

Efficient Coding of Natural Sounds

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Efficient Coding

"The hypothesis is that sensory relays recode sensory messages so that their redundancy is reduced but comparatively little information is lost"

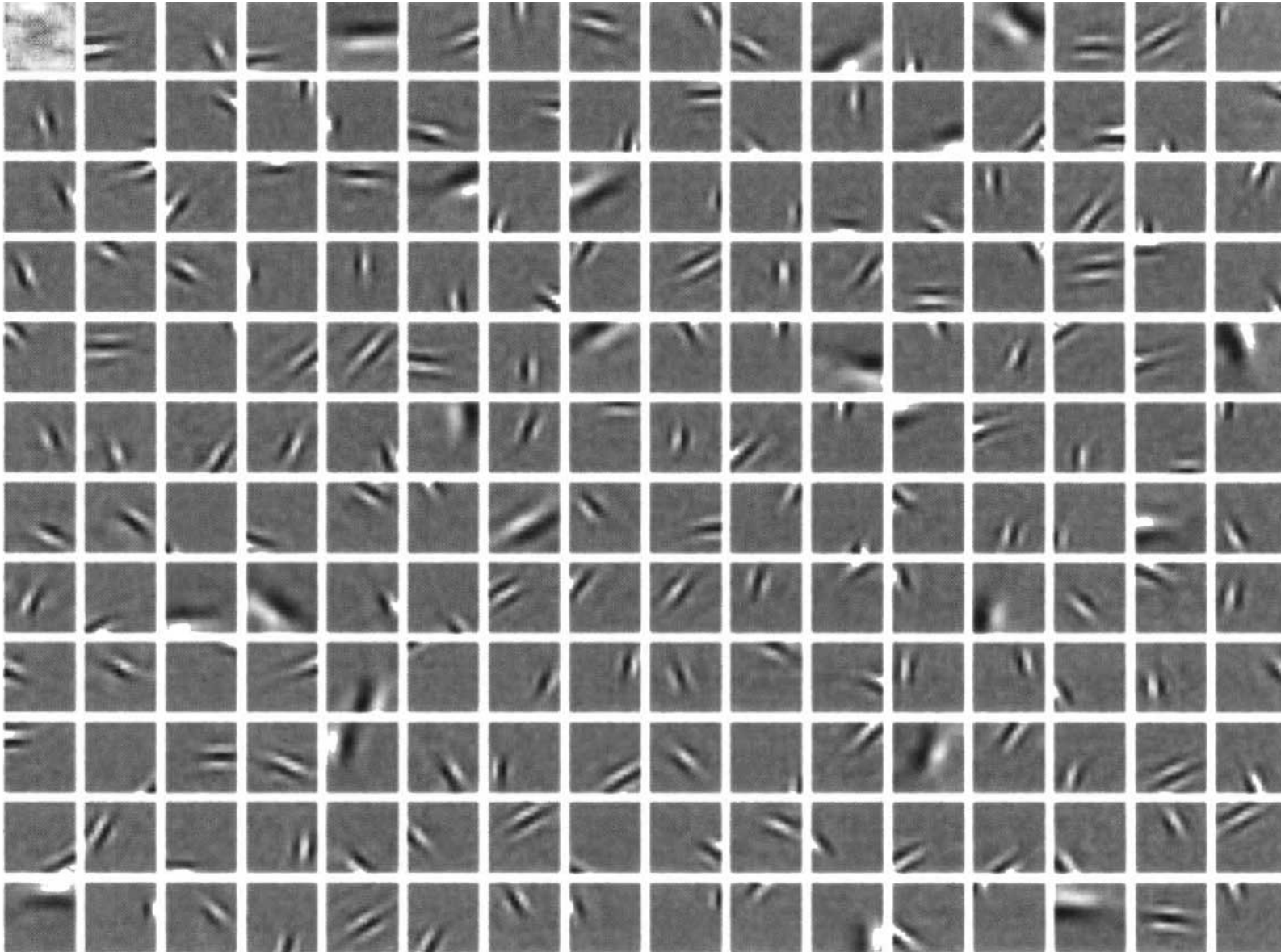
- H. B. Barlow

- Exploit statistical regularities in the environment to streamline the neural representation of stimuli.

Efficient Coding of Images

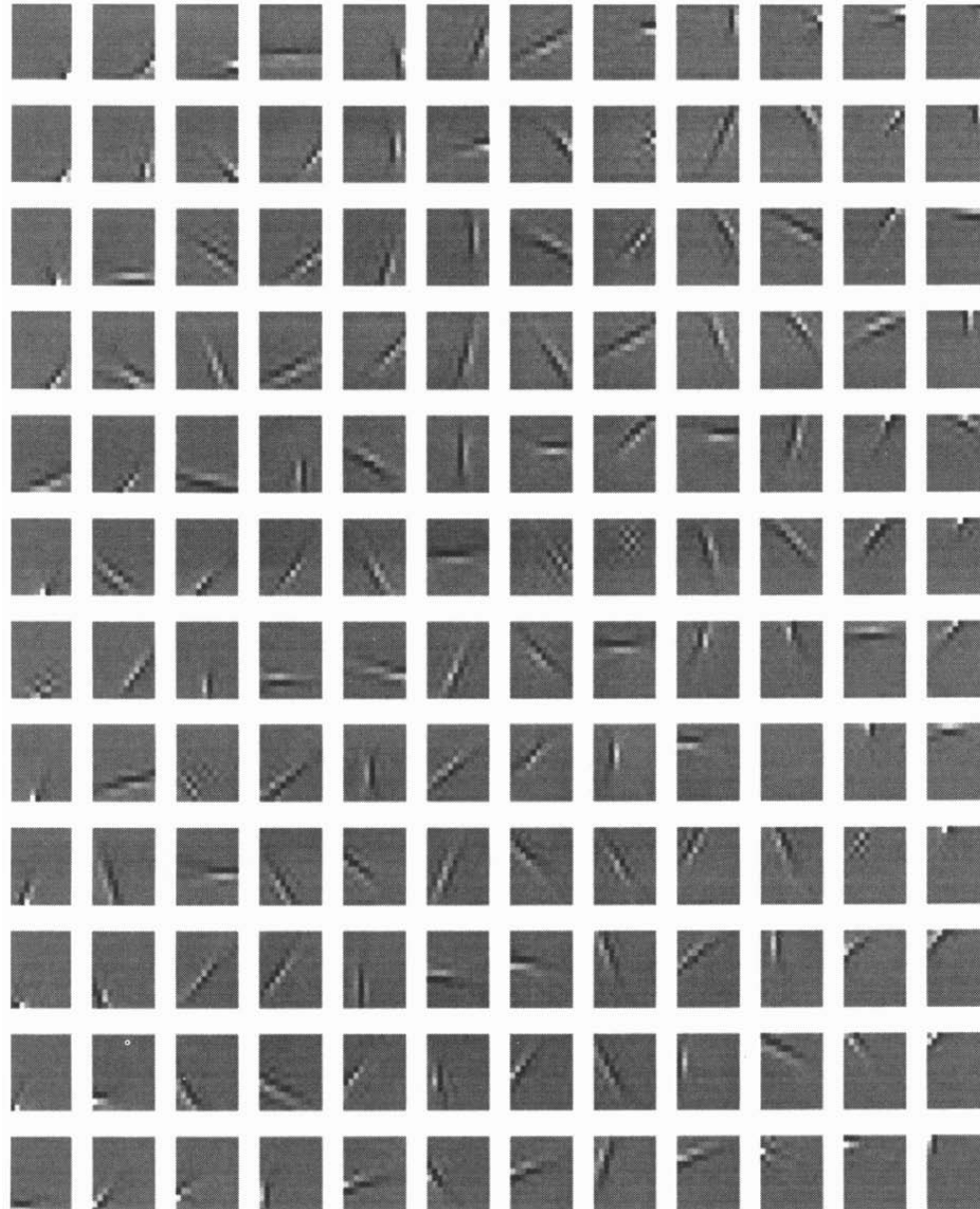
Olshausen & Field 1996:

