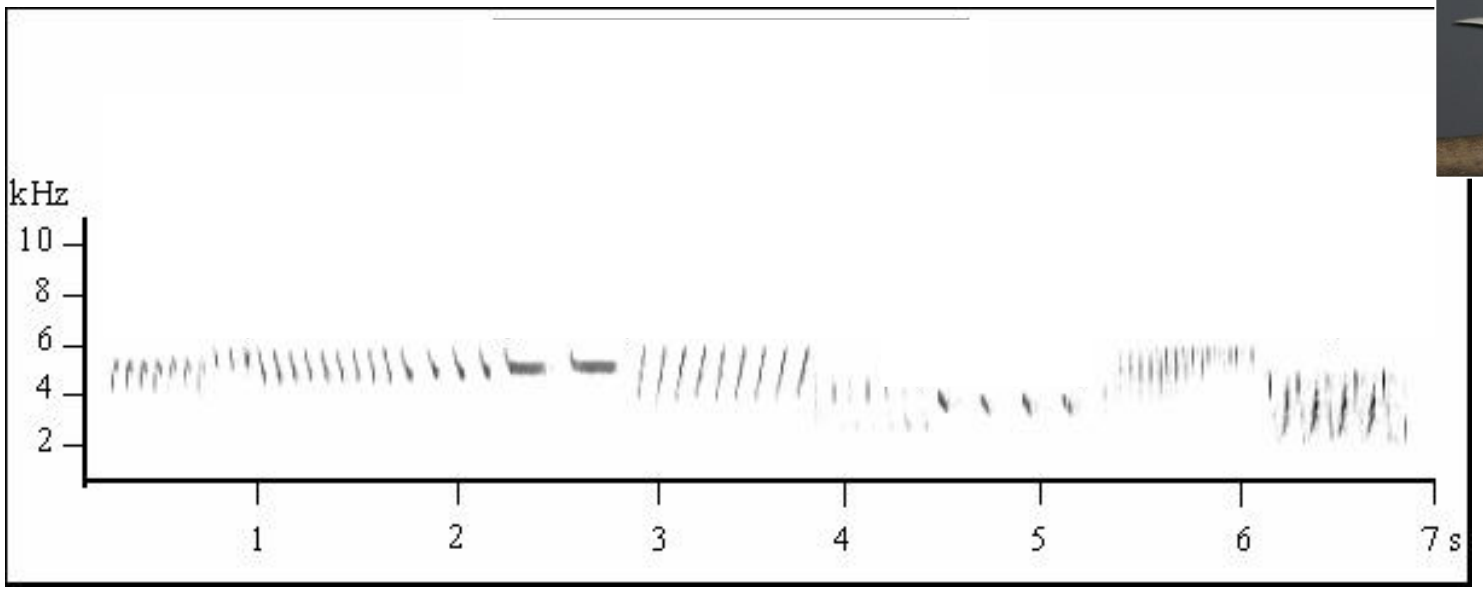
Sound spectrogram

Zebra finch

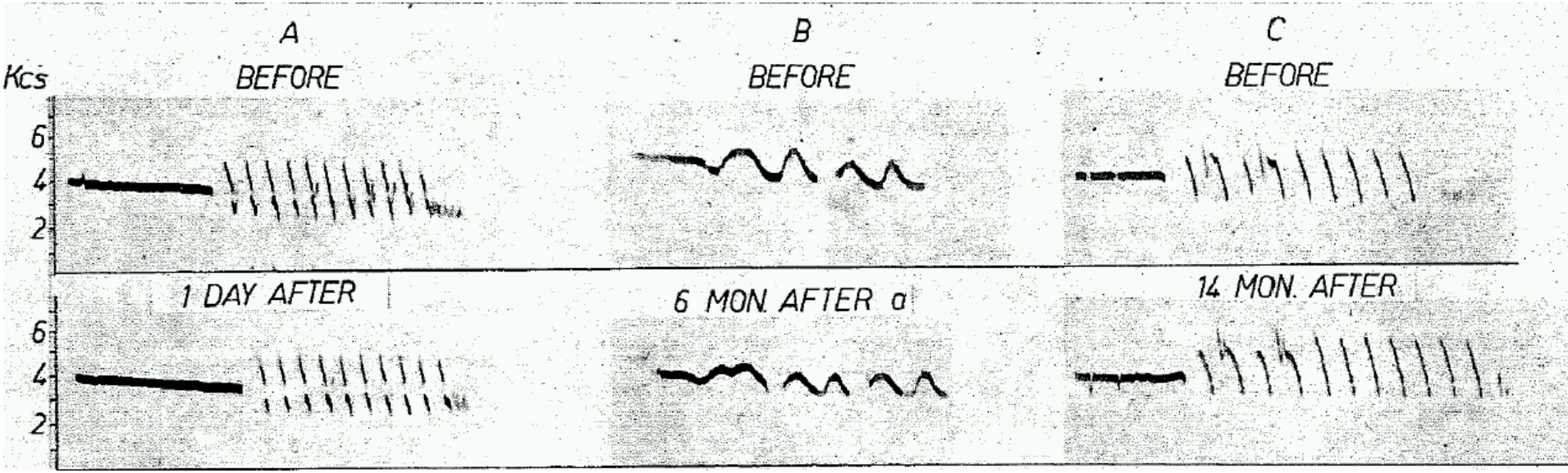



Motif

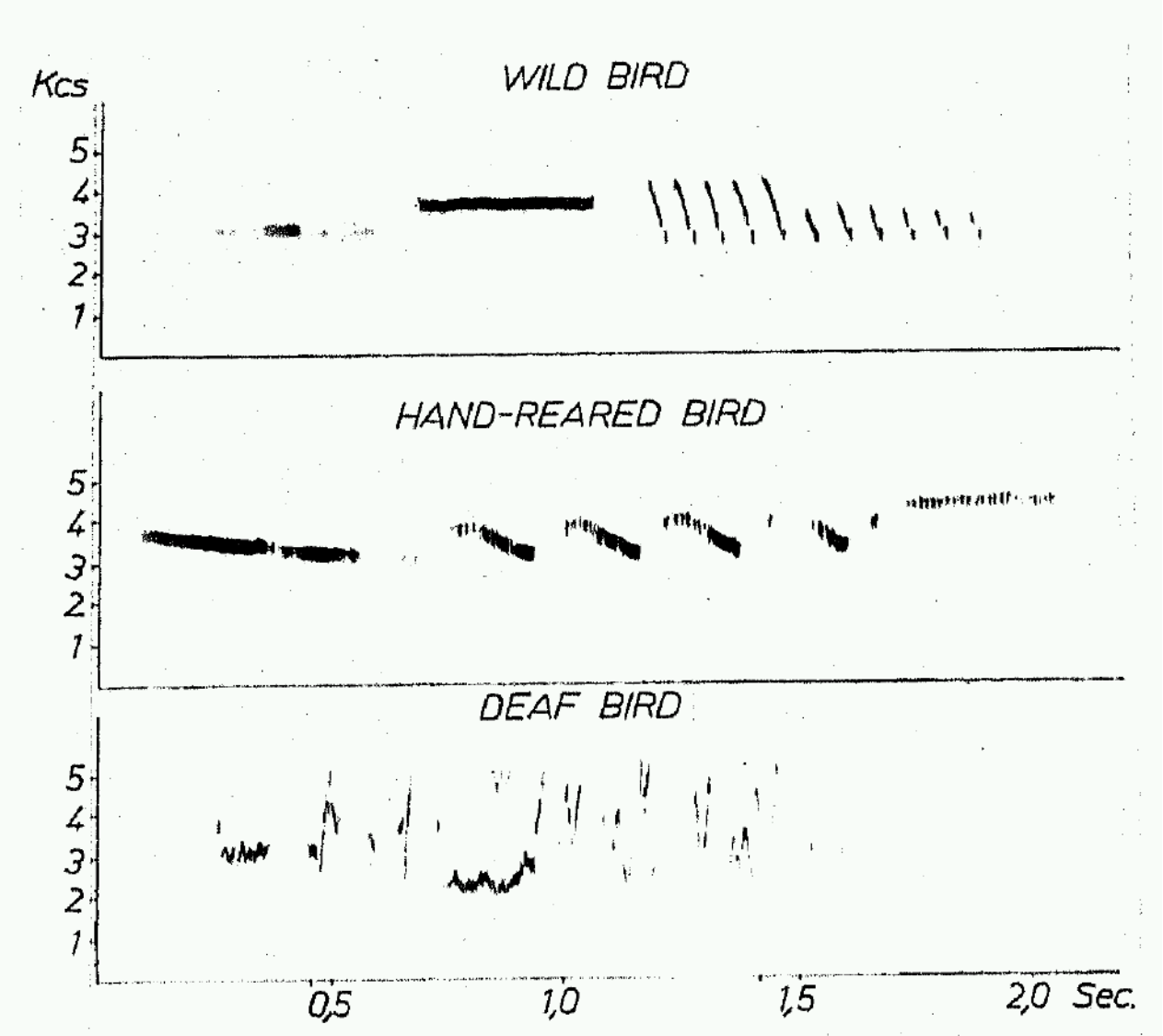
Canary



# Song persists after deafening!



# Auditory feedback is essential during development



# Why do birds sing?
# (what is the function of song?)

Territory defense


Attract females

