*EPISODE ONE:*
# HOW DO FISH HEAR?

## It's a wonder how and why fishes hear!

In this special *pilot episode* of ScatterLab, Samantha shares EVERYTHING from the basics to the bizarre in the world of fish hearing and sound perception. We are one step closer to discovering what would happen if we threw an underwater rave for our fishy friends!

*NOTE: This content was made originally as an honors project for the University of Washington course: FISH311 - Biology of Fishes.* ***This content is free and accessible to any and all.*** *Have fun!*

**Materials:**
**Video:** HOW DO FISH HEAR? | ScattrLab Ep1

**Assignment/Questions:** (multiple formats available)
- Google Docs (copy and edit)
- PDF

***Optional Materials:***
Assignment Key
Additional Resources/Activities

Otolith Poster/Sticker/Pin:
- PDF
- Redbubble

various saggital otoliths

## Course/Syllabus Learning Objectives:

- How do fishes hear, and what are some unique adaptations?
- Be able to make predictions about the brain of a fish, and the senses that are important, based on the environment.


## In this video, you will...

LEARN how sound moves differently in water than it does in the air, and that fishes have plenty of great reasons to rely on the sense of hearing

EXPLORE the anatomy and physiology of a modern fish's inner ear

DISCOVER that some fishes can hear beyond the frequencies audible to humans

EXAMINE case studies of unique adaptations that impact hearing abilities in different fishes

LEARN about the Lateral Line and how it connects to sound and pressure reception

## After this video, try your hand at these questions and...

PRACTICE reading and interpreting figures from scientific articles about the hearing ability case studies presented in the video

DESIGN your own experiments to test the limitations and adaptations of different parts of the hearing apparatus in fishes.

HYPOTHESIZE and JUSTIFY how evolutionary trends in fish hearing may have occurred based on information about life history

# Assignment/Questions

## Swim bladder Swindle

In a 2000 study, scientists examined the impact of intact versus deflated swim bladders OR the removal of suprabranchial chambers on hearing perception in goldfish and blue gouramis.

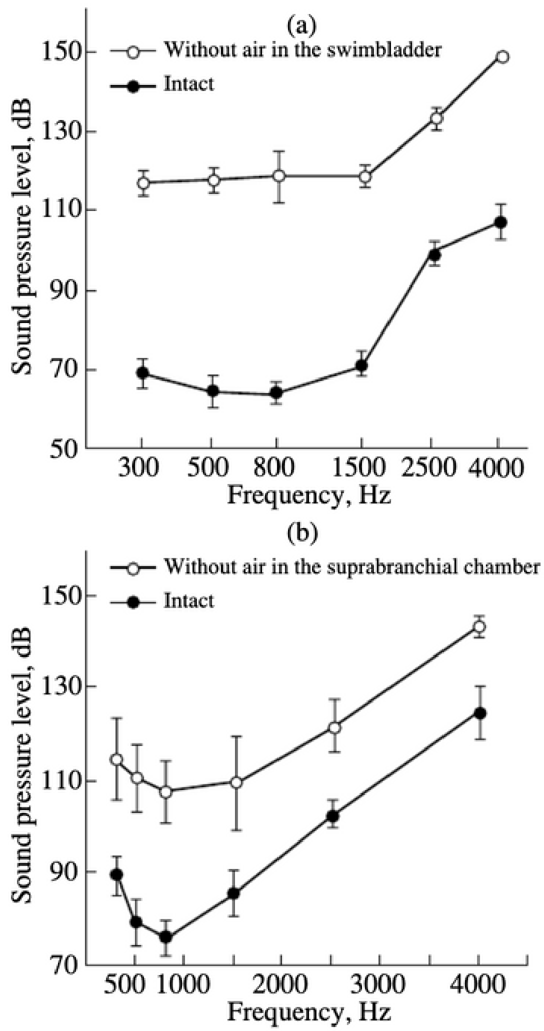



**Fig. 35.** Audiograms of the (a) goldfish *Carassius auratus* before and after the removal of air from the swimbladder and (b) blue gourami *Trichogaster trichopterus* before and after the removal of the air vesicle from the suprabranchial chamber. The sound-pressure level is expressed in dB relative to 1 µPa (from Yan *et al.*, 2000).

