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Grau en Biologia
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Compared **Echolocation** *in selected vertebrates*

Introduction & Aims

Echolocation, or biosonar, is an active sensory system that consists of the emission of sound and the determination of environmental characteristics from received echoes. Because of the wide array of echolocators, this review will focus on microchiropterans, odontocetes and birds (both oilbirds and swiftlets).

Function

Microchiroptera	Odontoceti	Aves
Foraging, orientation, **obstacle avoidance**, social uses	**Foraging**, orientation, **obstacle avoidance**, possibly social uses	Orientation and **obstacle avoidance**, possibly conspecific recognition

Signal acoustics

Microchiroptera	Odontoceti	Aves
Ultrasonic (20-60 kHz); 0,3-100 **ms**	**Ultrasonic** (30-200 kHz); 70-250 **μs**	**Non- ultrasonic** (0,5-15kHz); several **ms**

Modulation

Microchiroptera	Odontoceti	Aves
Highly modulated depending on situation. Shared **hunting and exploring patterns**	**Highly modulated** depending on situation. Shared **hunting and exploring patterns**	Shared **exploring pattern**. Slightly modified when approaching objects

Signal types

- **FM**: broadband, short. Species moving in open spaces
- **CF/FM**: narrowband, long CF component + FM component. Species living in cluttered habitats.

Fig 1: *Eptesicus* signal as a FM bat and *Rhinolophus*' as a CF/FM bat. Adapted from: Airas. *Echolocation in bats, in Proceedings of Spacial Sound Perception and Reproduction*, 2003.

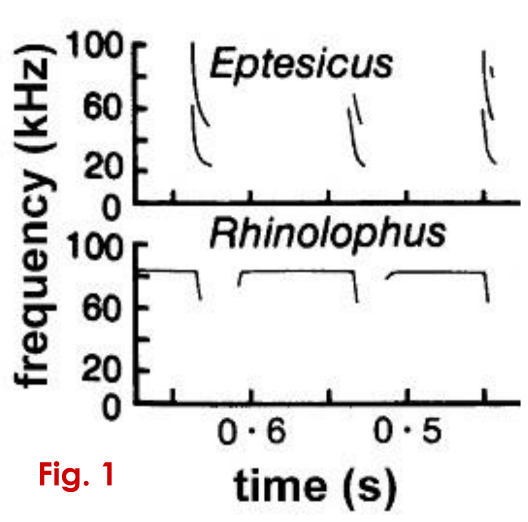


Fig. 1

- **Type I** : narrowband, long, higher frequency. Species living in cluttered coastal waters
- **Type II**: broadband, short, lower frequency. Pelagic species

Fig. 2: signal representations. Adapted from: Jones. *Echolocation*. Current Biology, 2005

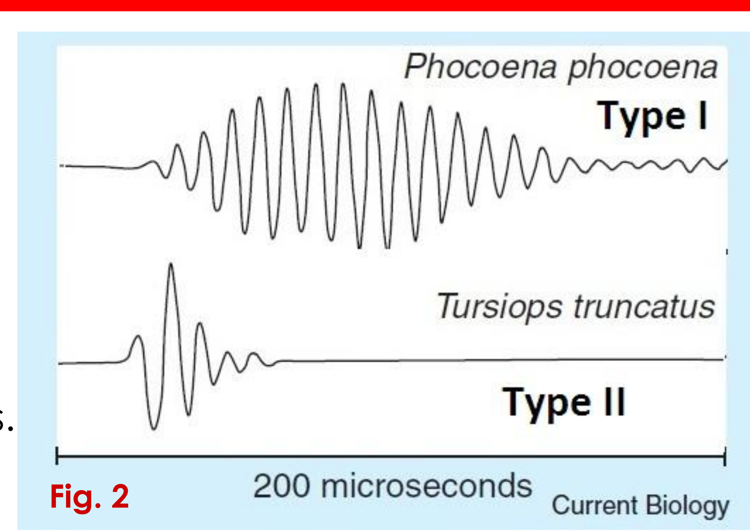


Fig. 2

Broadband, short, low frequency.
- **Oilbird**: 2-6 pulses per click
- **Swiftlet**: 1 or 2 pulses per click

Fig. 3: Oilbird and swiftlet signal Representations. Adapted from: Brinklov. *Echolocation in oilbirds and swiftlets*. Frontiers in Physiology, 2013.