# Zebra finch song learning: proof

1. Sensory phase

Tutor

2. Sensorimotor phase

Subsong Plastic song Crystallized song

45d 51d 56d

Time post hatch

0 10 20 30 40 50 60 70 80 90 100

Nestling Fledgling Juvenile

Marler 1955, Thorpe 1958, Konishi 1965

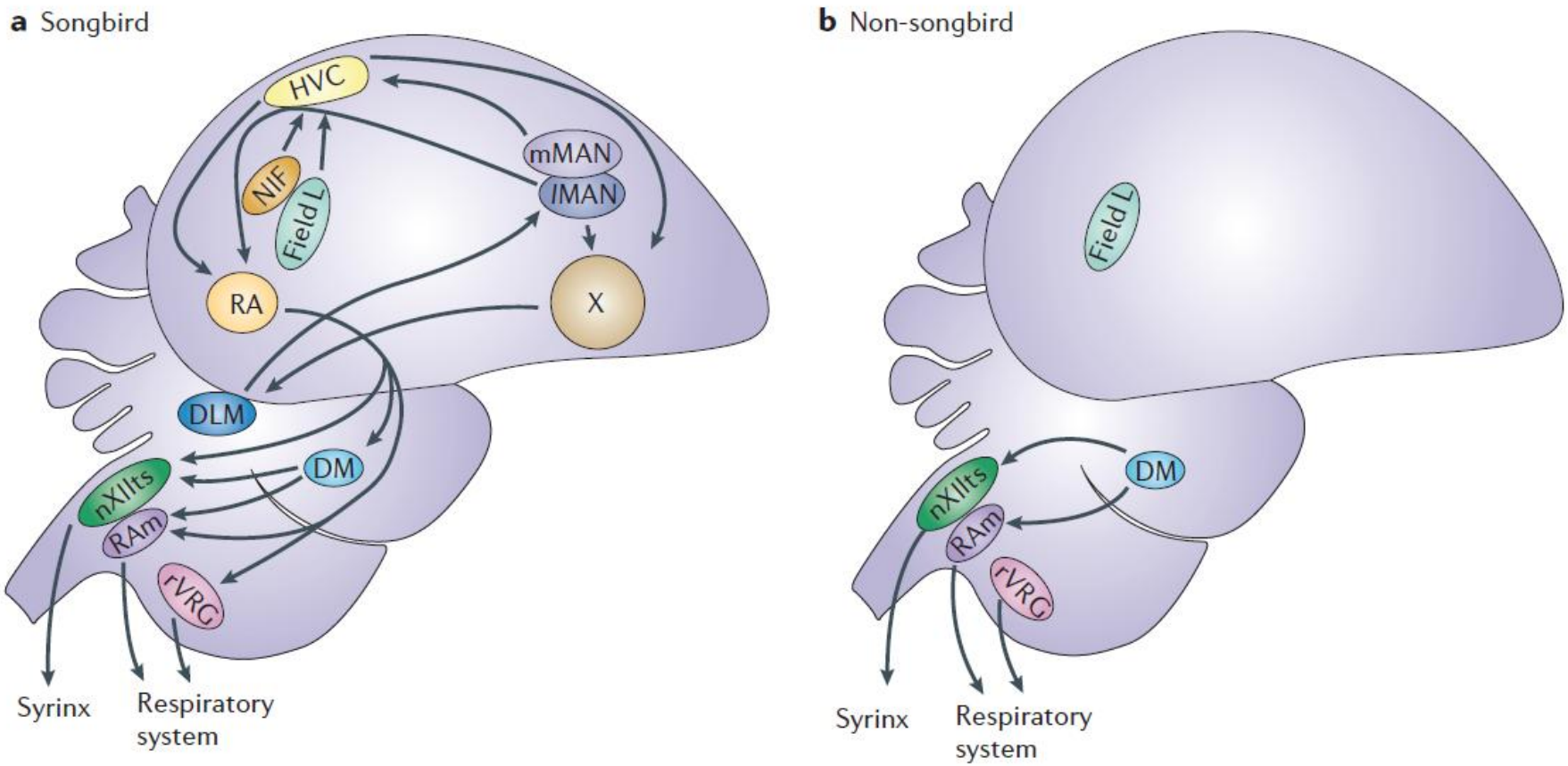
# How do birds learn best ?
# More or less playback ?