**1) Based on the Figure 35, what difference does an intact swim bladder make on sound reception, and which impediment is most detrimental to fish with swim bladders? Removal of air from the bladder, or removal of air from the suprabranchial chamber?**

**How can you tell?**

## Swim bladder Swindle (cont.)

In the same study, Yan and colleagues conducted the following experiment, measuring intact, deflated, and reinflated swim bladders of goldfish.

**2) Based on Figure 35, What does the data suggest about the overall impact of having a swim bladder full of air, versus a swim bladder that has no air?**

**3) Does refilling a swim bladder have the same effect as a completely intact/untouched swim bladder? What evidence supports your answer?**

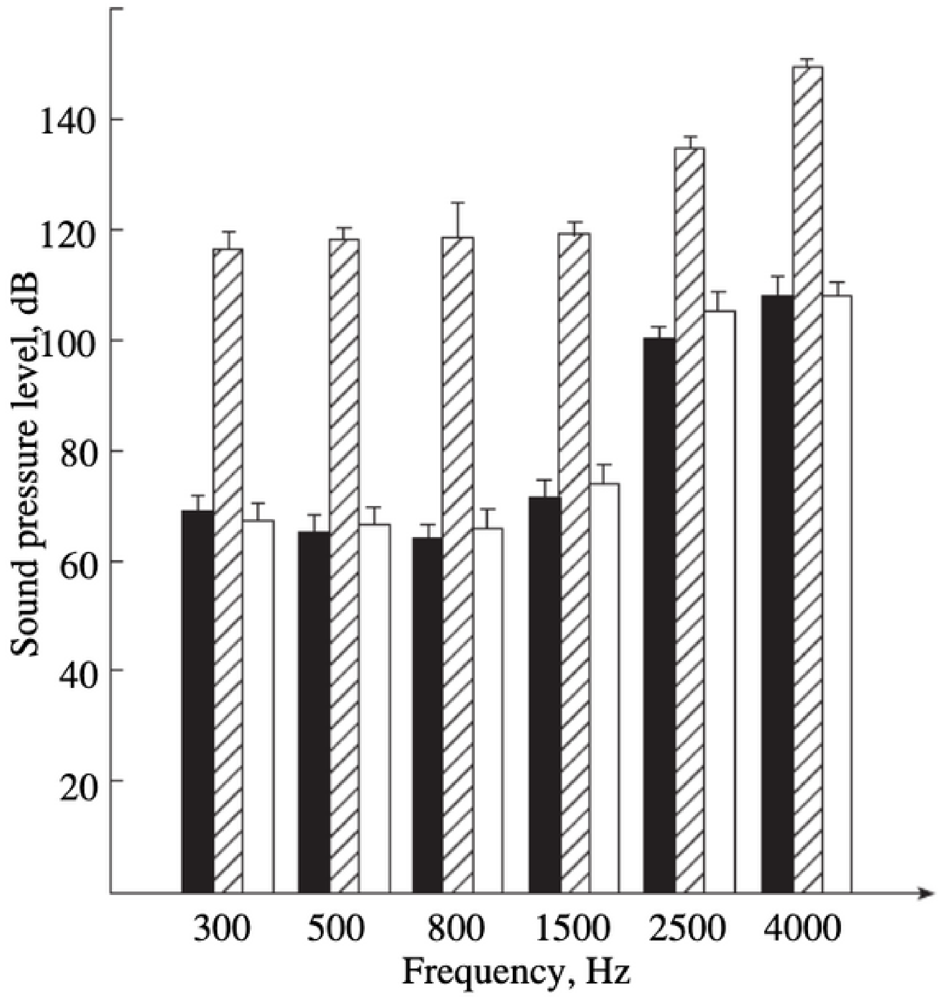



**Fig. 36.** Auditory thresholds in the goldfish *Carassius auratus*. Intact individuals, dark columns; after the removal of air from the swimbladder, stippled columns; after the repeated filling of the swimbladder by air, light columns. The sound-pressure level is expressed in dB relative to 1 μPa (from Yan *et al.*, 2000).

