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Infrasound and Low Frequency Noise: A Public Health Nightmare

**Mariana Alves-Pereira, Bruce Rapley,
Huub Bakker, Rachel Summer**

Glasgow, Scotland, Sept 22, 2017

ATKINSON & RAPLEY

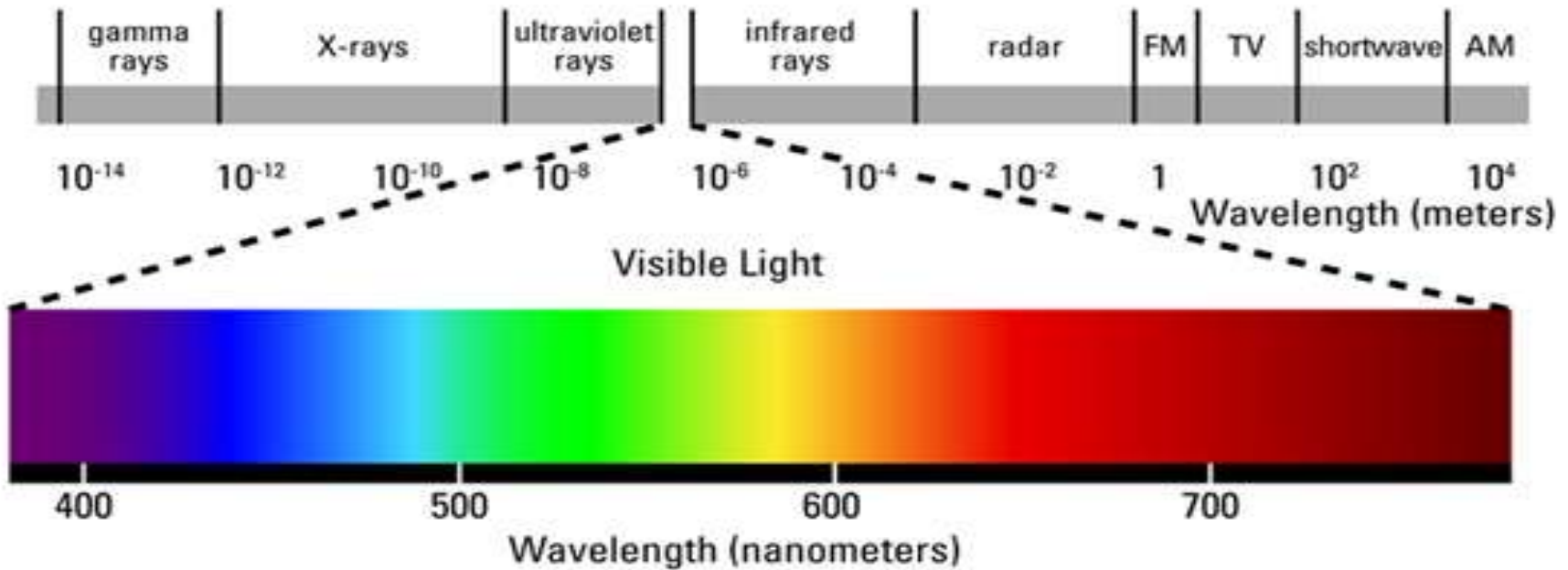
C O N S U L T I N G

Disclaimer

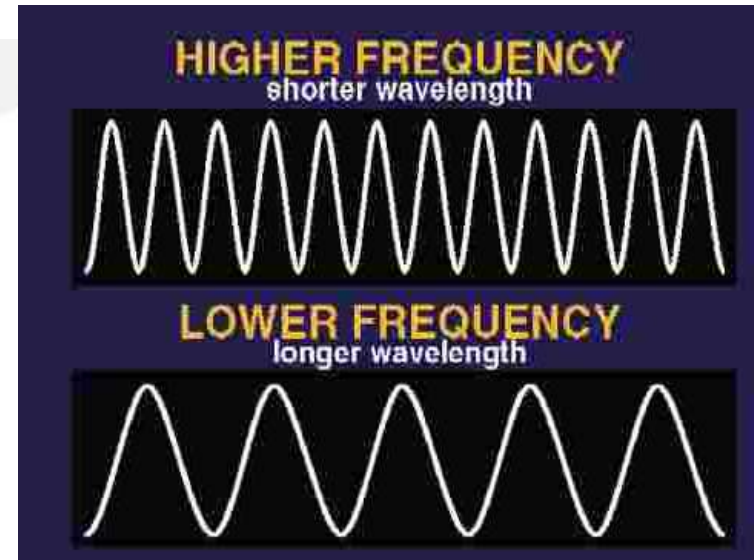
We:

- *Do not harbour anti-technology sentiments;*
- *Consider industrial activities to be important to modern technological societies;*
- *Have scrutinized data under one, and only one, agenda - pure scientific inquiry;*
- *Are not producing a report arguing against industrial complexes.*

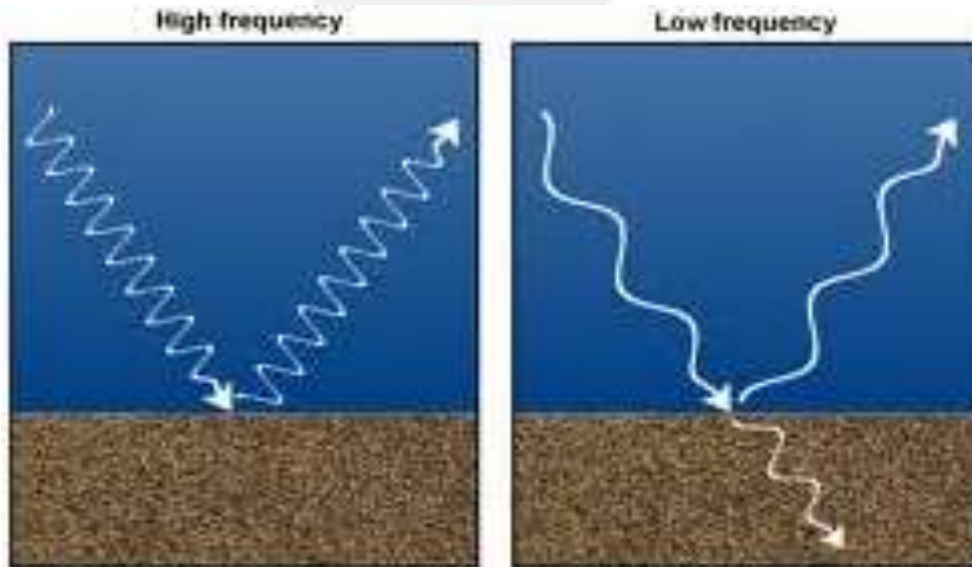
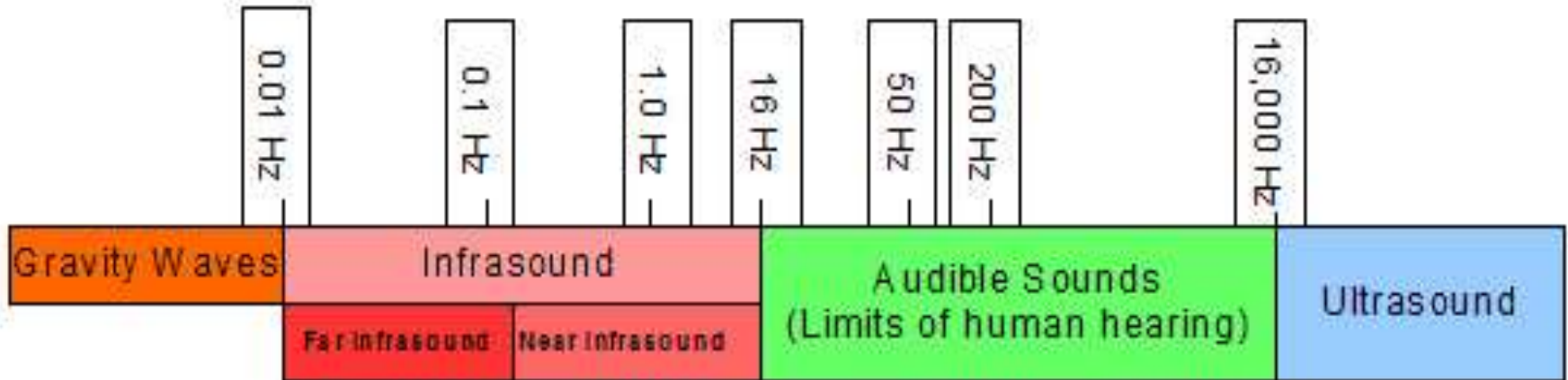
Radiation



- Humans do not perceive x-rays.
- Excessive exposure to x-rays can be harmful.
- A chest x-ray, once a year, is not considered harmful.