# Less is more !

Tchernichovski O, Lints T, Mitra PP, Nottebohm F (1999) Vocal imitation in zebra finches is inversely related to model abundance. *Proc Natl Acad Sci U S A* 96:12901–4.

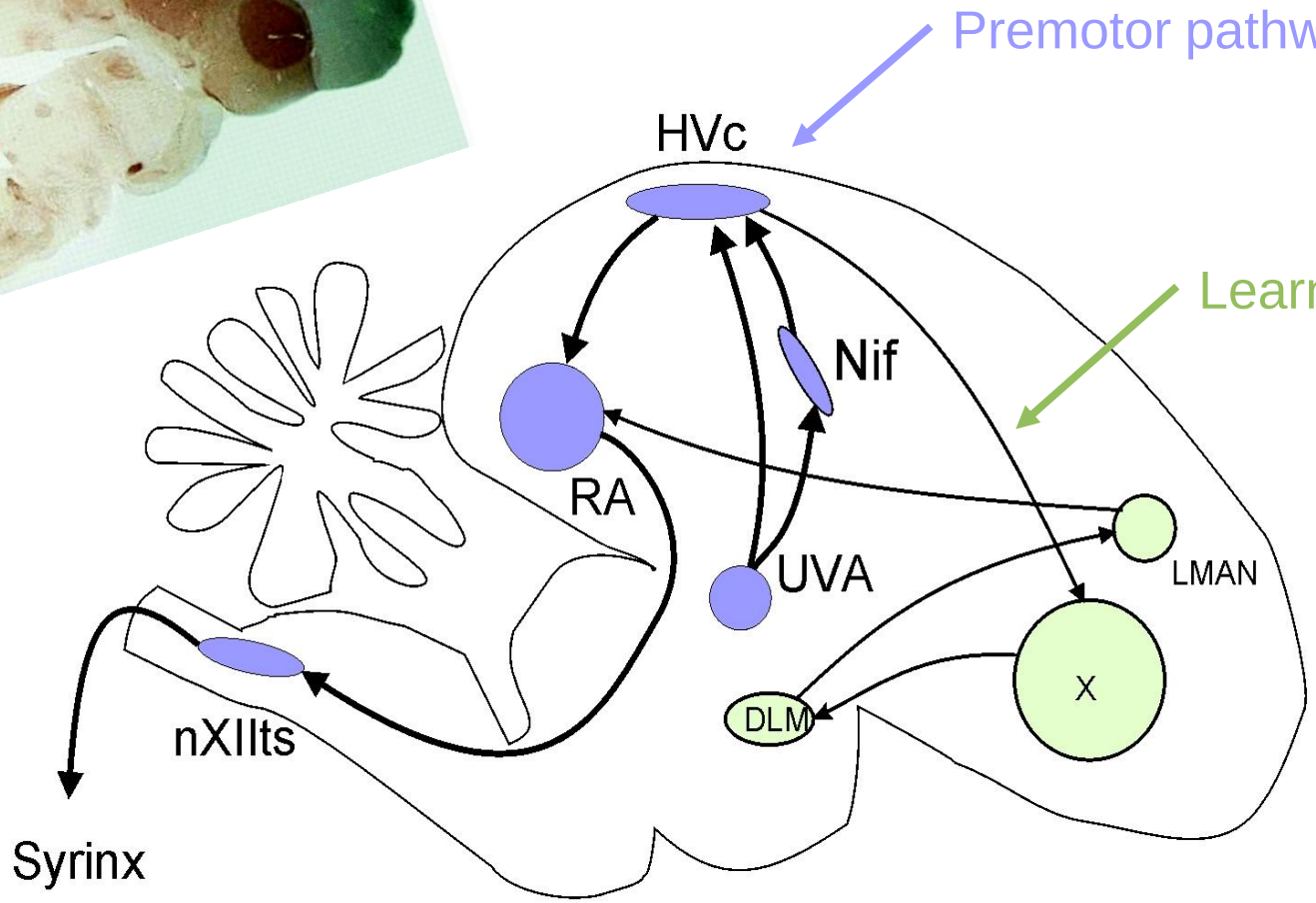
# Electrophysiology in the songbird

# The Song System

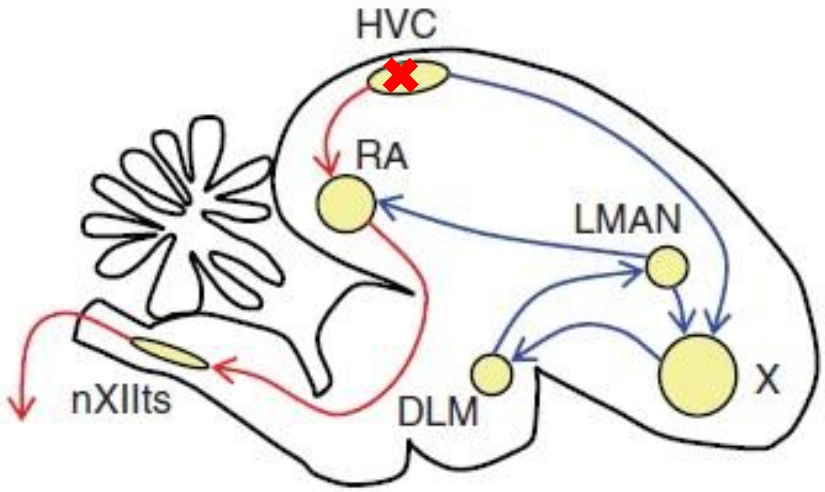



Bolhuis & Gahr, Nat Rev Neurosci 2006

# The Song-Control System



# Disabling or decreasing neural function




- Electrolytic lesions - Neural tissue is destroyed through the application of electrical shock trauma.