## Swim bladder Swindle (cont.)

The Common dab is known to have lost a functional swim bladder over the course of evolutionary history. In a 1974 study by Chapman and colleagues, scientists installed an artificial gas-filled balloon next to the fish during sensitivity studies and recorded what volume/dB of sound fish would react to with and without the balloon.

**1) What is artificial the balloon trying to simulate/emulate?**

**2) Even though this species has lost its swim bladder over the course of evolution, what does the data say about the overall impact of having any type gas-filled space on hearing ability?**

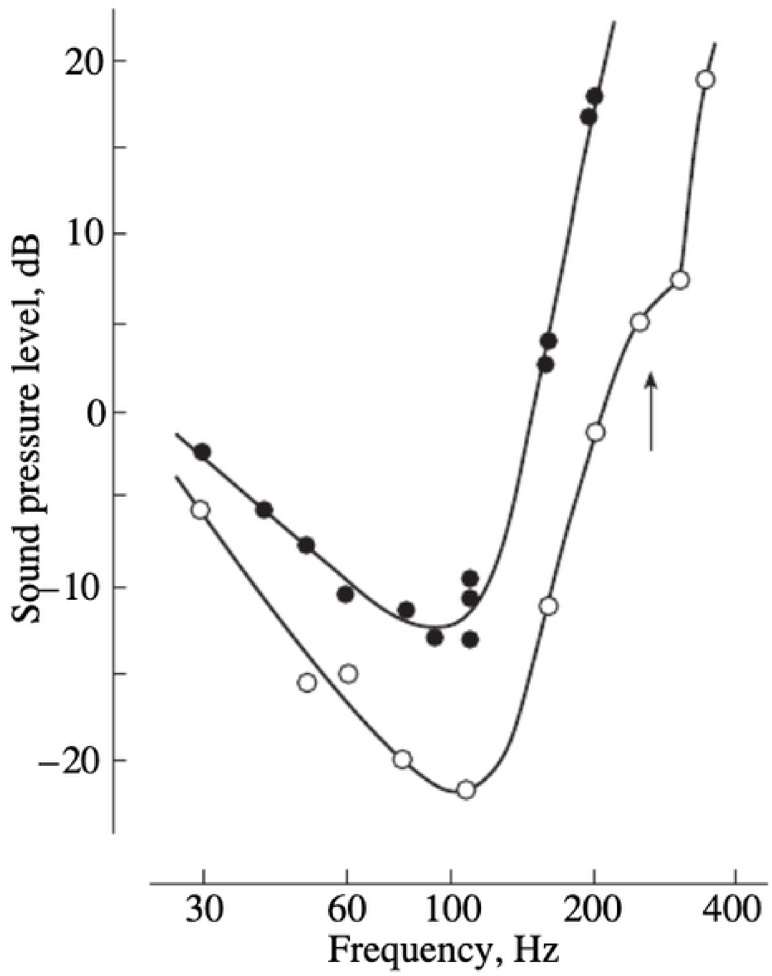



**Fig. 39.** Audiogram of the common dab *Limanda limanda*. Intact individuals, the dark circles; individuals with a small balloon filled by air, the light circles. The arrow indicates a resonance frequency of the balloon (from Chapman and Sand, 1974).

## Heard of Life History?

Think about the living conditions of a fish living in the bathypelagic (like members of the Melamphaidae family), against an open-water predator like the Bull Shark, and a larvae of an open-water forage fish like a herring.

**1) Predict which senses would be most helpful to each fish to best fit their life histories/habitat. How does hearing compare to their other senses?**

**2) What morphological clues can you look for to test your predictions if you had access to specimens of each species?**

## Hearing Above and Beyond

Many clupeid fishes (like herrings, shads, and sardines) have been known to recognize a wider and higher range of frequencies compared to most hearing generalist fishes. For example, the Black Sea Shad has been recorded reacting to frequencies from 6 to 36 kHz (Lebedev et al. 1965, 1966), breaking into the ultrasonic range. See the video for reference about clupeid fishes and their soundscape.