Acoustics

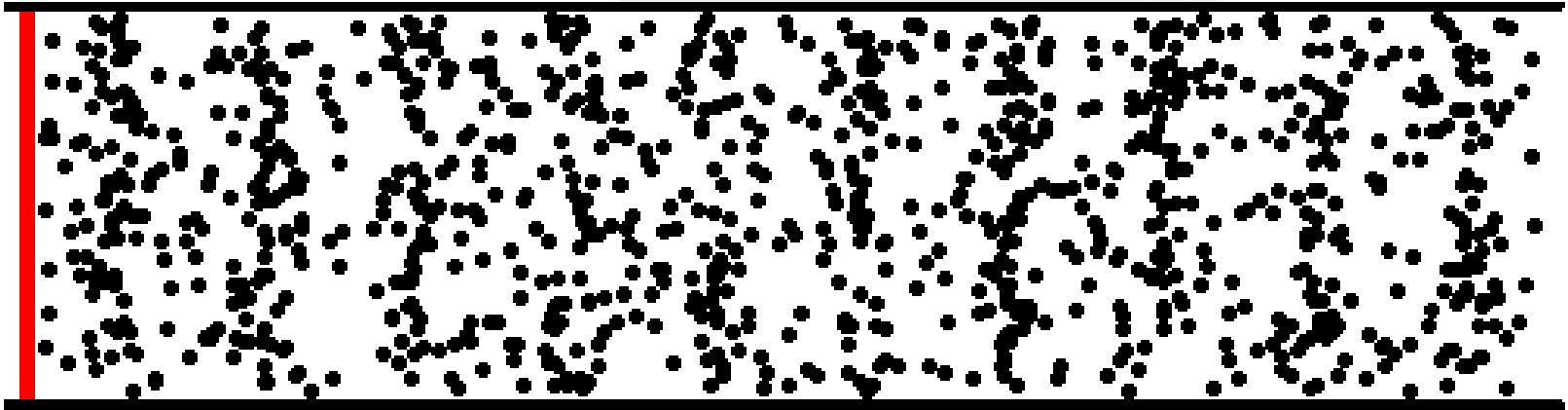


Wavelength of airborne sound at:

| | | |
|----------------|----|---------------|
| <u>3000 Hz</u> | is | 0.11 m |
| <u>500 Hz</u> | is | 0.68 m |
| <u>100 Hz</u> | is | 3.43 m |
| <u>20 Hz</u> | is | 17.1 m |

Low frequency waves can propagate over larger distances than higher frequency waves.

Acoustic Waves

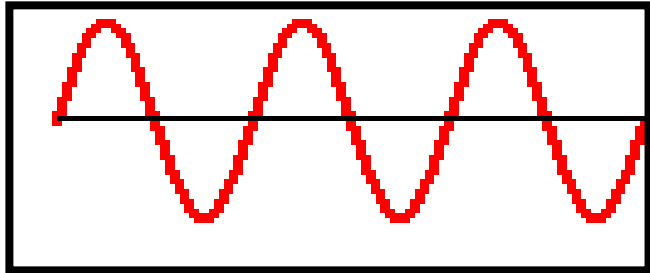


Acoustic wave = Pressure wave (longitudinal wave)

An acoustic wave = “sound”
if and only if
humans can perceive it with the ear.

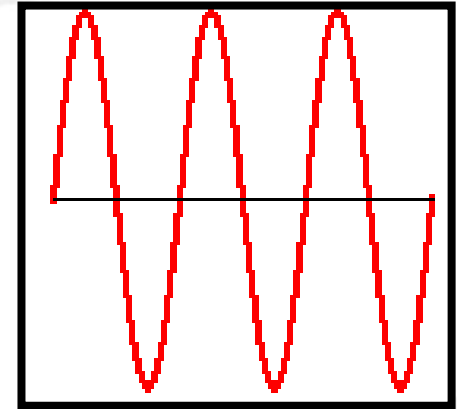
World Health Organization:
Noise = Inanimate Mechanical Forces

Acoustic Waves



Lower Amplitude

The deciBel unit, dB, is used to measure the amplitude of the acoustic waves



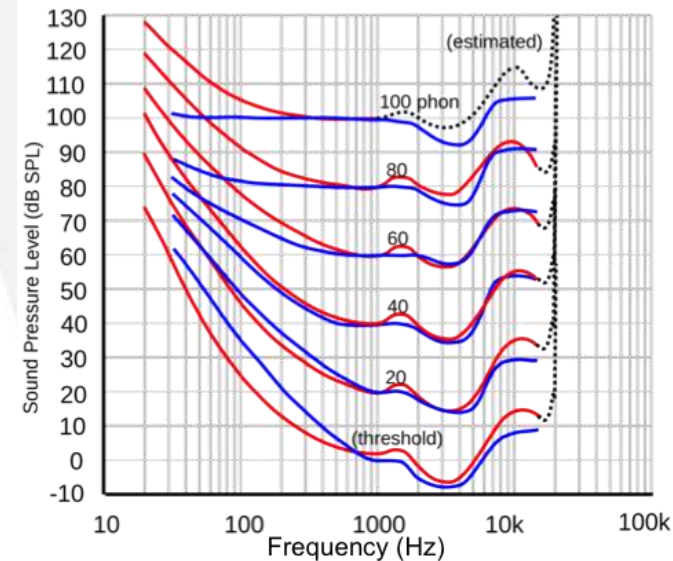
Higher Amplitude

1920

- 23 healthy, young males
- with good hearing (*assumed*)
- exposed to series of different, single, pure tones at different levels of loudness via telephone earpieces - occluded ear
- asked to score the sounds for equal loudness.



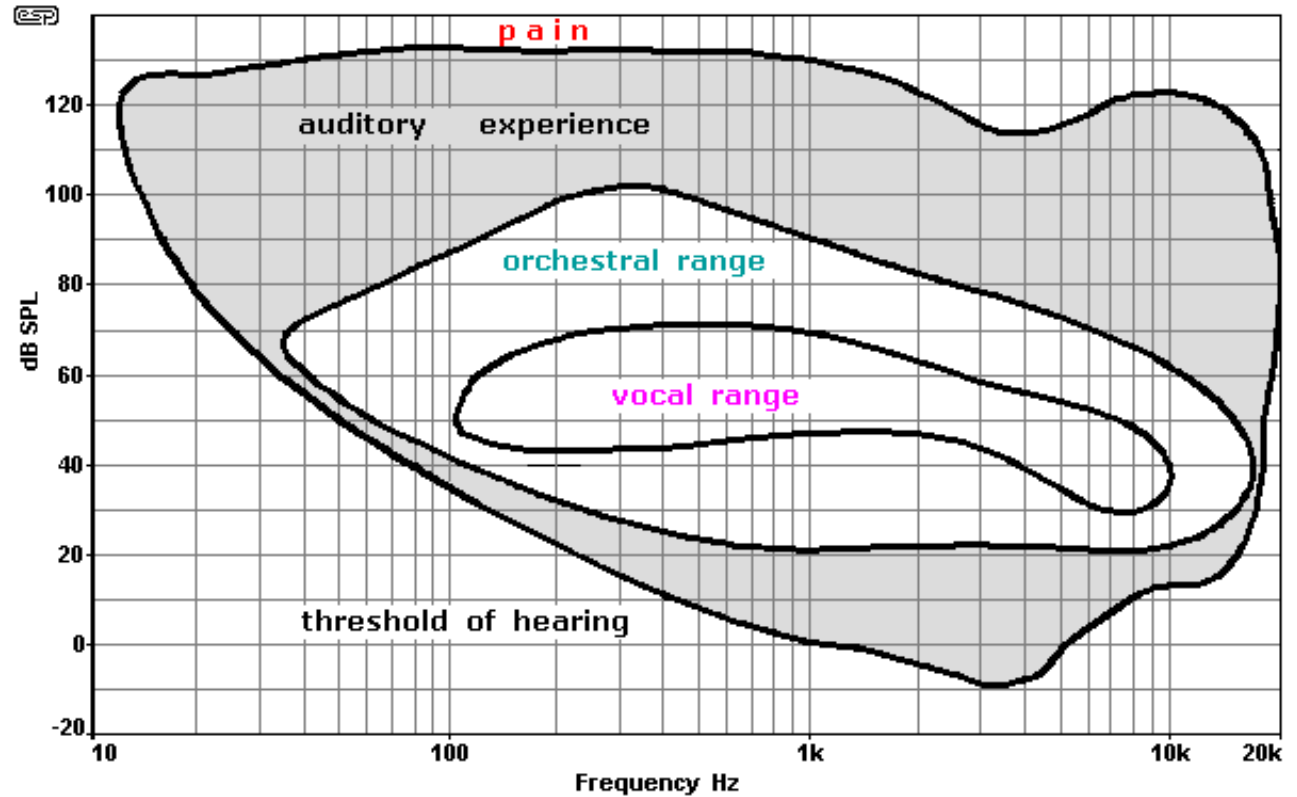
Harvey Fletcher
(1884-1981)