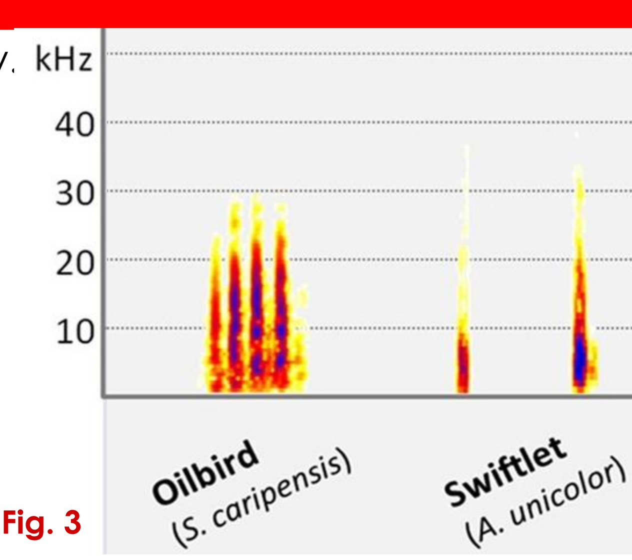


Fig. 3

Signal production

Microchiroptera	Odontoceti	Aves
Production in the **larynx**. Emission possibly modulated by noseleaves.	Production in the **nasal tract**. Transmission through the **melon**	Production through vibrations of the **syrinx**

Signal reception

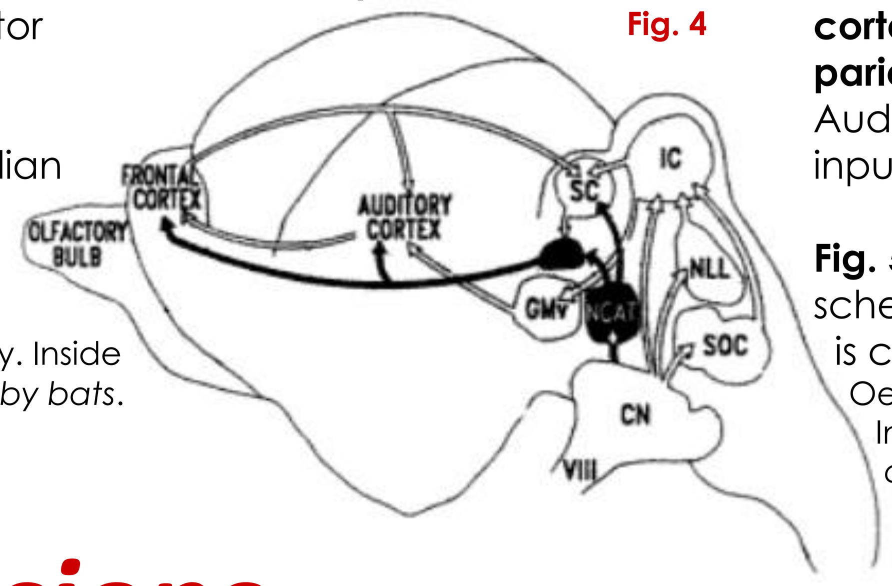
Microchiroptera	Odontoceti	Aves
Highly developed pinnae, amplify sound and provide cues for sound source location. **Stiff middle ear** isolated by ligaments. **Long, stiff cochlea**, with **acoustic fovea** improving resolution in the echolocation frequency	**No pinnae. Acoustic fats** transmit sound to the **middle ear**, which is **stiff** and isolated. **Long, stiff cochlea**, echolocation frequency area **densely innervated**	**No pinnae**. **Simple ears**, do not allow high-frequency hearing

Signal processsing & integration

Enlarged auditory nuclei.
CF areas greatly expanded in most nuclei. Sound source location in the azimuth axis shifted to higher levels. **Target distance processing in the thalamus and the auditory cortex.**
Close integration of motor and auditory systems.

Fig. 4: General mammalian auditory pathway, represented on a microchiropteran brain. From: Covey and Casseday. Inside of: Popper and Fay. *Hearing by bats*. Springer-Verlag, 1995.

Fig. 4



Enlarged auditory nuclei. Faster transmission and neuron recovery in the auditory pathway.
Target distance processing in the thalamus and the auditory cortex, which is shifted to the **parietal lobe**.
Audition is the main sensory input of the motor system

Fig. 5: Odontocete brain scheme. The auditory pathway is colored in blue. From: Oelschläger and Oelschläger. Inside of: Perrin *et al. Encyclopedia of Marine Mammals*. Academic Press, 2008.