**1) What kind of information do fish receive with the sense of hearing? What are some of the things that exist in the soundscape of the open ocean that might be of interest to clupeid fishes?**

**2) Make a prediction as to why this range of reception is advantageous to this group of fishes based on their life history and/or habitat.**

## Design and Designate

When studying fish hearing, scientists often record signs of sound perception based on a fish's activity, or physical response to a stimulus. But as you have discovered, fish often have two sensory systems that work incredibly close together when detecting sound, pressure, and positioning: the lateral line and the inner ear.

**1) Design a hypothetical experiment to isolate and study the limitations of the lateral line and inner ear in a way that scientists can better understand which system is triggered by a given stimulus.**

*Think about treatment groups, results you'd want to compare, and examples of past studies presented here on fish hearing. There are no right or wrong answers, just answers with more depth into considerations and parameters.*

## Low-Rollers

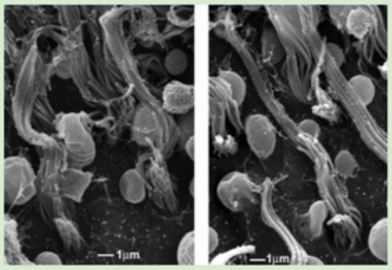
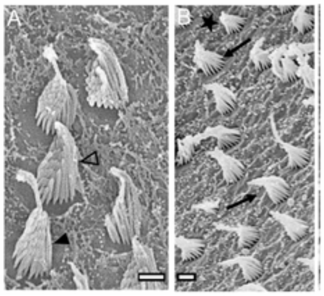
Many small fishes have been recorded to produce pressure waves/sound when swimming and moving, around 10-20 Hz in frequency (Kalmijn, 1989). Many species of fish have been recorded to express physical avoidance reactions to artificial sound matching this range of 10-20 Hz when produced within 2 meters of the fish's body.

**1) What sensory system is this fish MOST LIKELY relying on to perceive such low frequencies, aka infrasounds?**

**2) Make a prediction as to why it is advantageous for fishes to recognize low frequencies by providing two examples of fishes with different lifestyles, diets, or life stages, and how they might use low-frequency reception.**

## Melamphidae Case Study

Thorough morphology investigations of the inner ear system of the deep-sea dwelling family Melamphidae have unearthed some interesting adaptations! To help you discover and explore the purpose of the detailed components of the inner ear, follow along with these figures and guiding questions from this study, specifically about hair cells/sensory epithelium of the inner ear.

| Family | Melamphidae | Clupeidae | Poeciliidae |
|---|---|---|---|
| SEM Photo of Hairs in Macula |  *"Hair bundles as tall as 15-20 $\mu m$ comprise more than 80% of all bundles on the saccule"* |  *"In the herring utricle there are large numbers of bundles which have a kinocilium at least 6-7 $\mu m$ long and some stereocilia which are nearly as long."* |  *"Ciliary bundle with a kinocilium at least three times longer than the longest stereocilium. Scale bars=1 $\mu m$."* |
| Depth Range | 150 - 3,400 meters | 20 meters - 200 meters | 0 - 1 meter (in fresh-brackish water) |
| Hearing Range | **unknown** | Up to 3000 Hz | 200 - 1500Hz |
| Predators | large seabirds, large squid, oceanic dolphins, and large pelagic fish, like tuna. | Large fish, sharks, skates, marine mammals, and seabirds | Bull Frogs, Racoons, and Snowy Egrets |
| Prey | Zooplankton and other small crustaceans | planktonic crustaceans, occasionally other fish larvae | Small invertebrates, and algae |

**Compare and contrast these SEM photos of the sensory epithelium hairs within the maculas of Clupeid and Melamphid fishes, and information about their life histories.**

*Consider the lifestyle, habitat, and the "exceptionally tall hair bundles" of Melamphidae fishes, in comparison to the well-studied Clupeidae and Poeciliidae specimens on the right, which have known hearing ranges.*

## Melamphidae Case Study (cont.)

**1) What could you predict about the relationship between hair cell length and hearing ability based on comparisons you've made from this table?**

**2) What other variables in inner ear or body morphology impact hearing ability that isn't shown in the table above? AKA, what morphology information would be helpful to know and test if you had to determine the relationship between hair cell length and hearing ability)?**

**3) Optional: How would you test your prediction about hair length and hearing ability?**

**IF YOU WISH TO CHECK YOUR ANSWERS, ACCESS THE KEY HERE!**