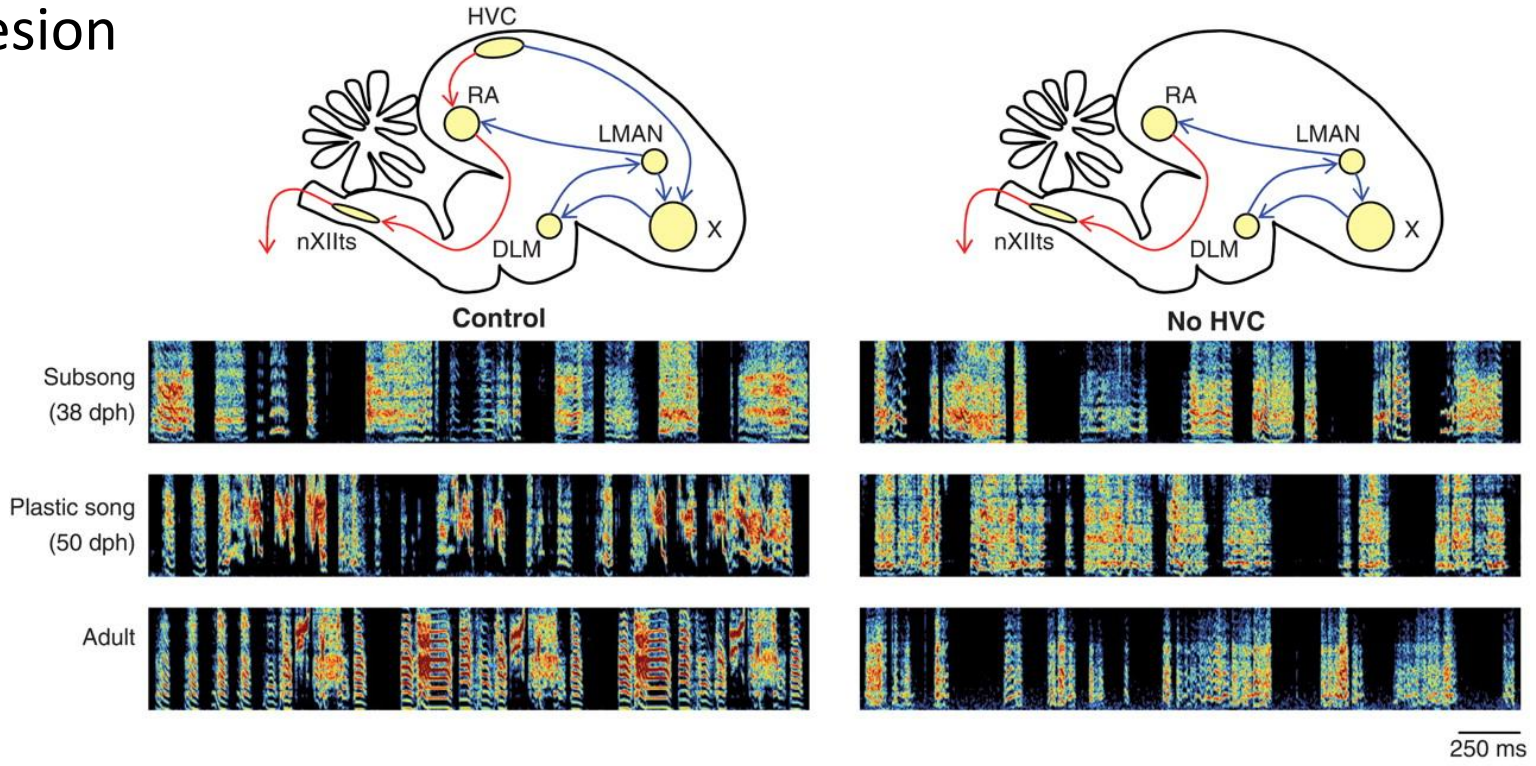
- Chemical lesions - Neural tissue is destroyed by the infusion of a neurotoxin

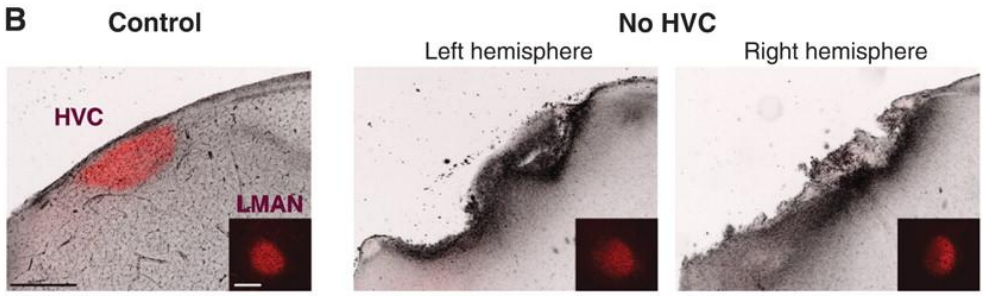
- Temporary lesions - Neural tissue is temporarily disabled (cooling or anaestetics)

Effects on song?