a



Efficient Coding of Images

Bell & Sejnowski 1997:



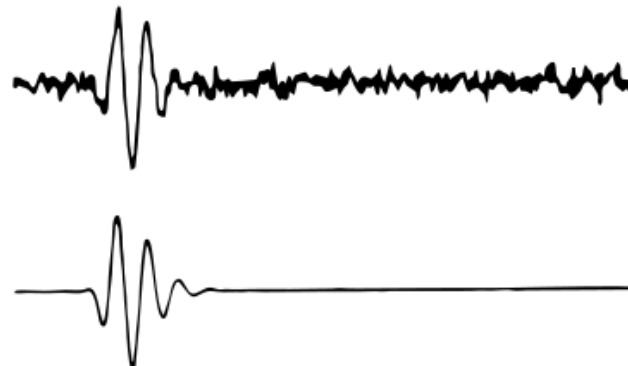
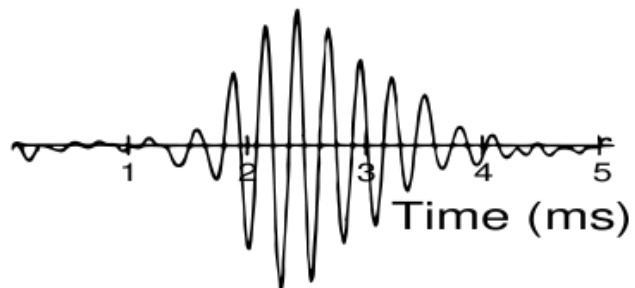
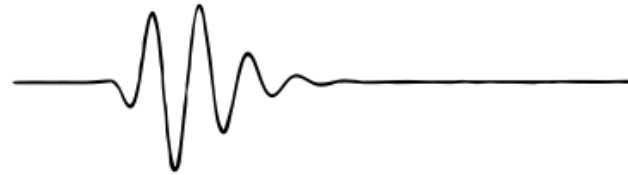
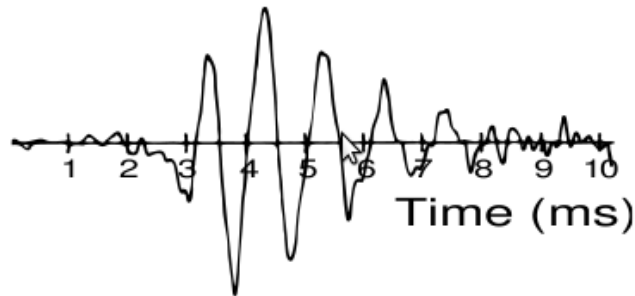
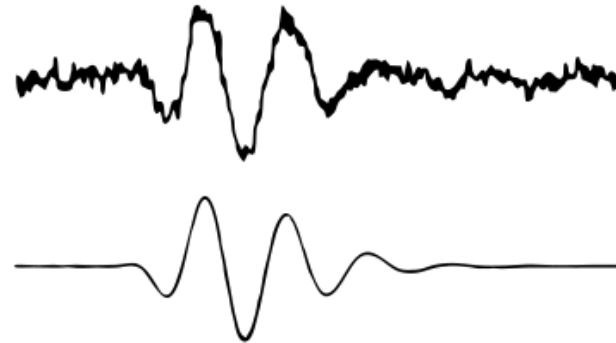
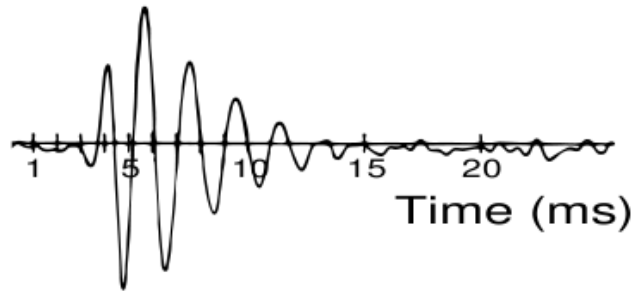
Model of Auditory Response

$$a_i(t) = \sum_{\tau=0}^{N-1} x(\tau)h_i(t - \tau)$$

- a_i is the response (of neuron i)
- x is the input stimulus
- h_i is the filter ("receptive field" of neuron i)
- convolve filter with input to get response