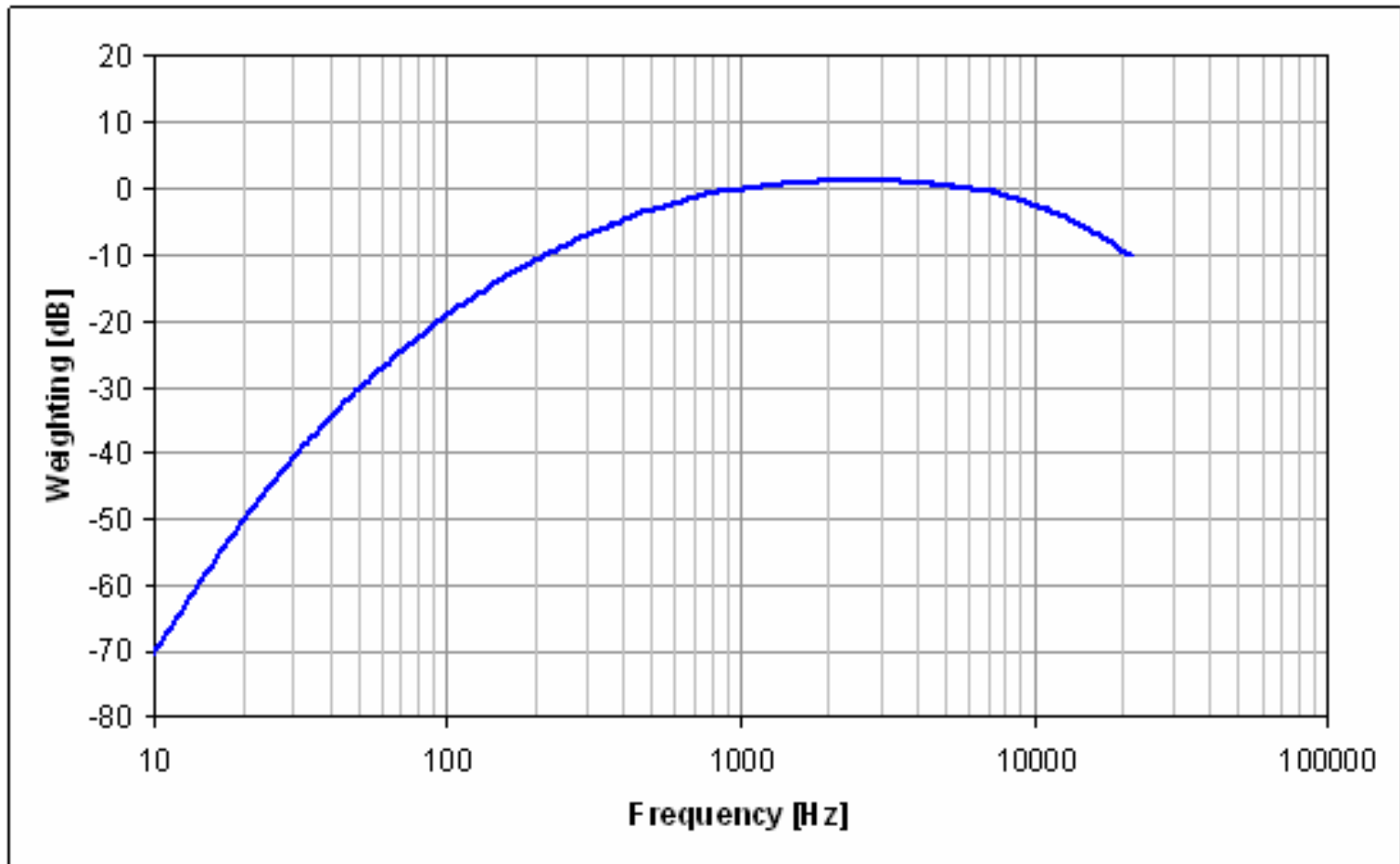
Fletcher-Munson
Equal Loudness Curves

Human Hearing & Noise Protection

1932

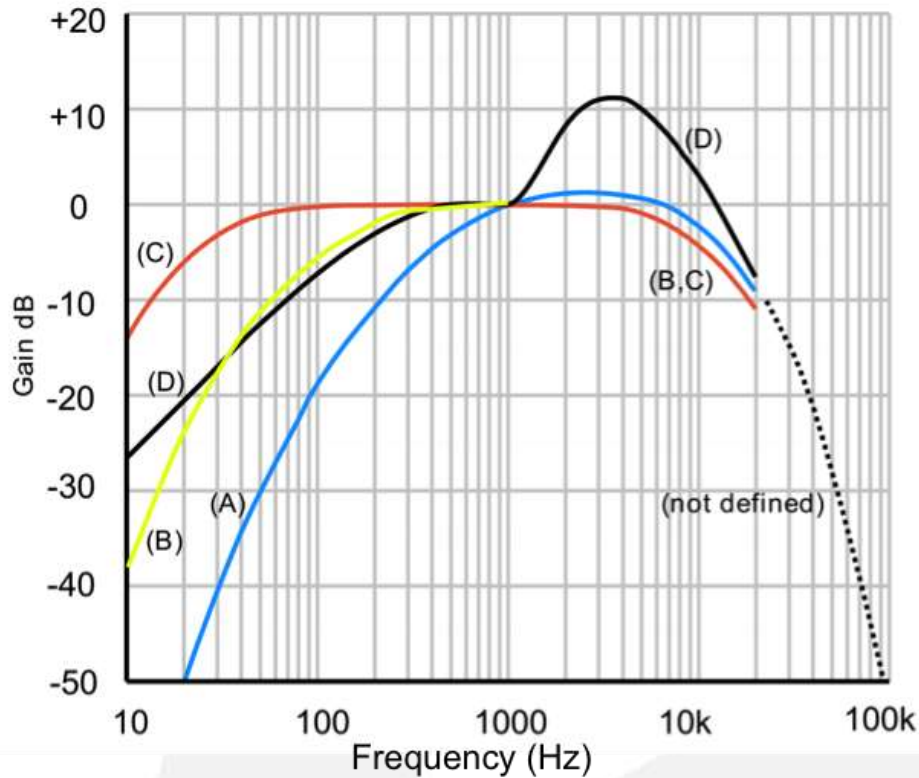


The dBA metric

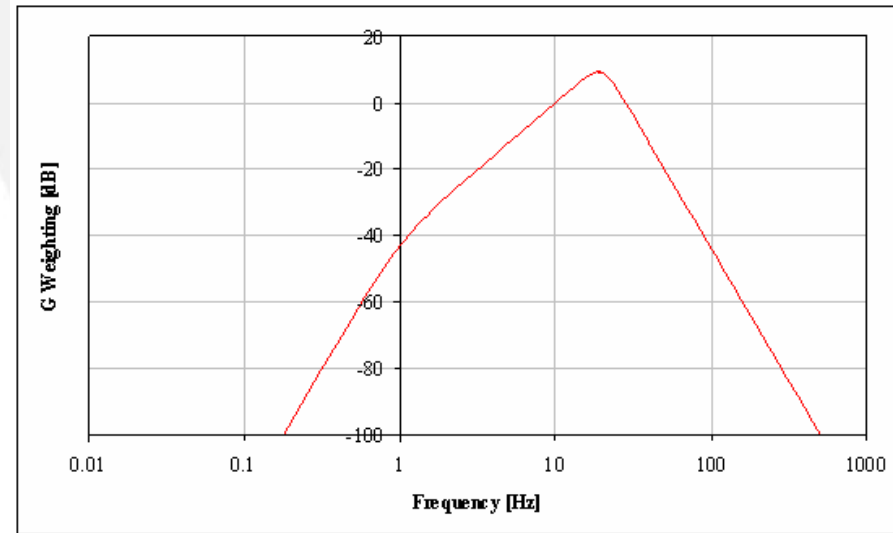


Specifically designed (decades ago)
to protect the human hearing function.

Other dB metrics



dBA - blue
dBB - yellow
dBC - red
dB(D) - black

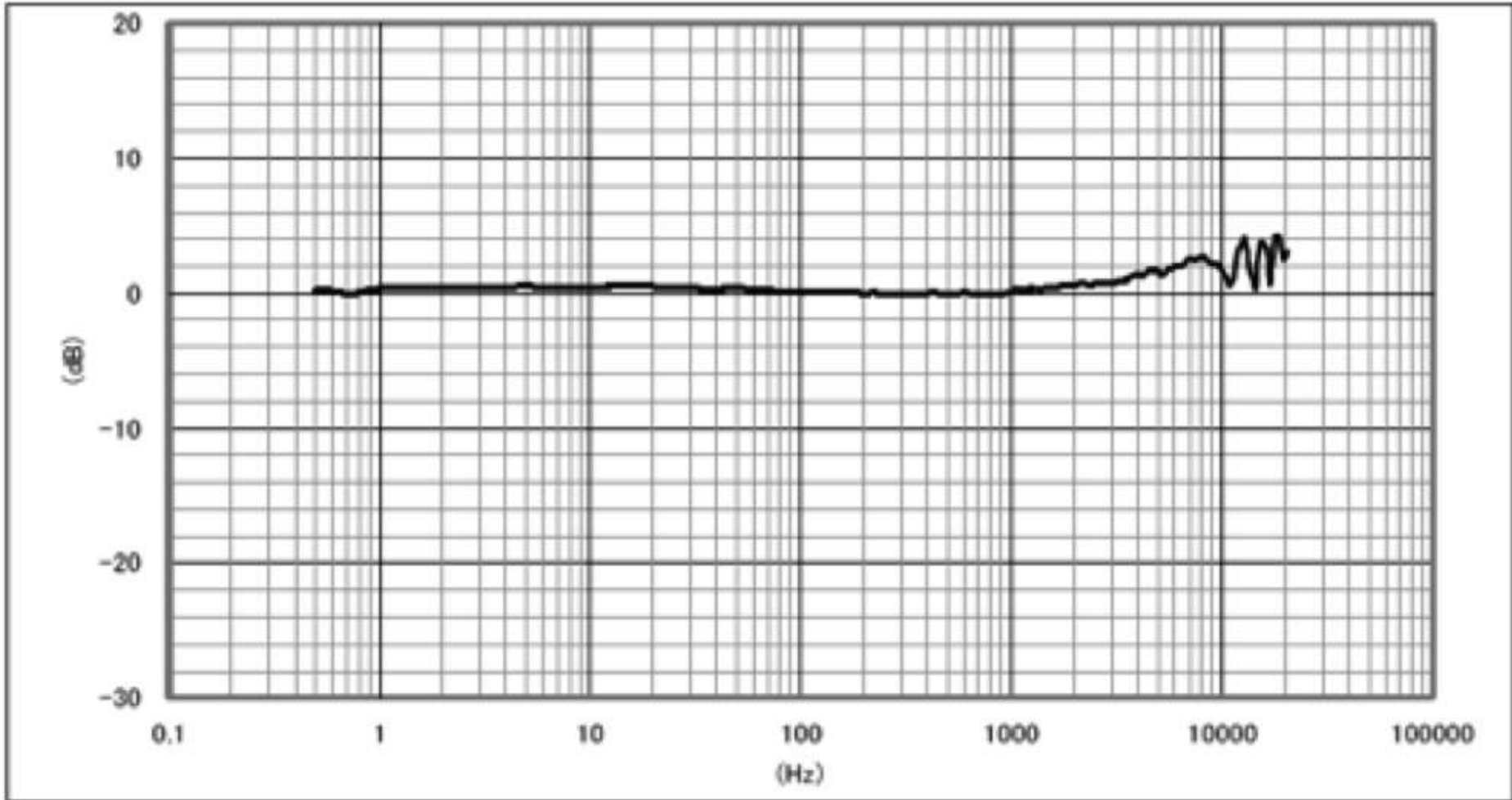


dBG

This team of scientists
prefers **dB Linear**.