# Disabling or decreasing neural function

HVC Lesion

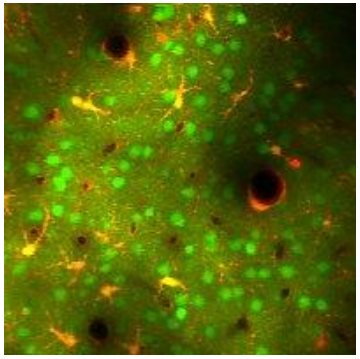


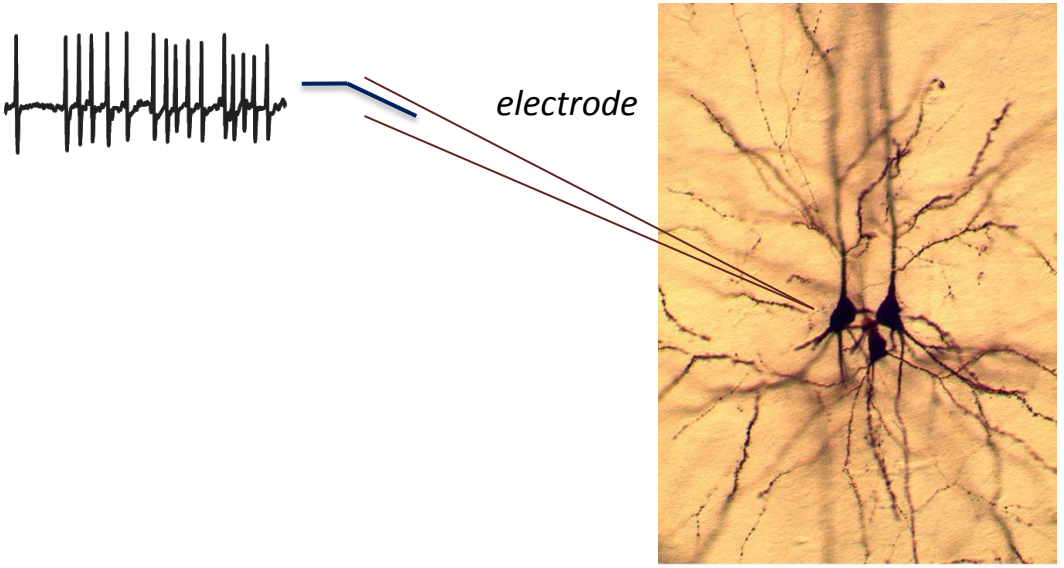

Intact **HVC** important for production of highly stereotypic song

Aronov et al., 2008

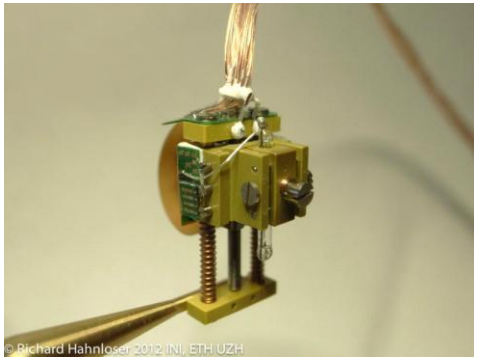
# Measuring neural activity

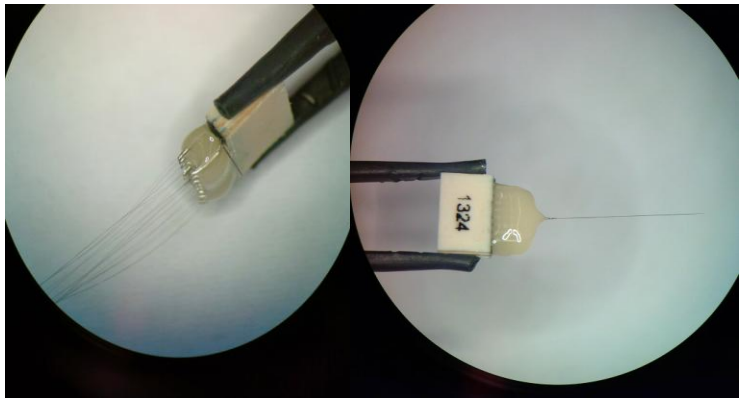


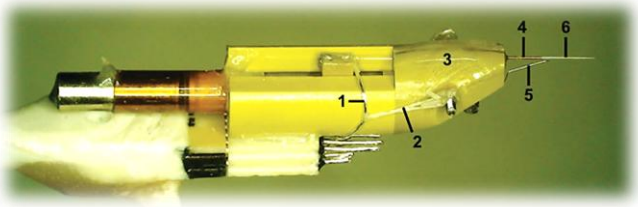
- Electrophysiological recordings



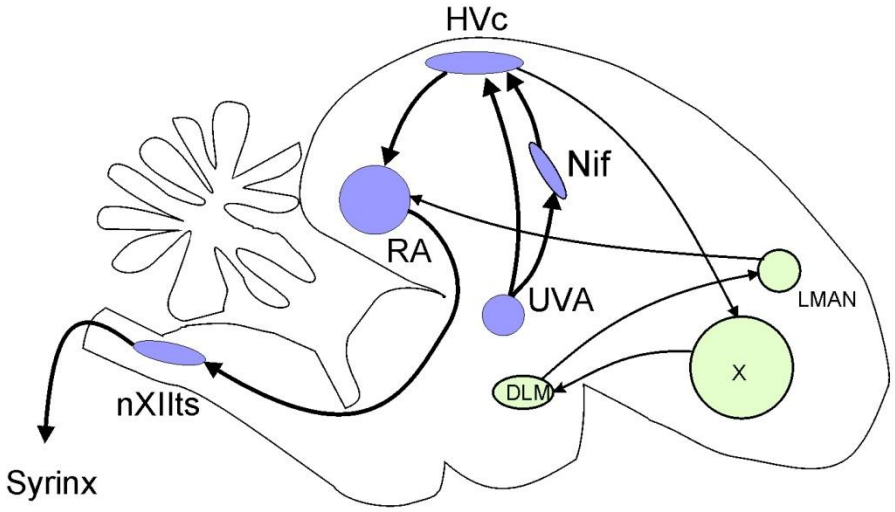
# Chronic recordings in the freely moving bird