Auditory Nerve Responses

d



Data

Environmental Sounds

- Twigs snapping, rain, fire, streams

Vocalizations

- Animal sounds from the neotropical rainforest



Speech

- Samples from the TIMIT dataset

128-sample (~8ms) segments taken at random from the sets

Filters

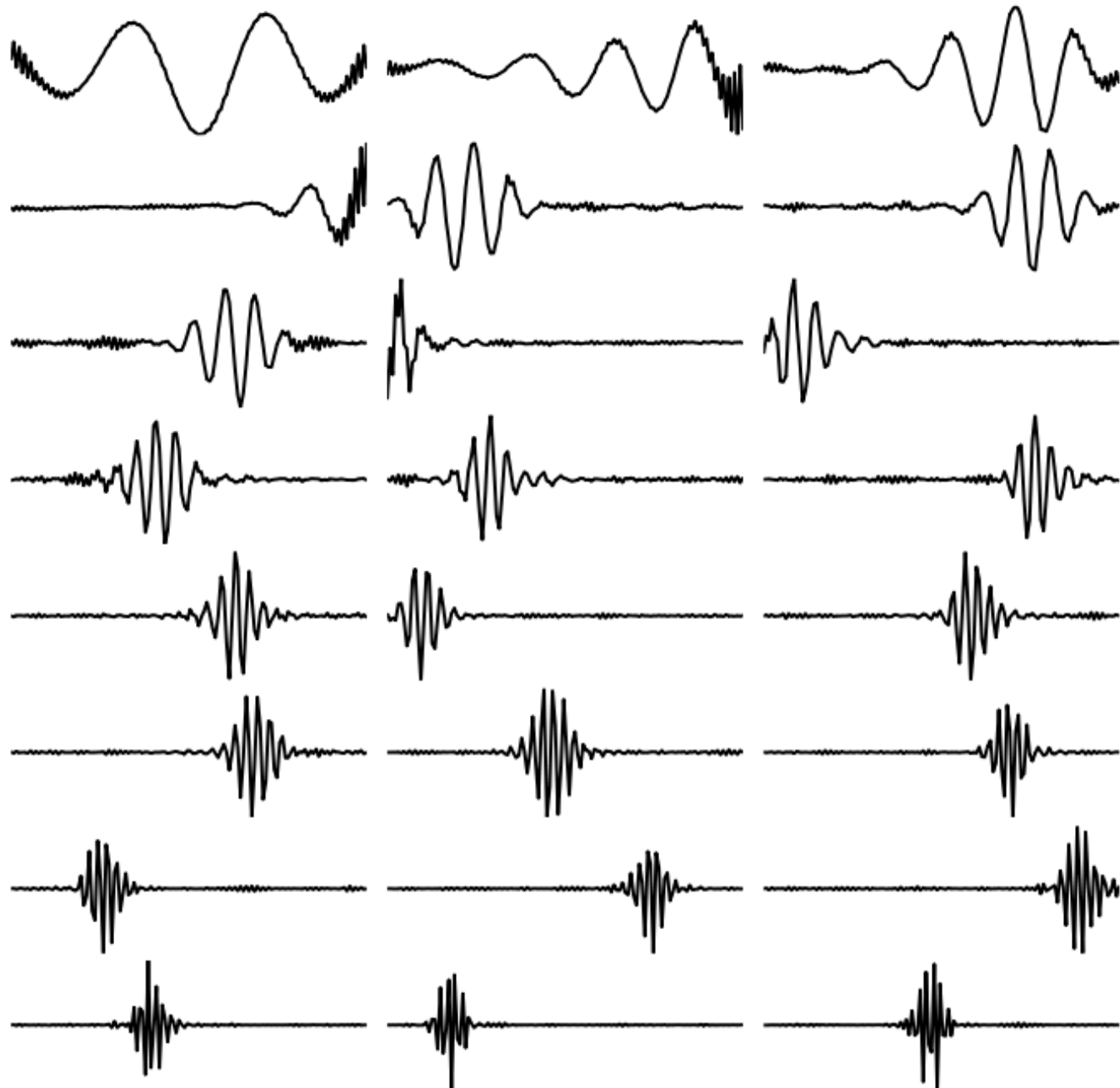
- Independent components found using the gradient of the probability of the signals given the components

$$\Delta\Phi \propto \Phi\Phi^T \frac{\partial}{\partial\Phi} \log p(\mathbf{x} | \Phi)$$