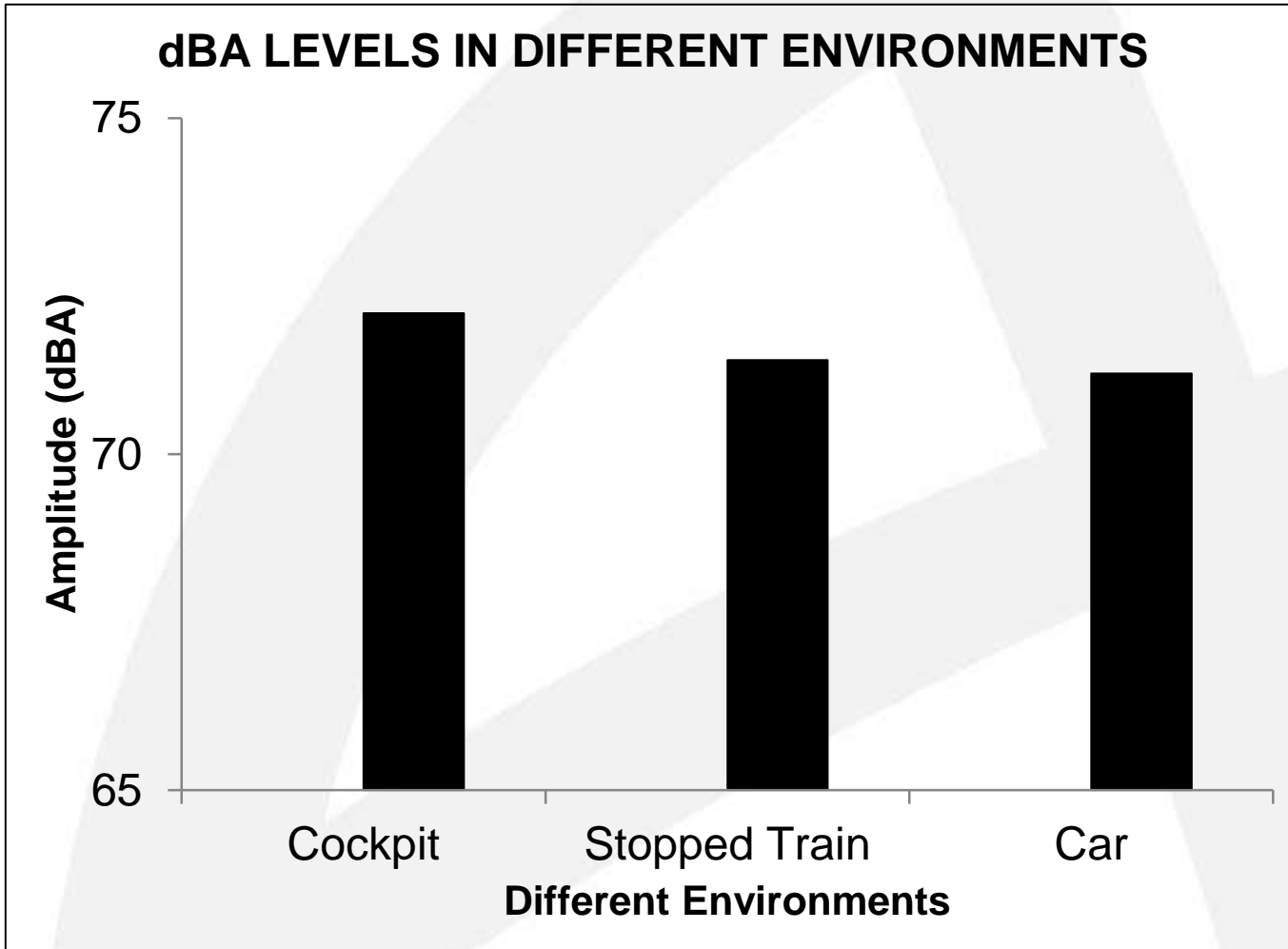
NO weighting network!

Linear capture



Microphone frequency response curve,
as used by this team.