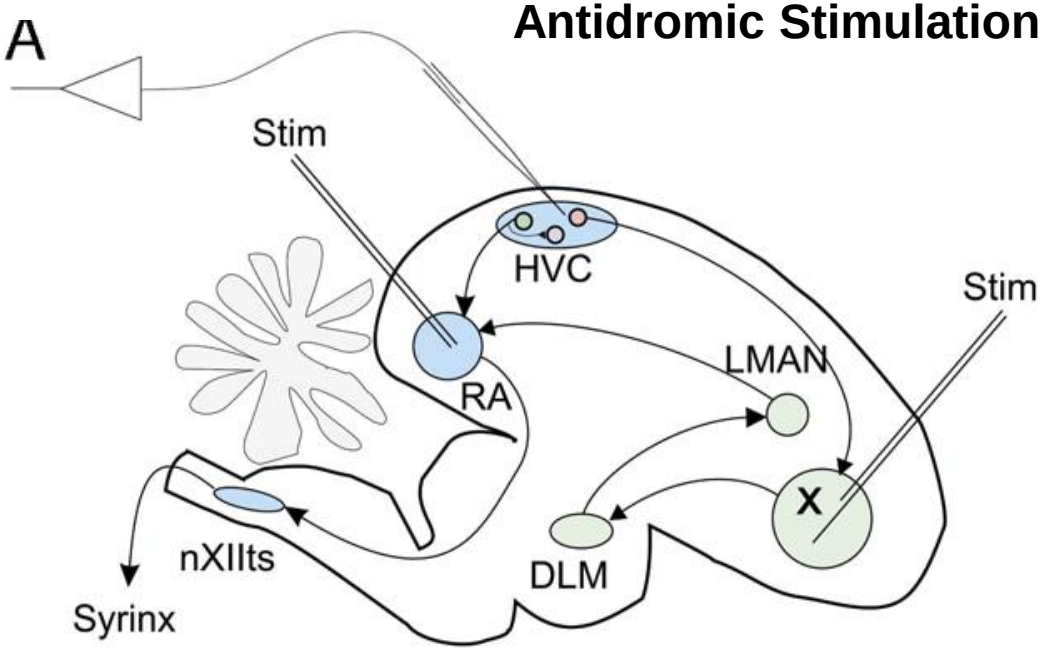



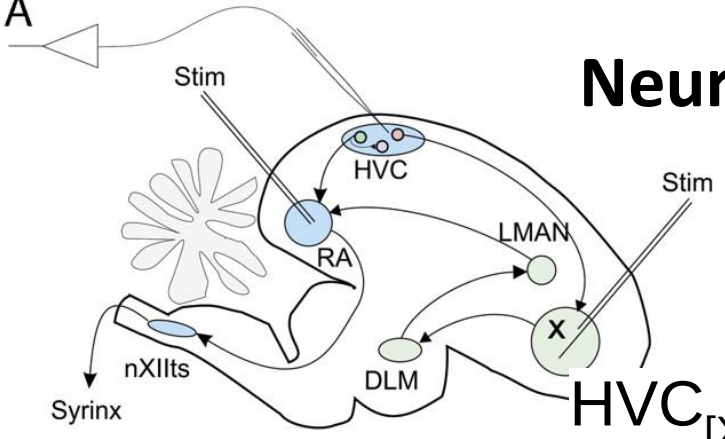

# Neurons in HVC



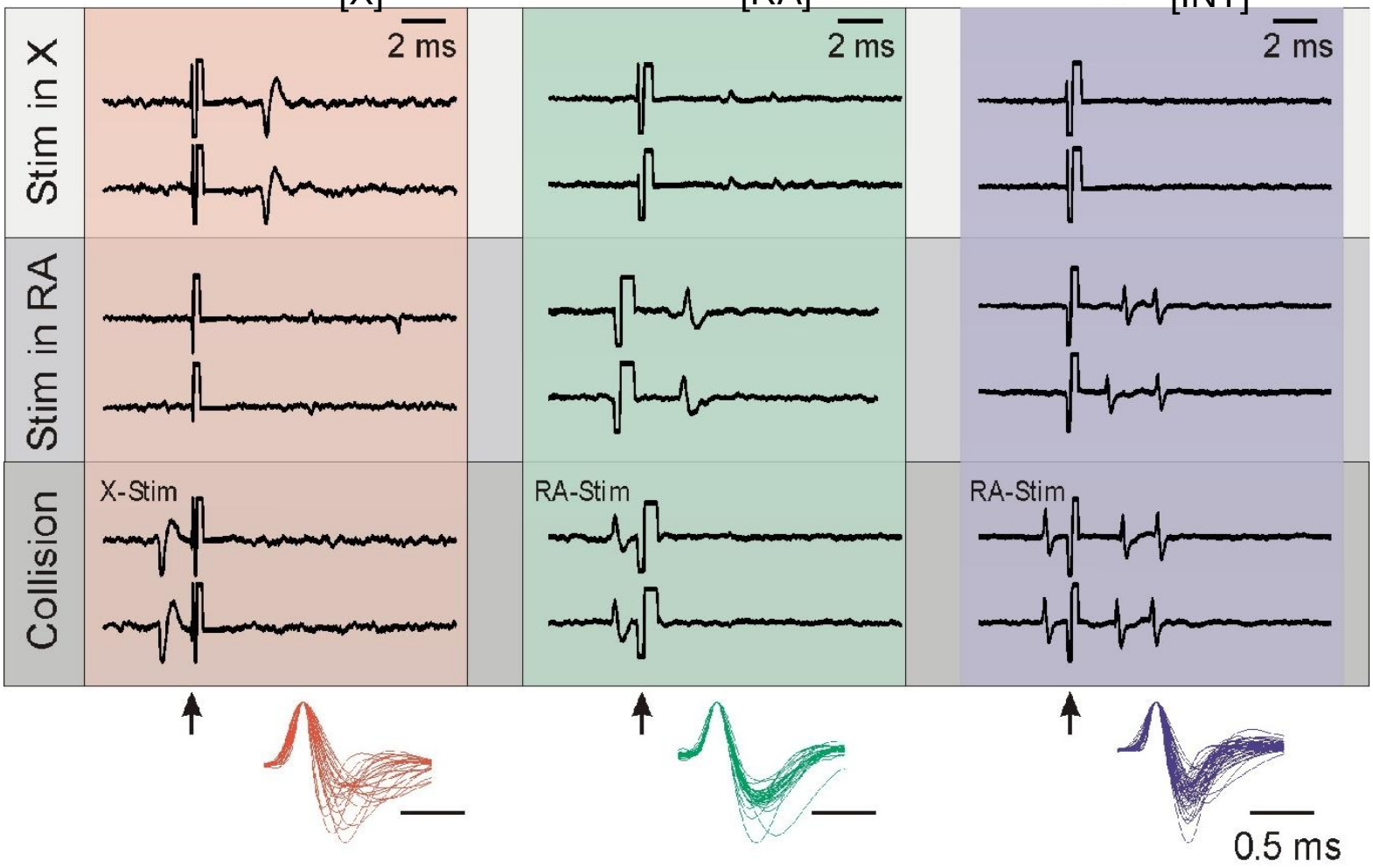

## Antidromic Stimulation



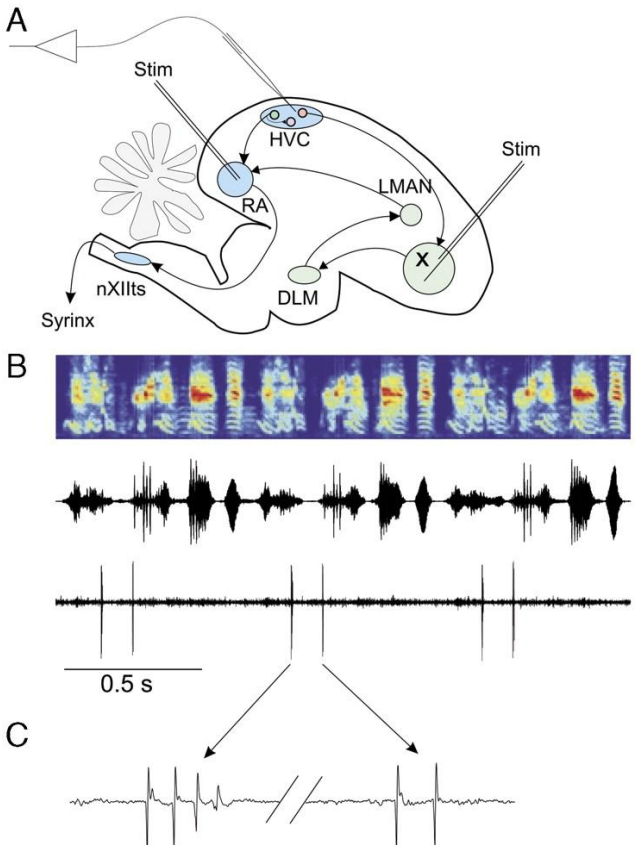
# Neurons in HVC

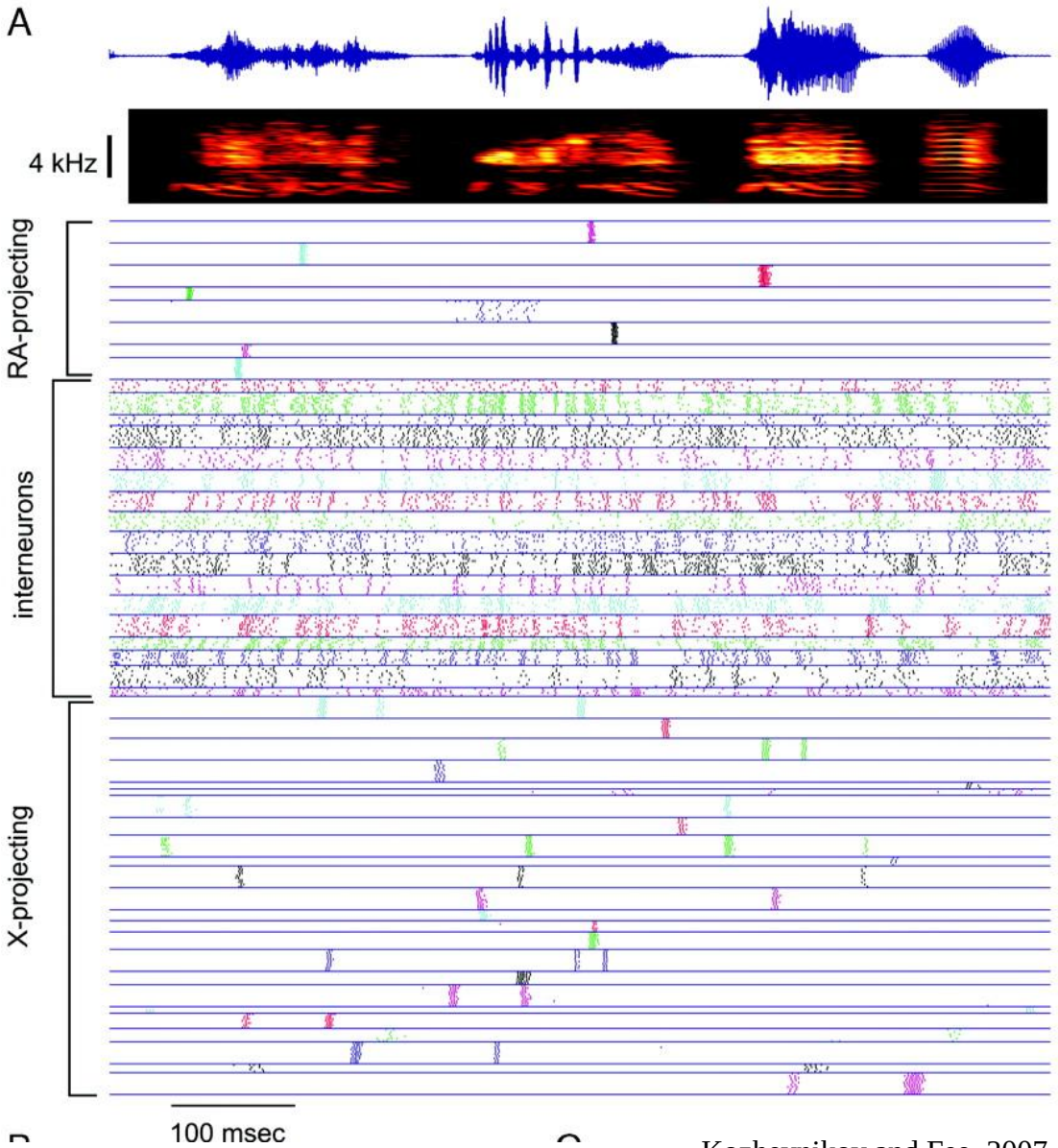



## Collision Test



# Neurons in HVC




$HVC_{RA}$ and $HVC_{X}$ neurons:

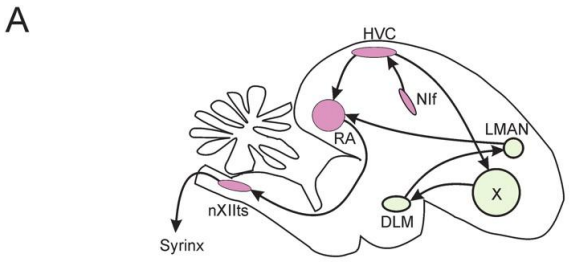
- Inactive in awake non singing bird
- Highly stereotyped (1 burst)
- Tightly time-locked to the song motif
- Occurs reliably on every motif rendition