- Not intended to be biologically plausible

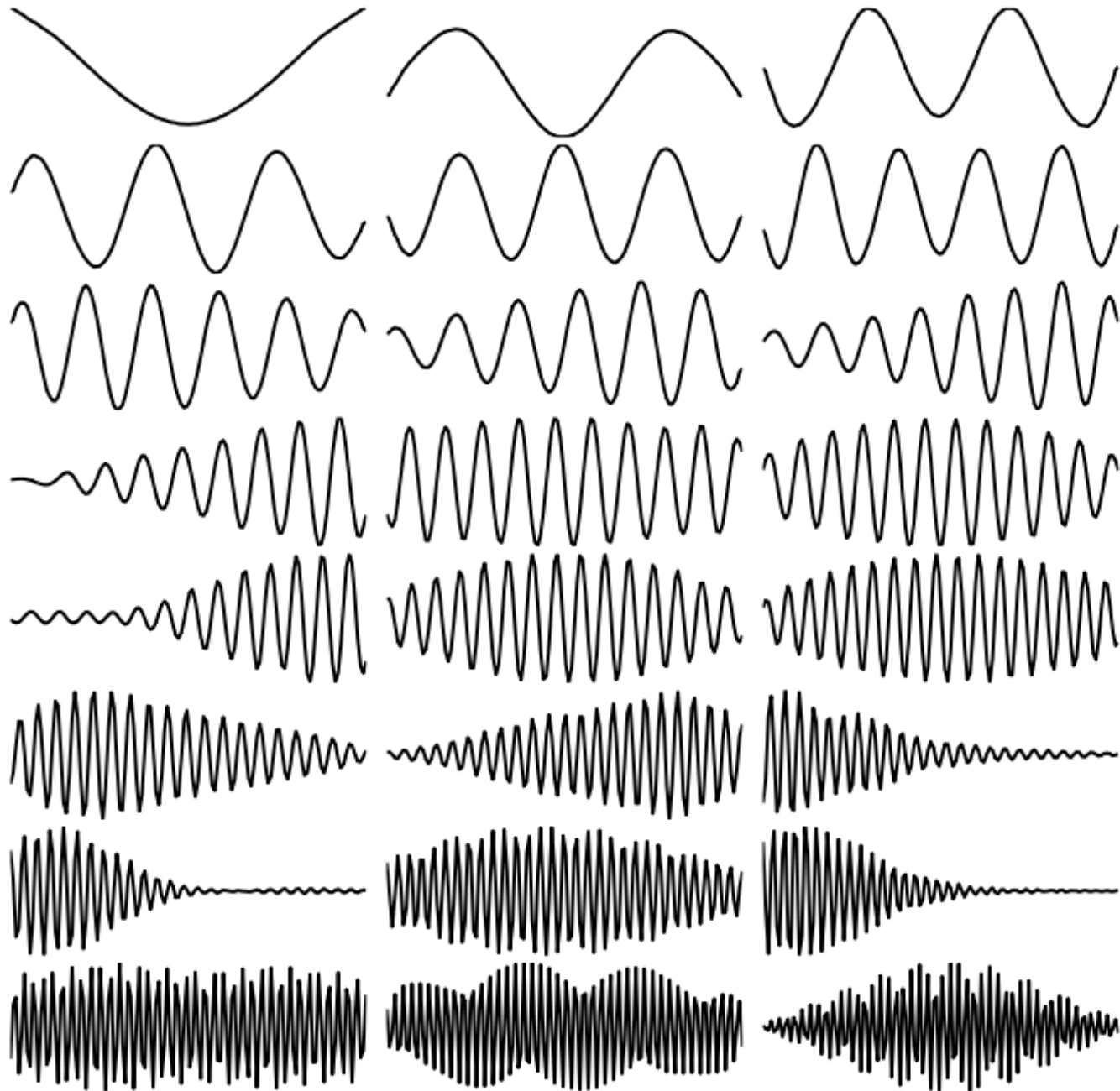
Results - Environmental Sounds

a



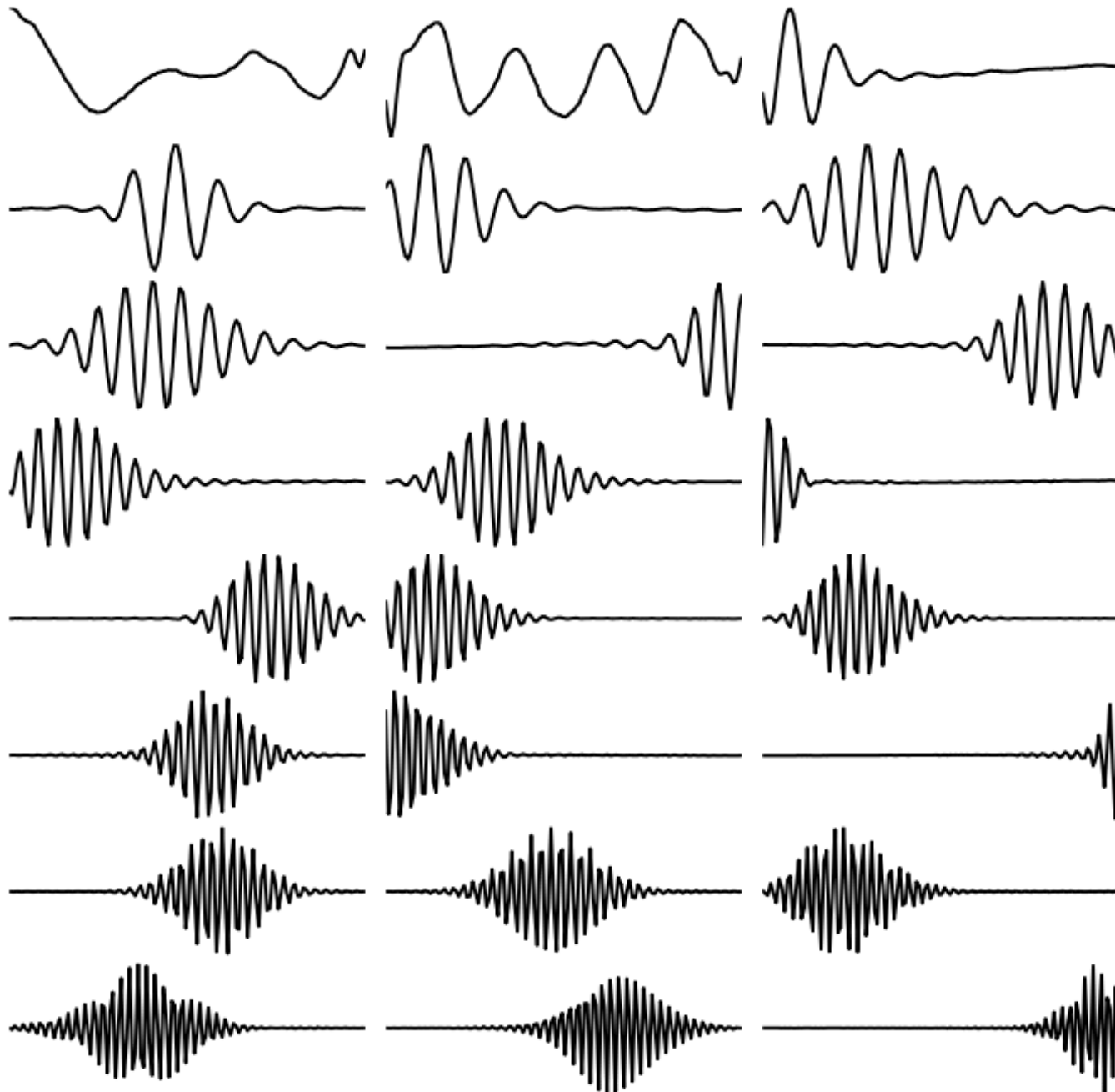
Results - Vocalization

b

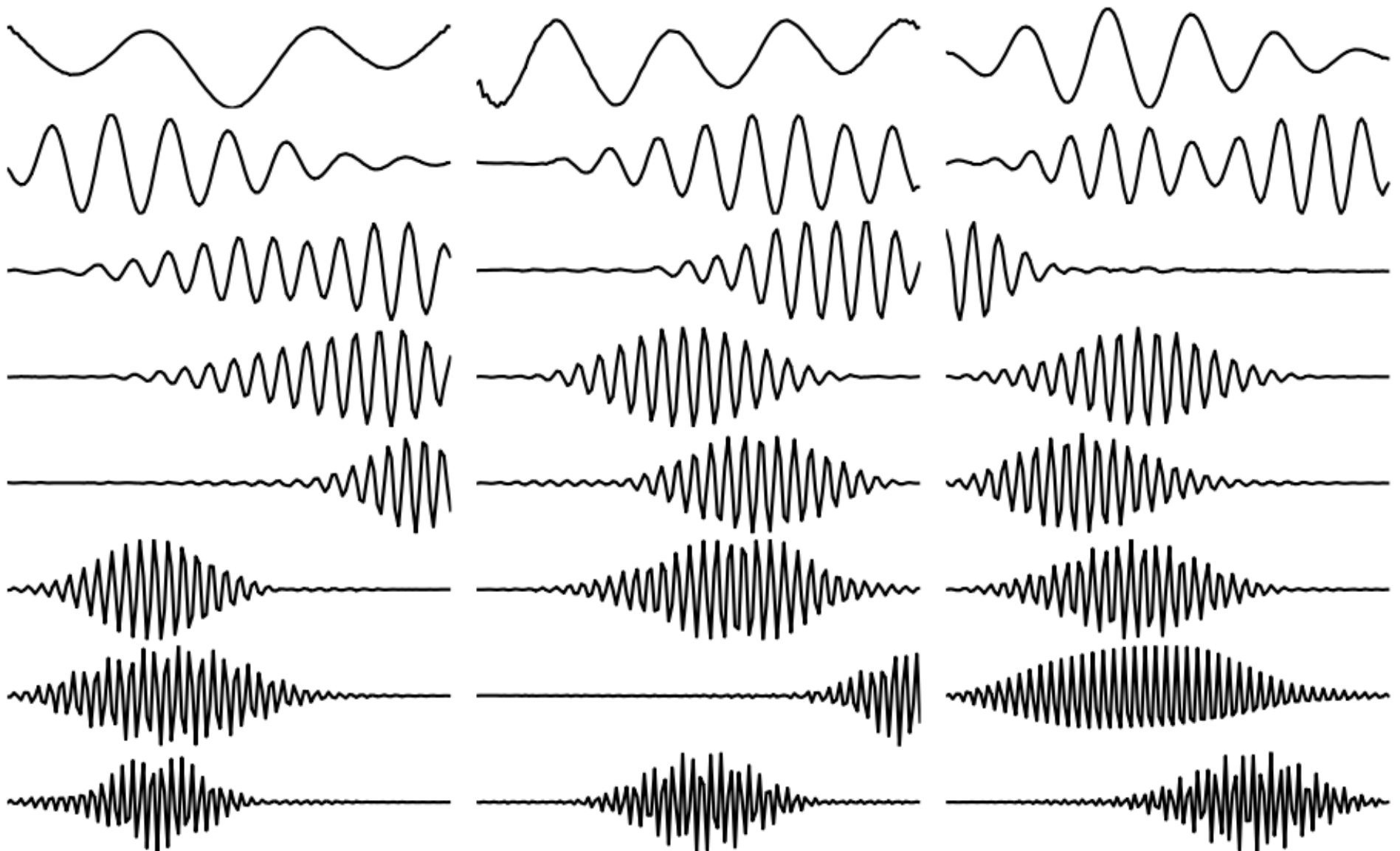