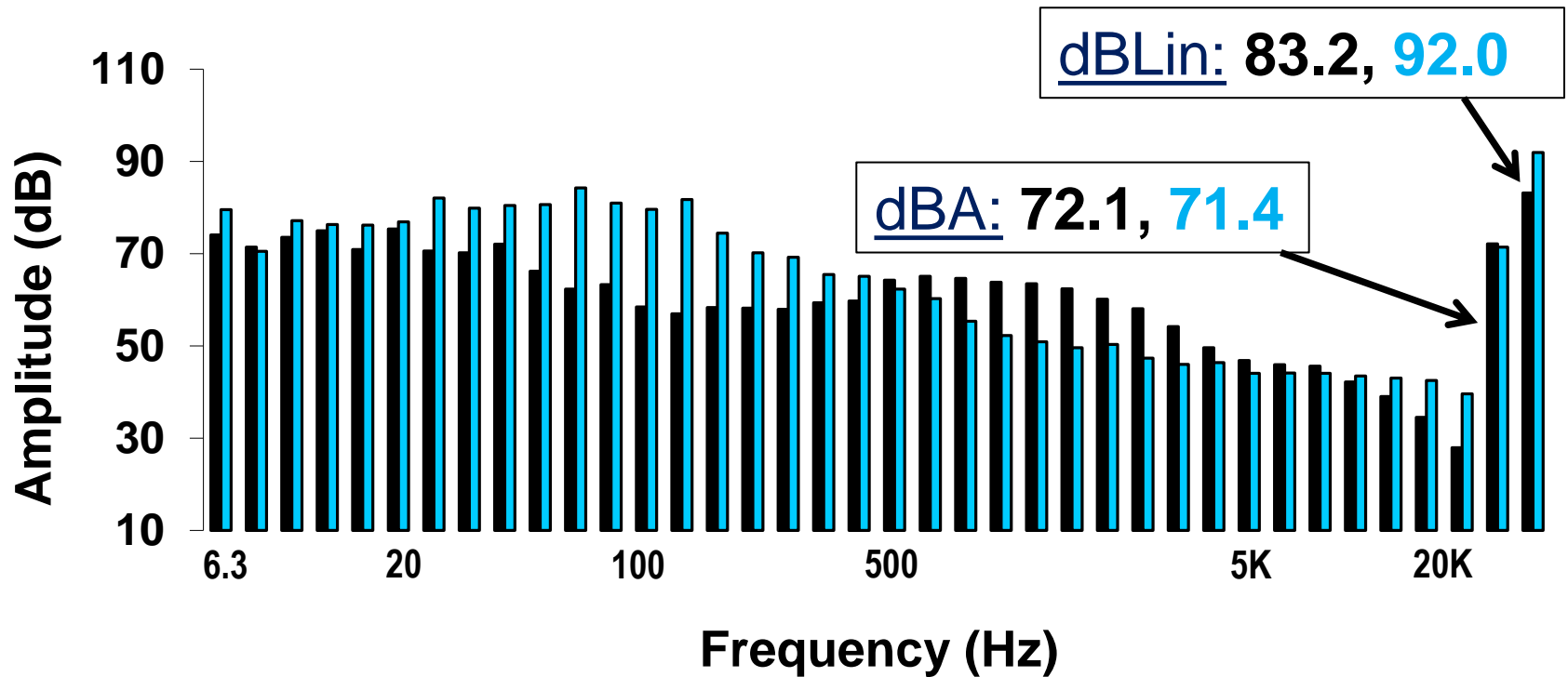
dBA vs. dBLinear



- *Cockpit:*
72.1 dBA
- *Train:*
71.4 dBA
- *Car:*
71.2 dBA

Similar dBA, but not acoustically equivalent environments

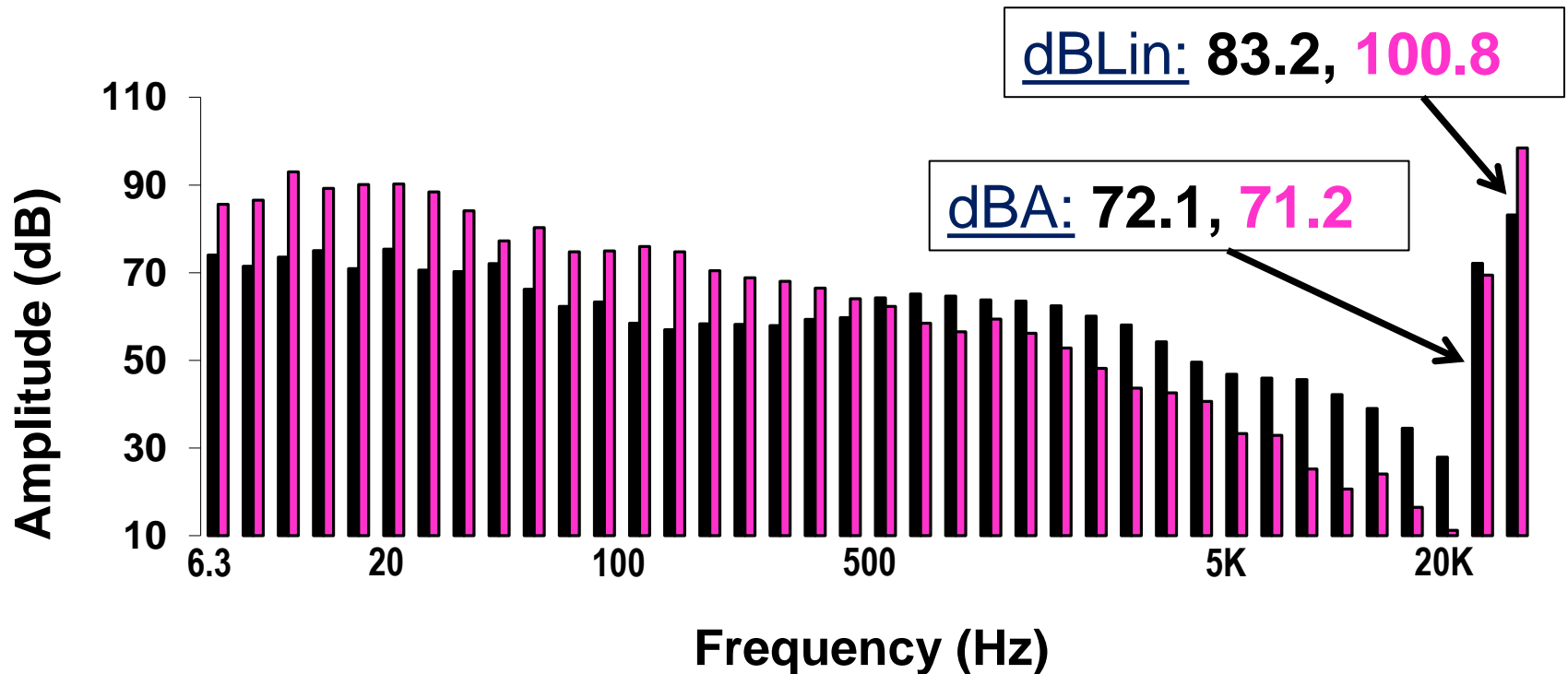
Cockpit vs. Stopped Train



The person hears 72.1 in the cockpit and 71.4 on the stopped train.
The person is exposed to 83.2 in the cockpit and 92.0 on the train.

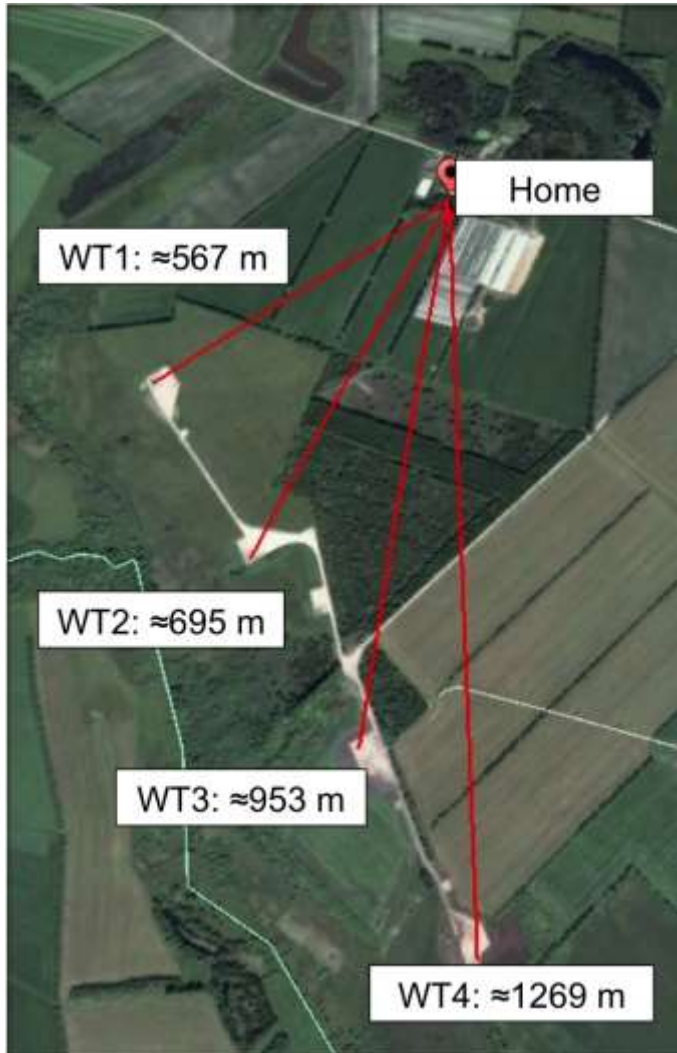
Similar dBA, but not acoustically equivalent environments

Cockpit vs. Car



The person hears 72.1 in the cockpit, and 71.2 in the car.
The person is exposed to 83.2 in the cockpit, and to 100.8 the car.