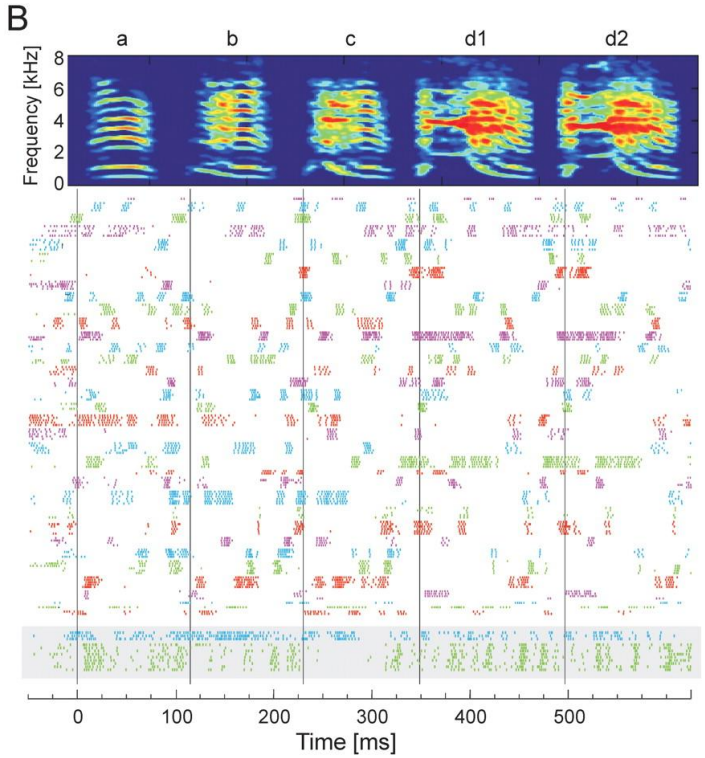
$HVC_{INT}$ neurons:

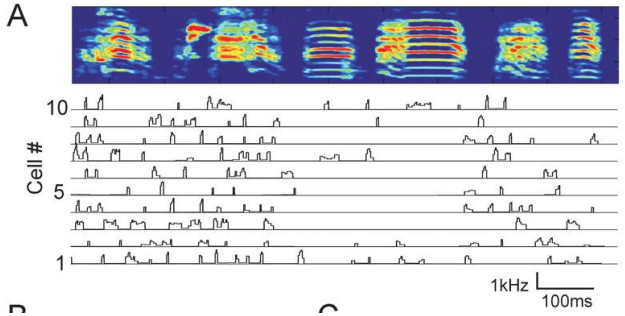
- Spontaneously active in non-singing bird
- High rates of spiking and bursting activity throughout song and call vocalizations

Kozhevnikov and Fee, 2007

# Neurons in RA



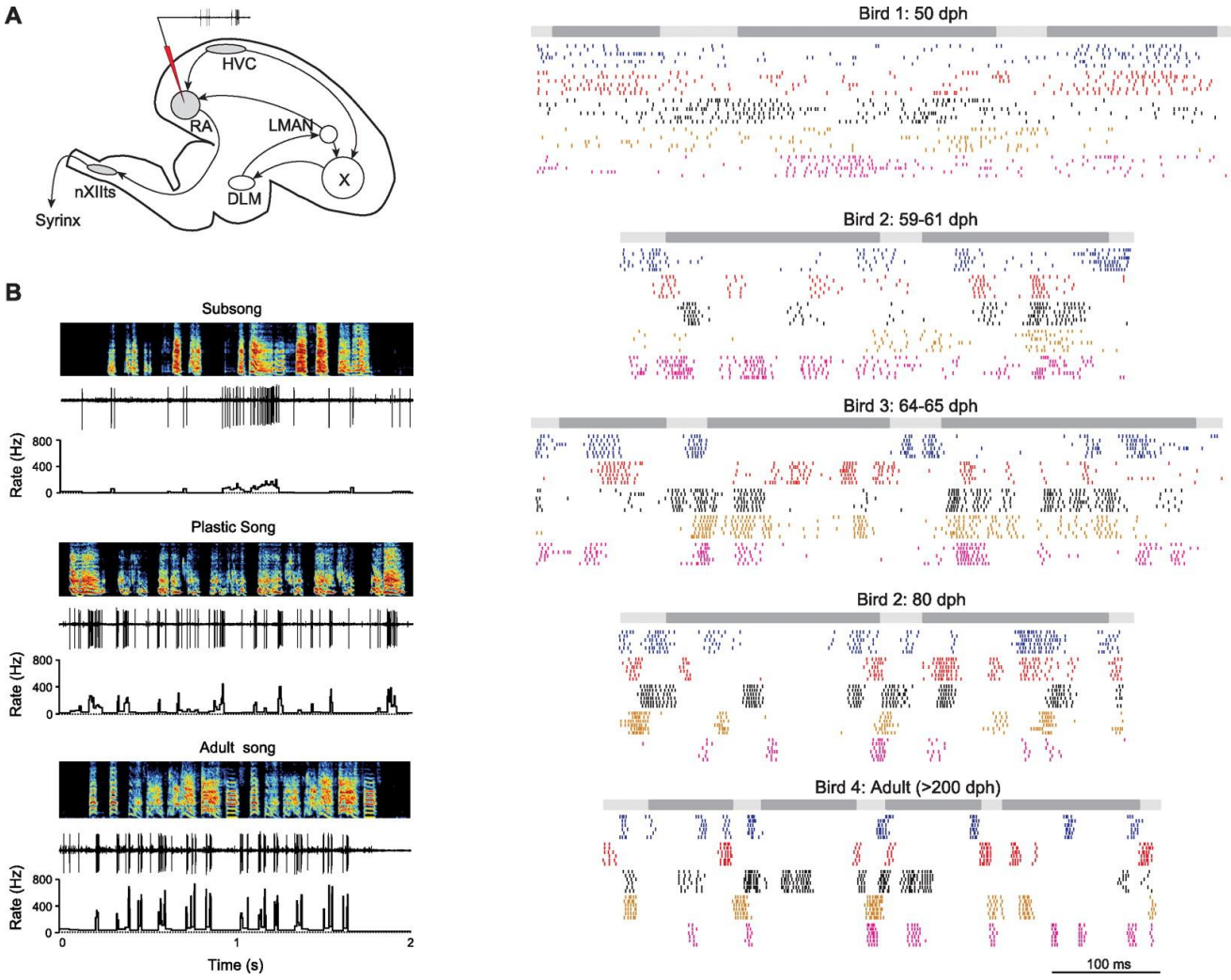




Interneurons

RA movie

Leonardo and Fee, 2005

# RA coding during development




Oelvetzky et al., 2011