Results - Speech

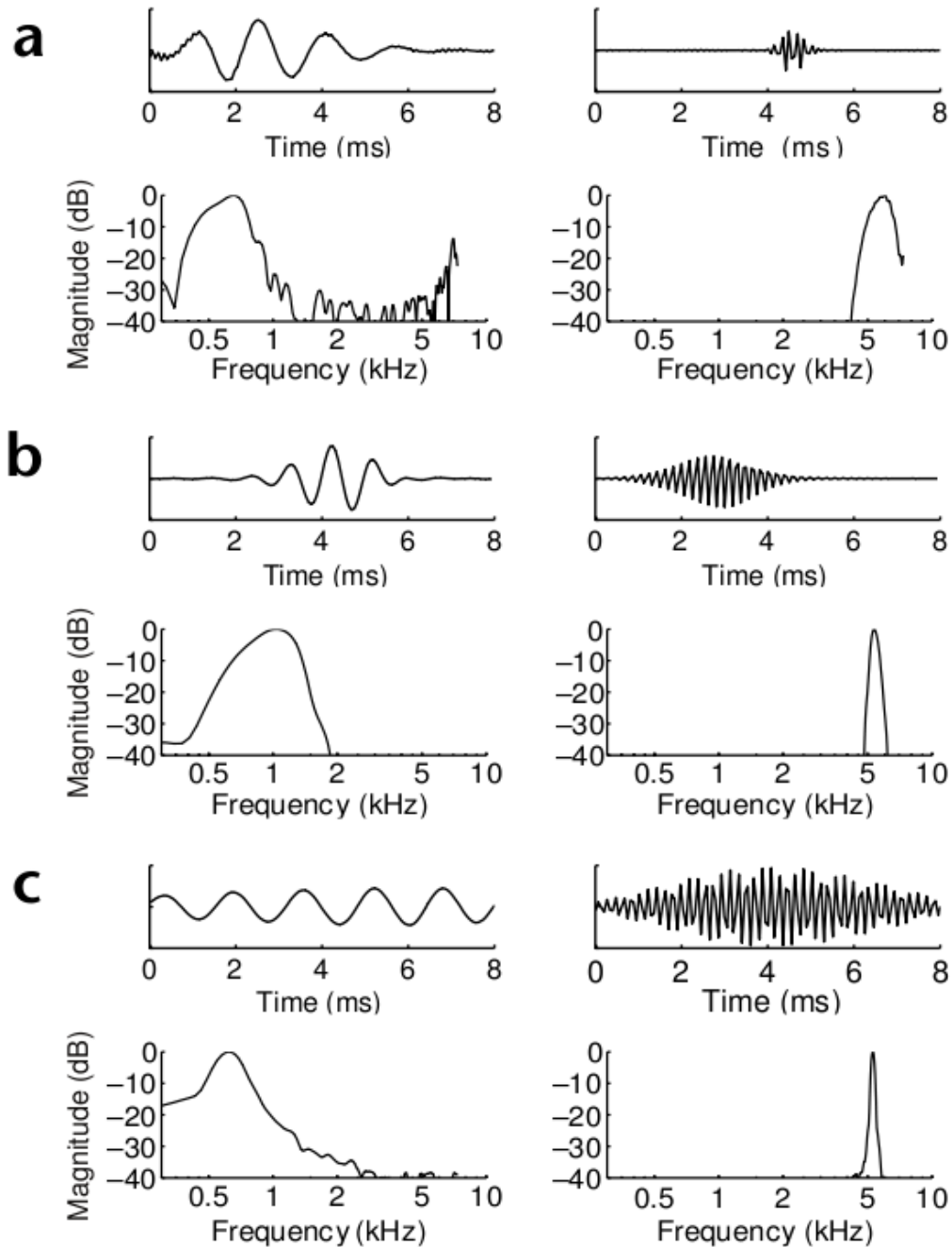
c



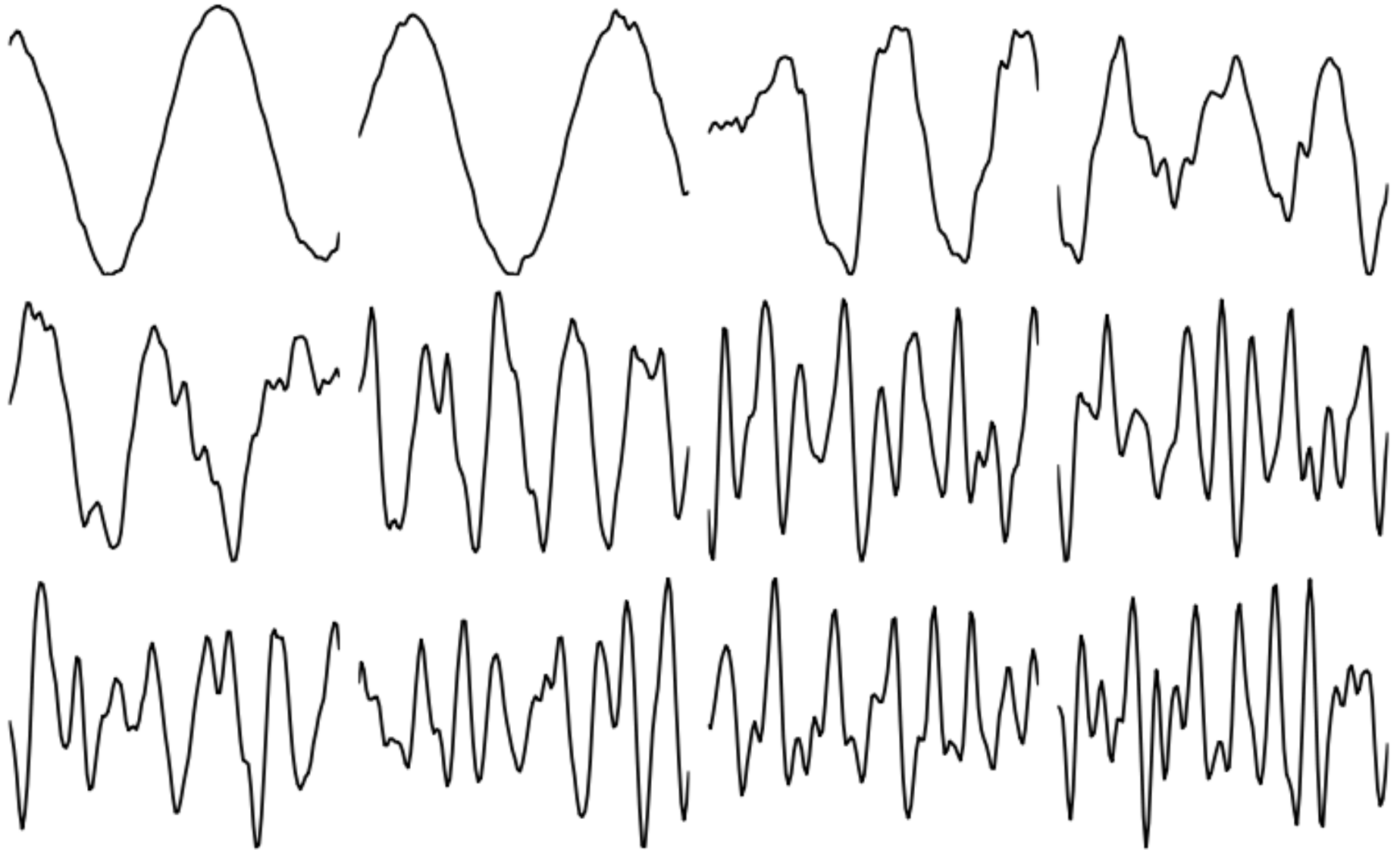
Results - 2 Sound : 1 Vocalization



Time/Frequency Tradeoff

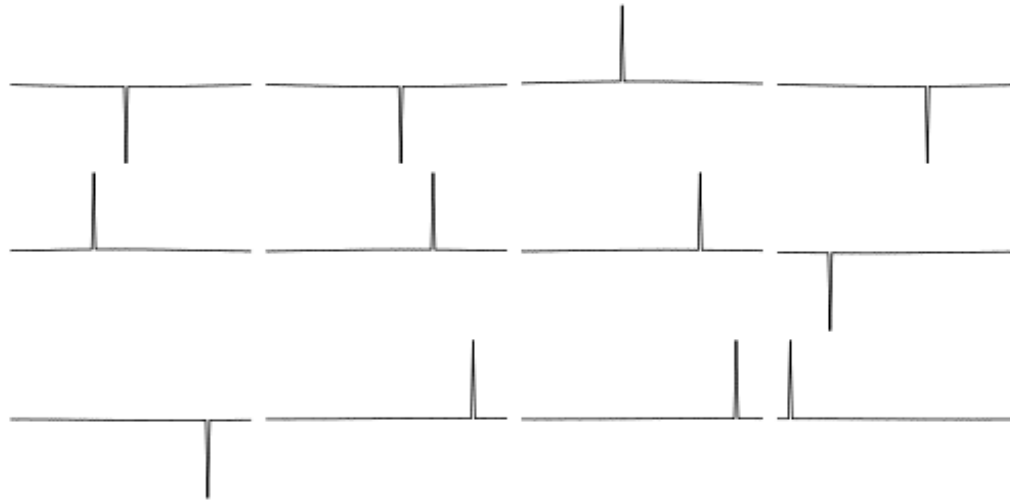