Mink Farm



3 MW, Total Height: 150 m

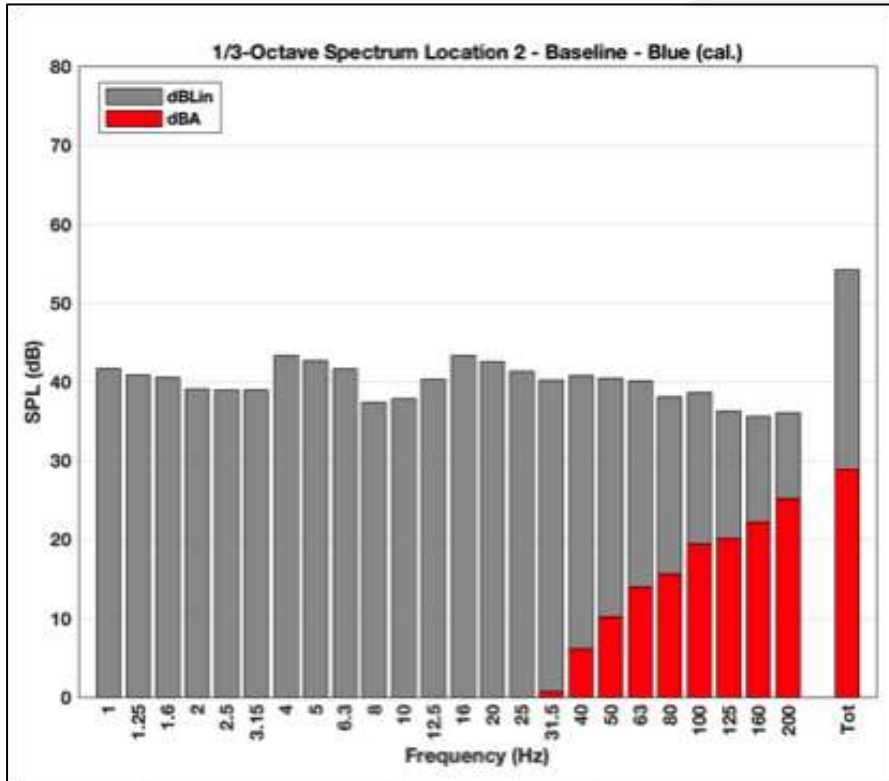


Location 1



Location 2

Location 2



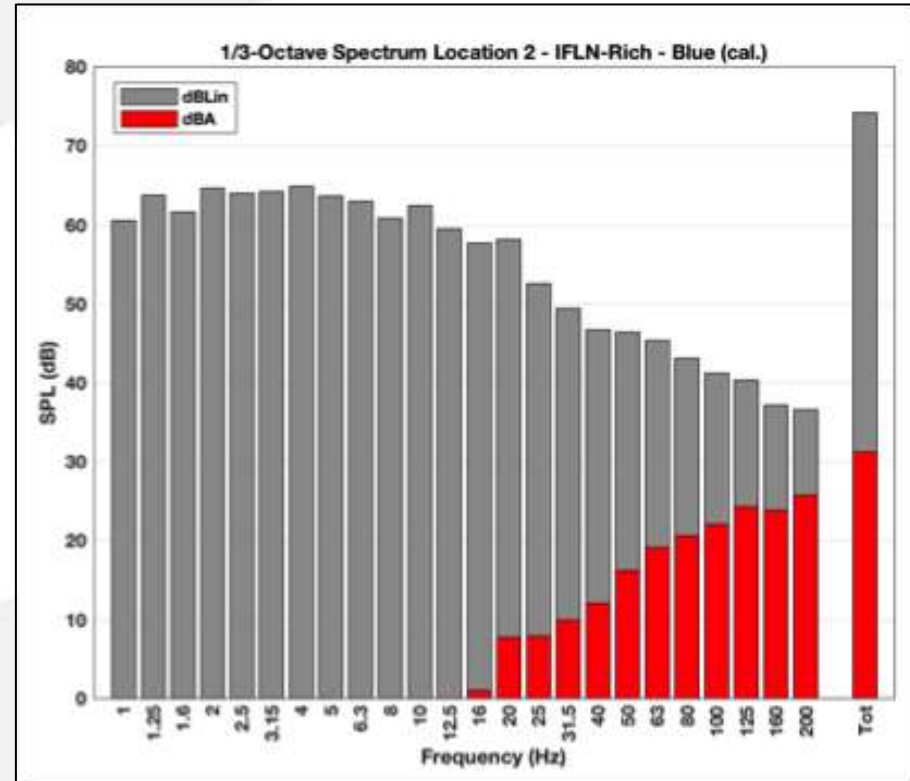
No rotation of WTs

Windspeed: 0.5 – 1.5 m/s

Wind Direction: S SW

Temperature: 0-1 °C

Date: 16DEC16



WTs rotating

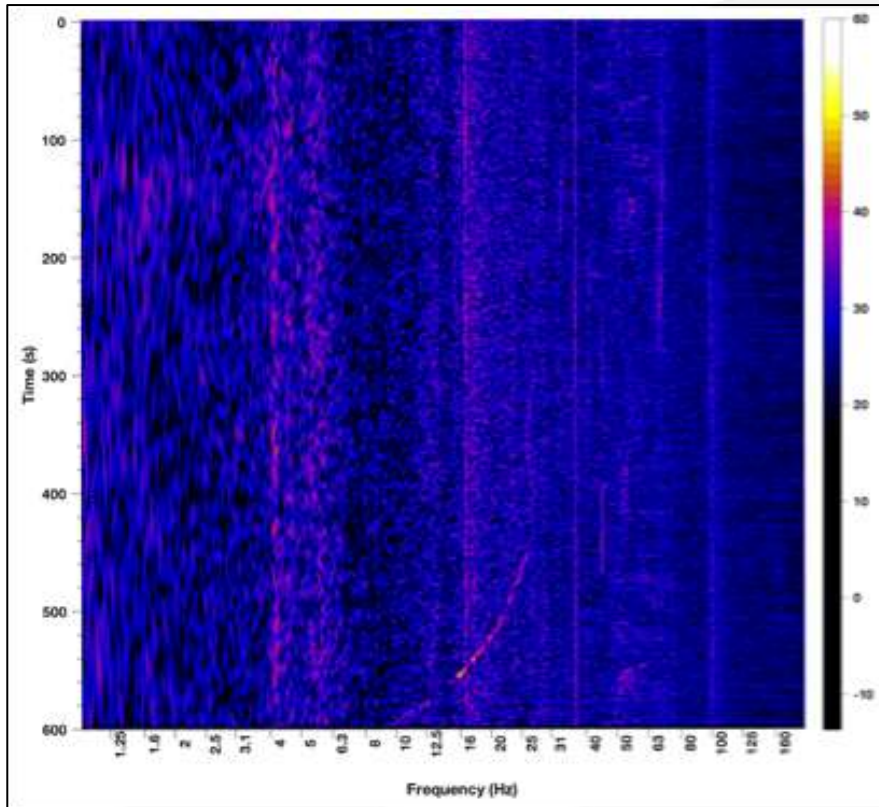
Windspeed: 4.0 – 6.5 m/s

Wind Direction: SW

Temperature: 6-8 °C

Date: 30DEC16

Location 2



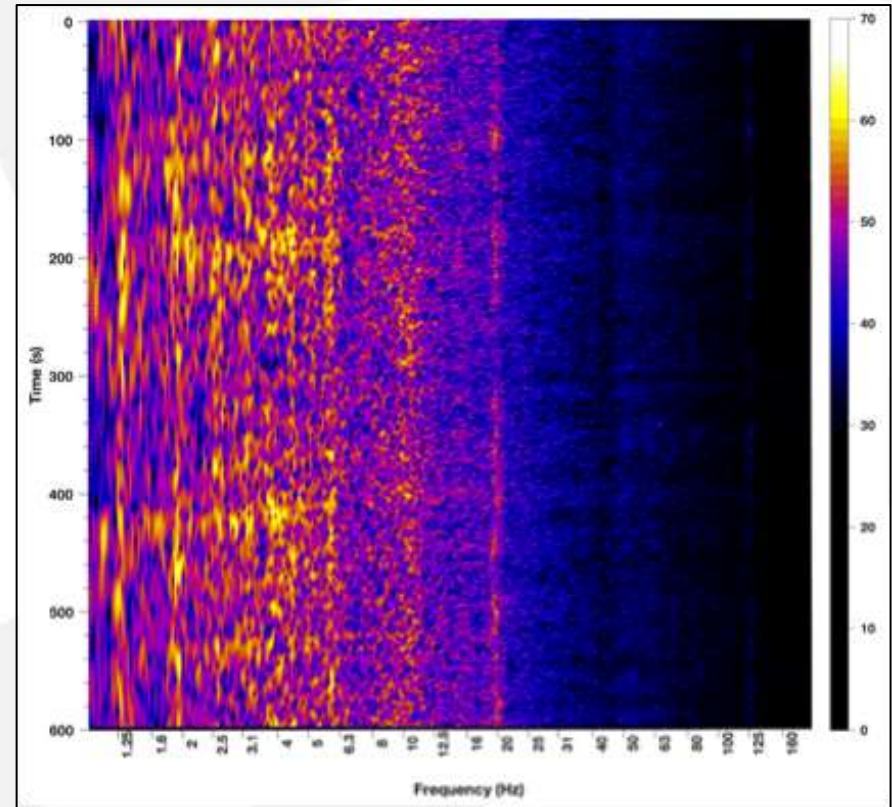
No rotation of WTs

Windspeed: 0.5 – 1.5 m/s

Wind Direction: S SW

Temperature: 0-1 °C

Date & Time: 16DEC16



WTs rotating

Windspeed: 4.0 – 6.5 m/s

Wind Direction: SW

Temperature: 6-8 °C

Date & Time: 30DEC16

Consequences of excessive infrasound and low frequency noise exposure: Vibroacoustic Disease (VAD)



1984



1985



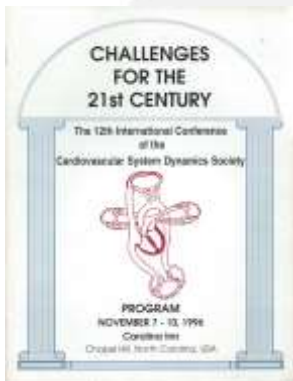
1989



1991



1993



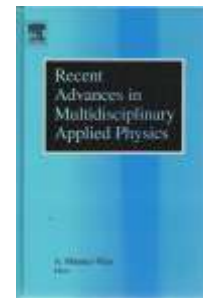
1996



1999



2003



2005



2007



2017

1980

Portuguese Air Force Aeronautical Plant



- Dr. CB is chief medical officer
- Observation of automatism in worker
- Evaluation of cases of epilepsy
- 10% of aeronautical technicians already diagnosed with late-onset epilepsy

Portuguese General Population: 0.2%

1980-1986

Neurological Changes

- Evoked Potentials: Measuring brain response time to a stimulus.
- Brain Mapping: Evaluates spatial distribution of brain potentials
- Brain MRI: Evaluates brain morphology and lesions
- Humor and Cognition: Increased aggressiveness, depression, memory and attention disorders

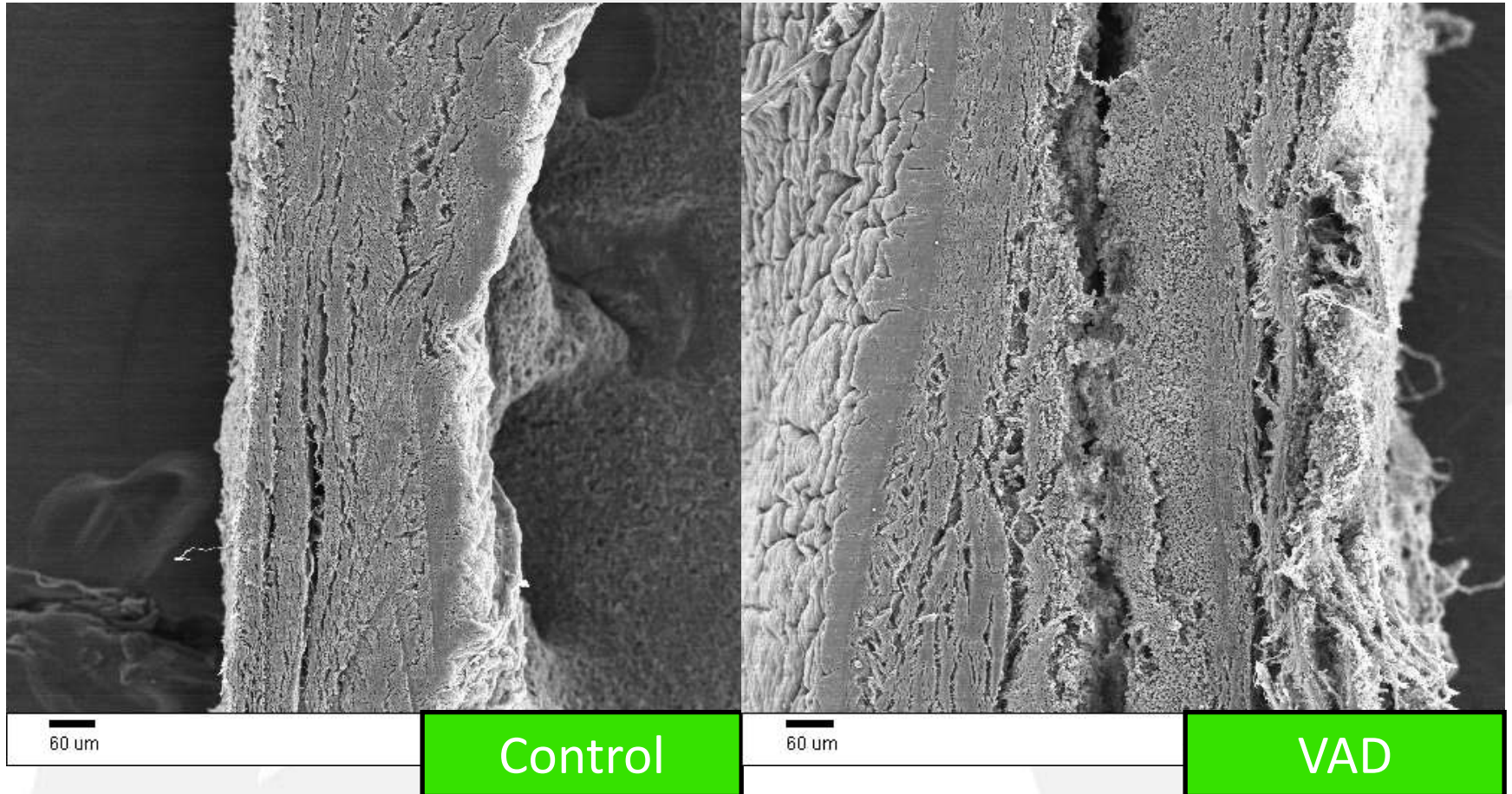
1987

Autopsy of Mr. Filipe Pedro

- 2 tumors (kidney and brain)
- Scars from 11 prior, silent cardiac infarcts
- Cause of death: 12th small infarct (<2mm)
- Abnormal thickening of cardiovascular structures
- Pulmonary fibrosis

***Pathology not restricted to
Central Nervous System !!***

Pericardial Thickening



The scale of these two micrographs is the same.