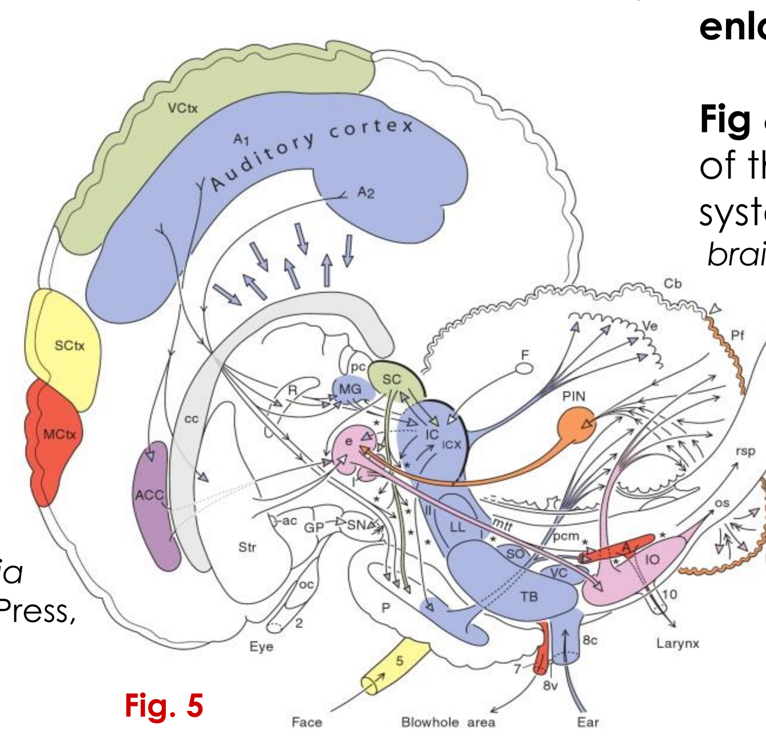


Fig. 5

Auditory nuclei seem to be **enlarged.**

Fig 6: general representation of the avian auditory neural system. From: Jarvis *et al. Avian brains and a new understanding of vertebrate brain evolution*. Nature Reviews Neuroscience, 2005.

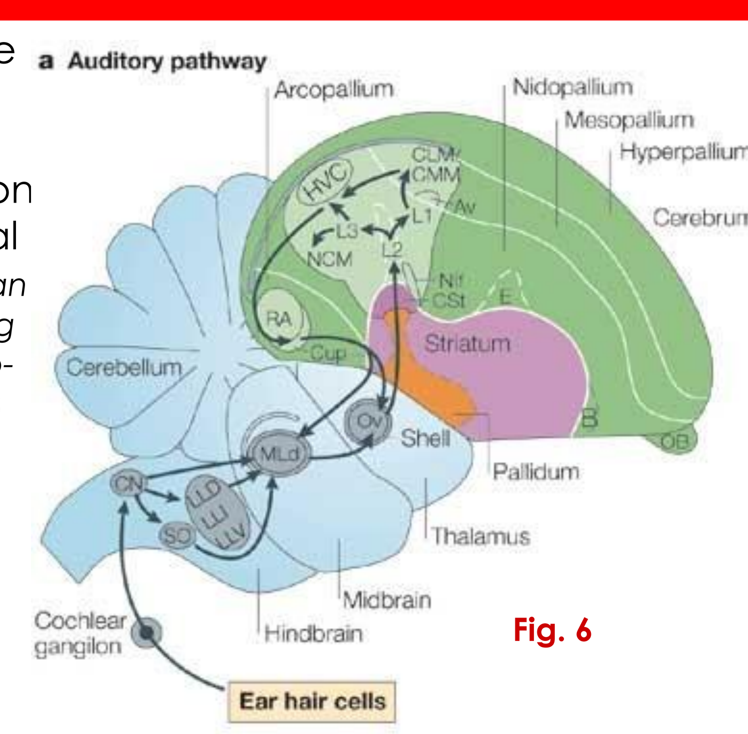


Fig. 6

Conclusions

Although these taxa are very different animals indeed, they all move in an environment where vision is limited. This has forced the development of echolocation.
Each group has found its own ways to achieve many shared traits; such as signal emission patterns. Odontocete and Microchiroptera have very similar signals and adaptations to environments that are acoustically alike. Therefore, signal-dependent reception adaptations are also similar; even though emission systems are quite different. Aves' signals are more primitive, since their anatomical features strongly limit sound perception.
Neural adaptations are not very well known, but tend toward the amplification of auditory areas and increasing complexity of biosonar processing.

Selected references

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