PCA on Environmental Sounds

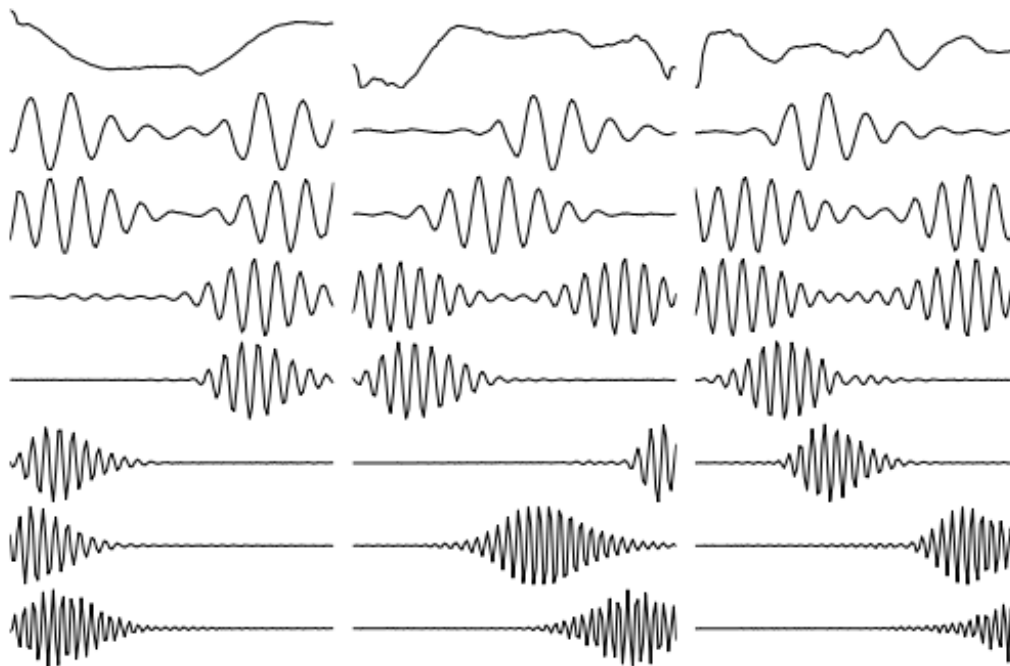


Sparse Noise and Single Speaker

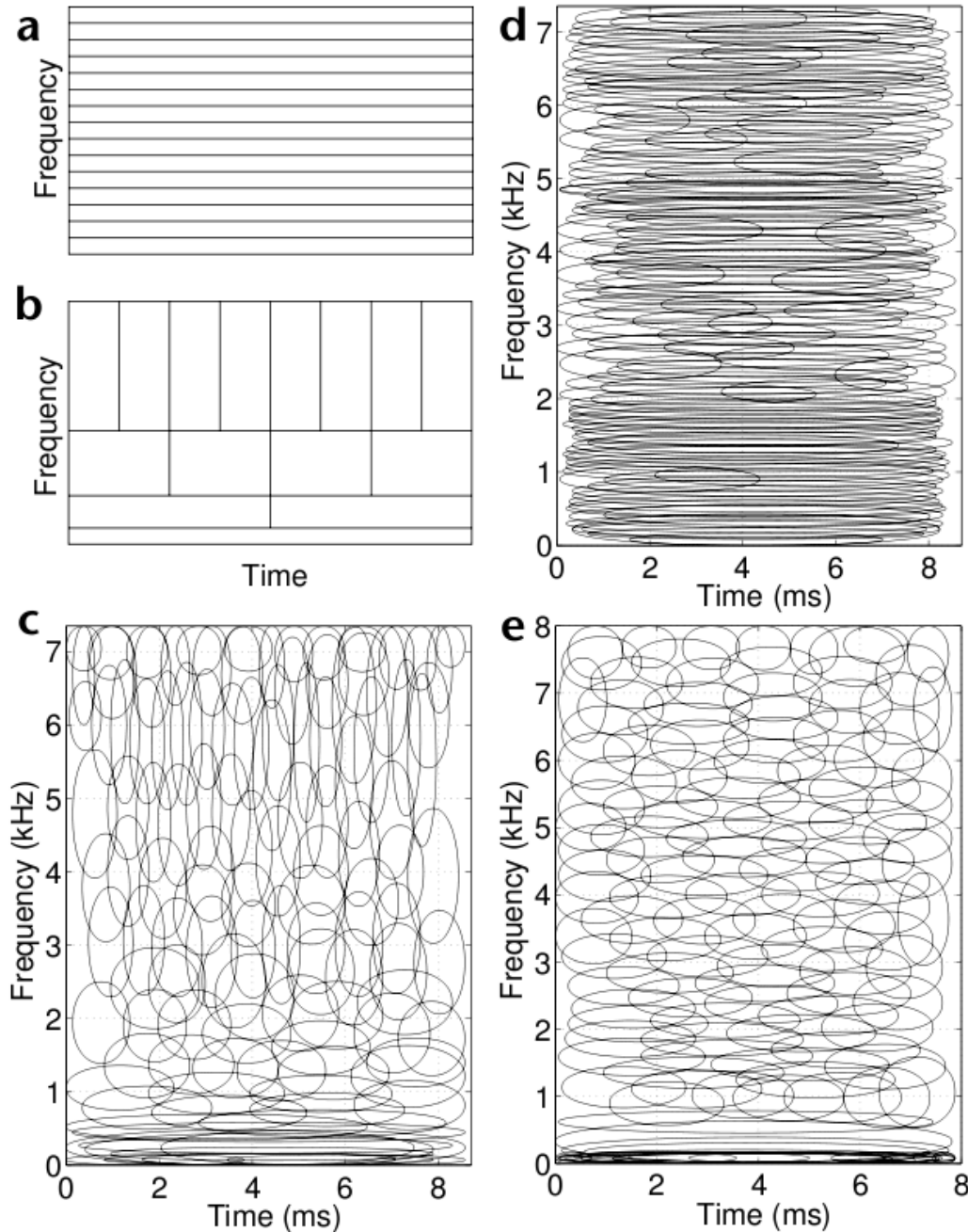
a



b

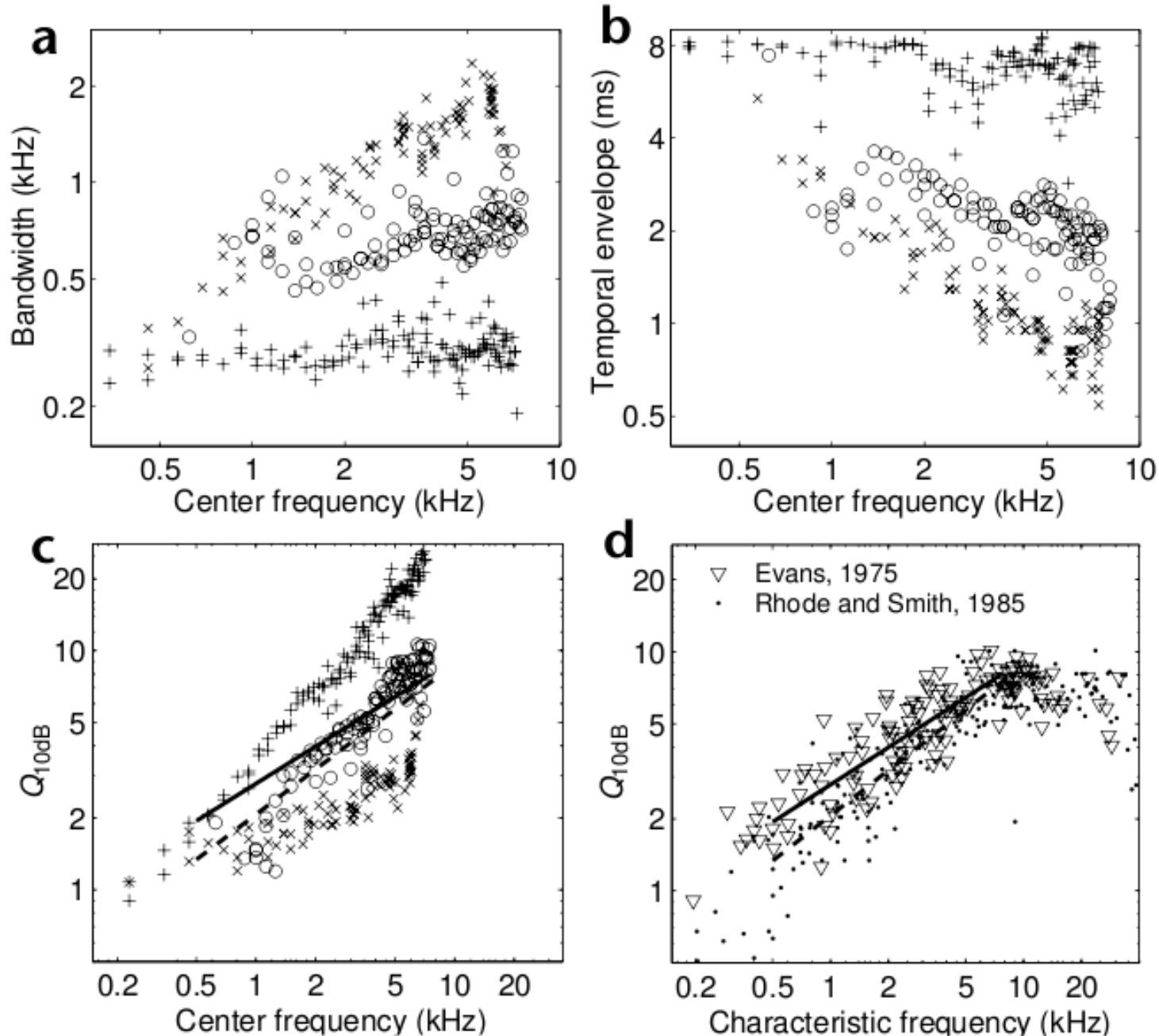