Respiratory Pathology in VAD

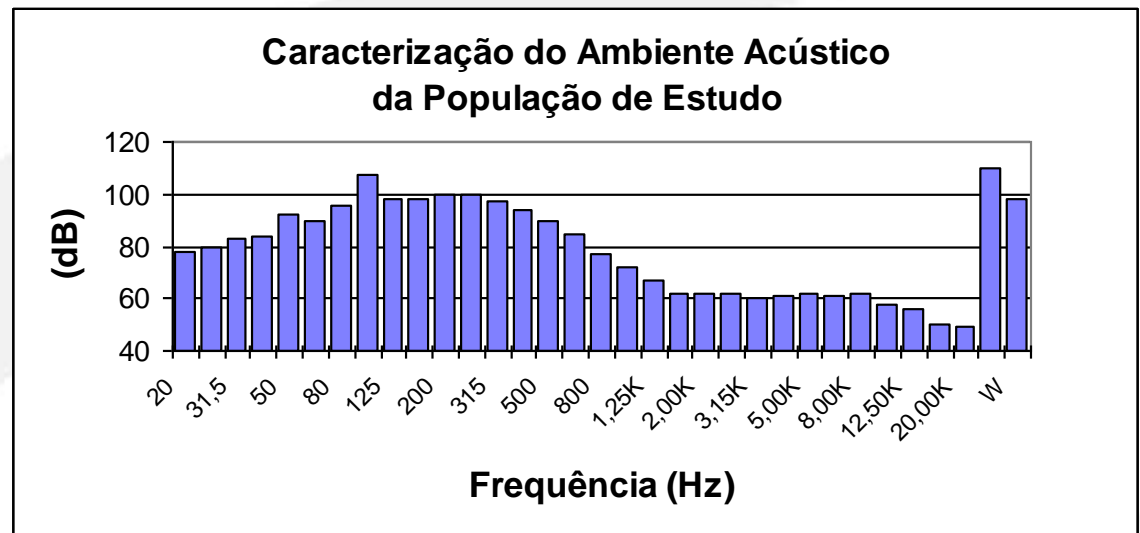
In smokers and non-smokers alike:

- Bronchitis
- Repeated Throat Infections
- Unexplained Hoarseness
- Dry Cough
- Unexplained Cases of Pleural Effusion

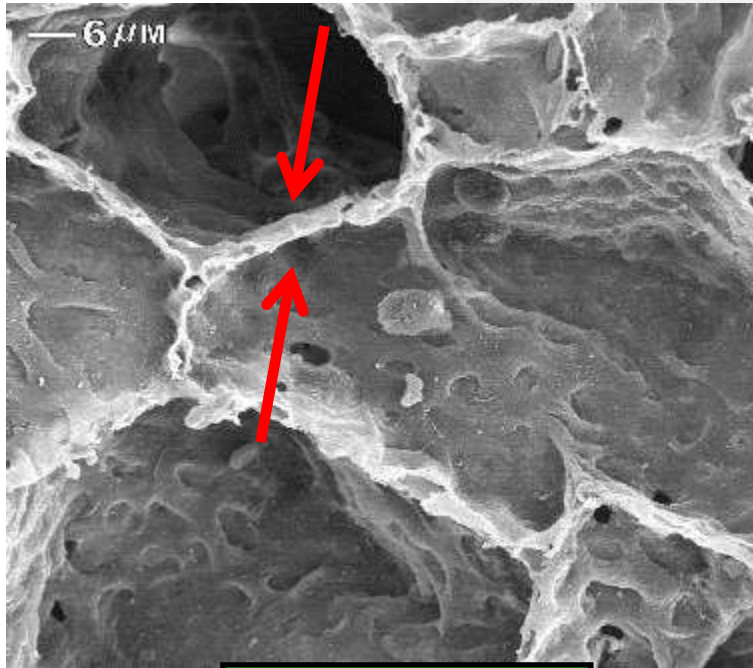
1992

Begin using laboratory animal models

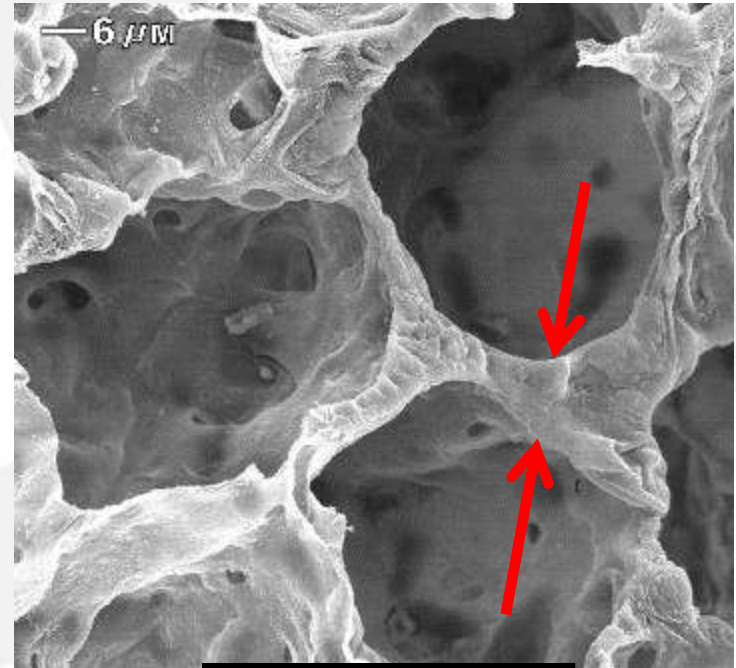
- Exposed to low frequency noise
- Occupationally-simulated schedule: 8 hrs/day, 5 days/week, weekends in silence