Time-Frequency Analysis

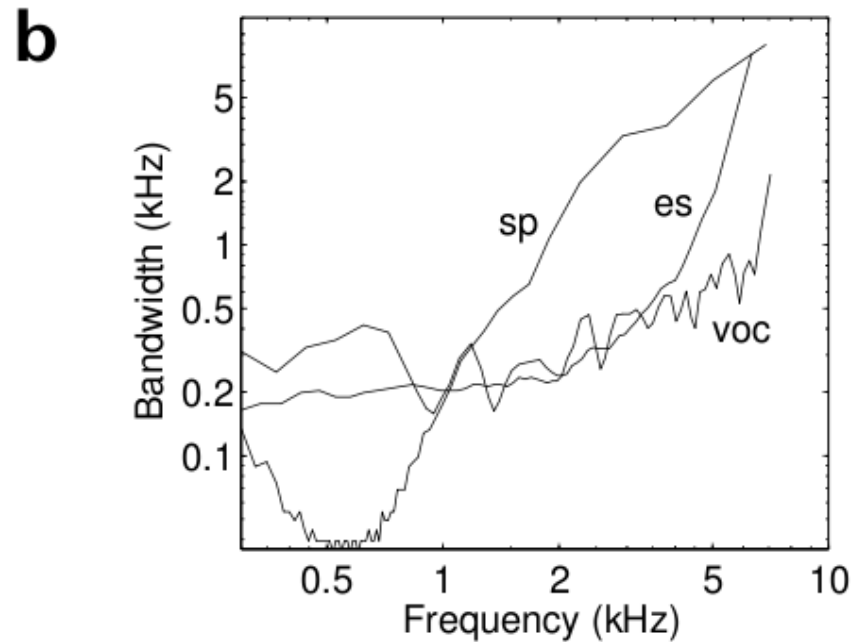
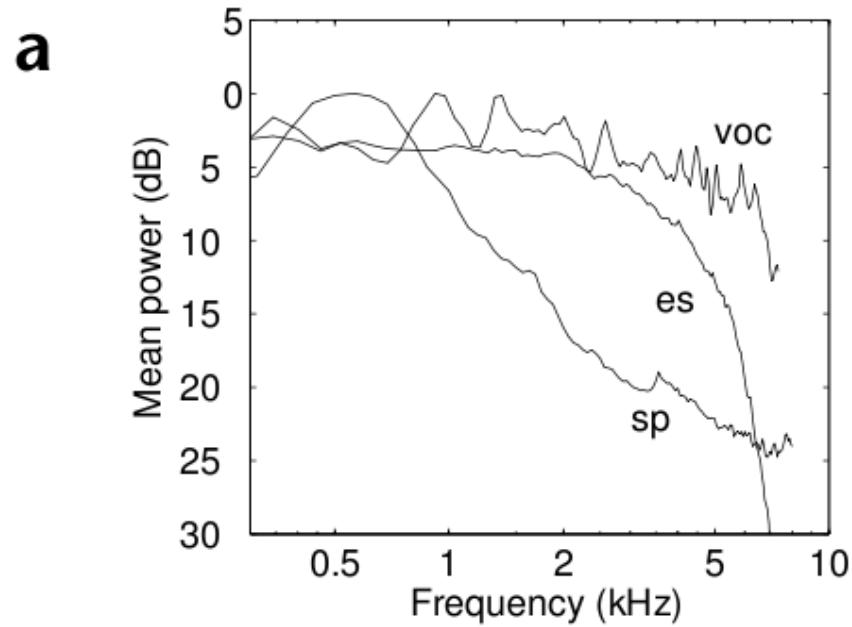


Comparison to Physiological Data

+ Voc
o Sp
x Es



Equalized power spectra



Discussion

- Results provide an explanation for cochlear responses as efficient codes of natural sounds
- Limitations:
 - Linear
 - Small timescale
 - Not causal filters
- Resemblance of filters to data shows that efficient codes evolved
 - Why not learned?