Alveolar Wall Thickening



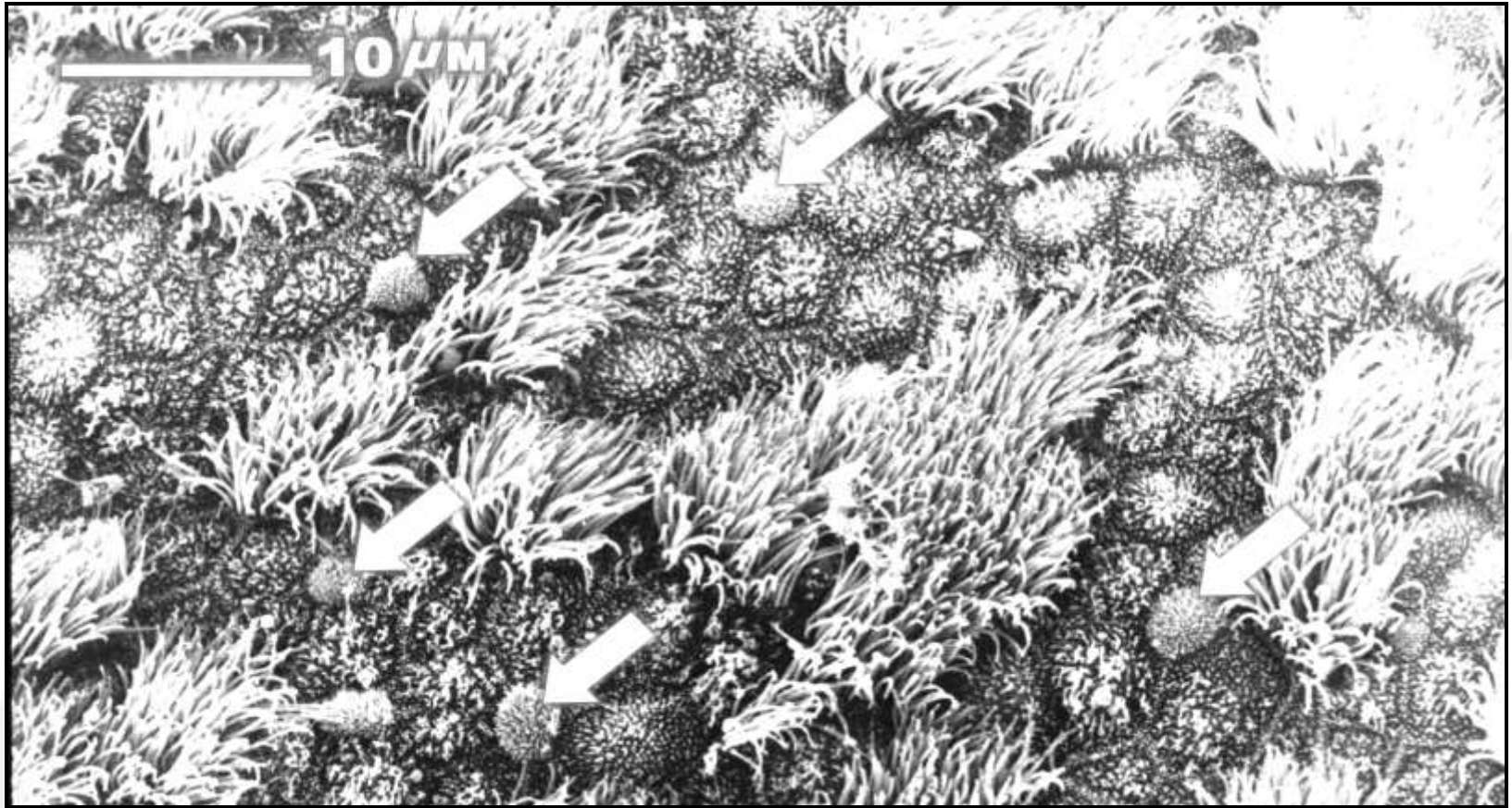
NORMAL



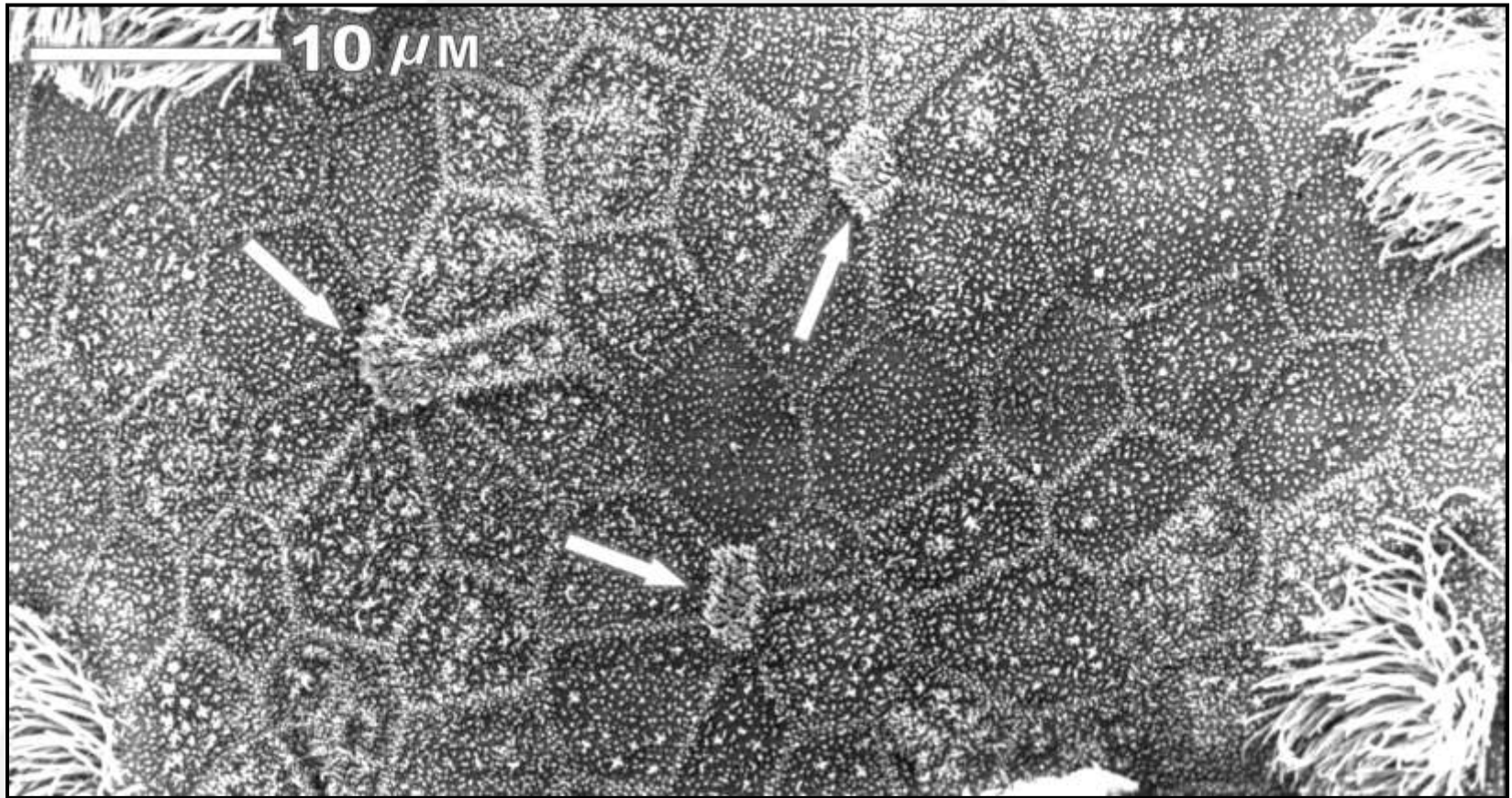
EXPOSED

The scale of these two micrographs is the same.

Normal Rat Trachea



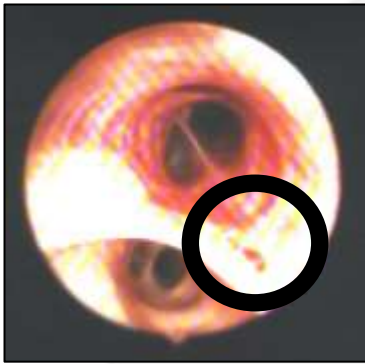
Rat Trachea - 2213 hrs



Case of Environmental ILFN

The Irish Lady and the Dublin Bus company

Bronchoscopy: Appearance of “pink lesions”



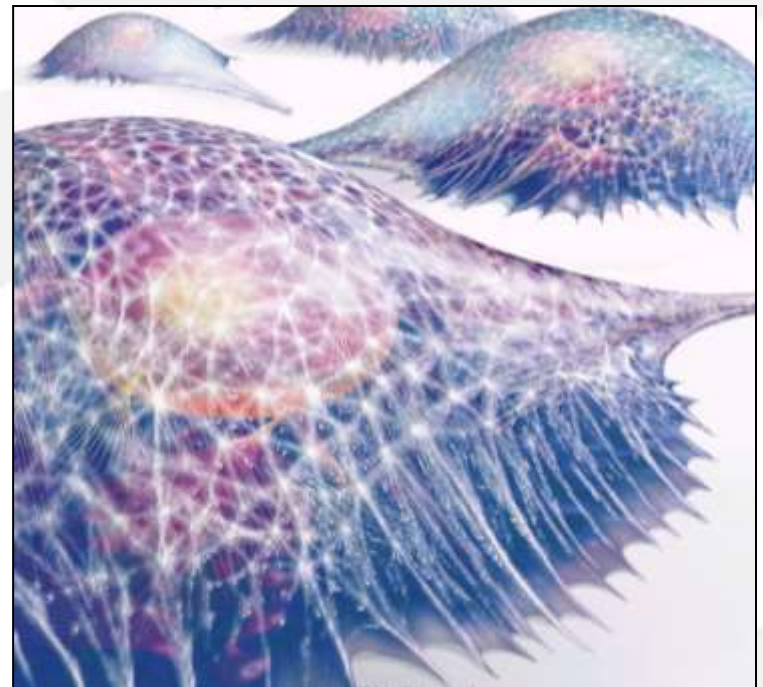
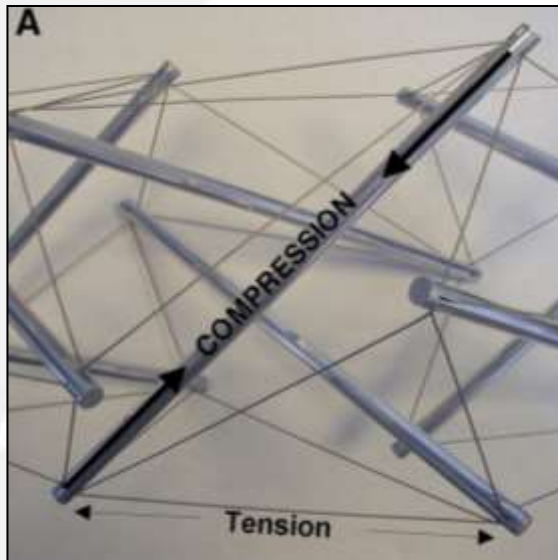
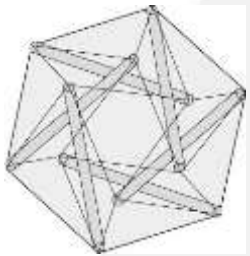
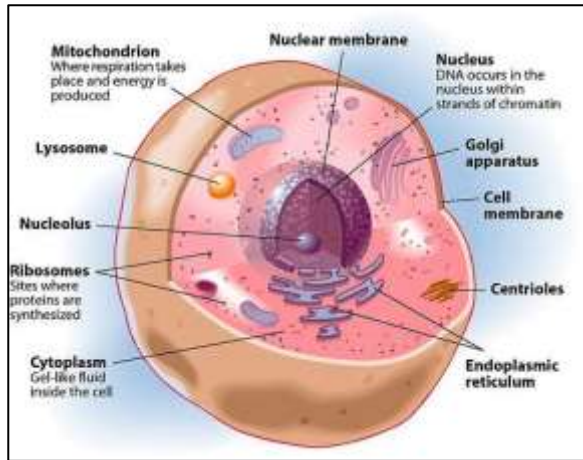
Voice Acoustic Analysis: Fundamental frequency of three vowels significantly increases with increasing ILFN exposure time.



Cell Biology

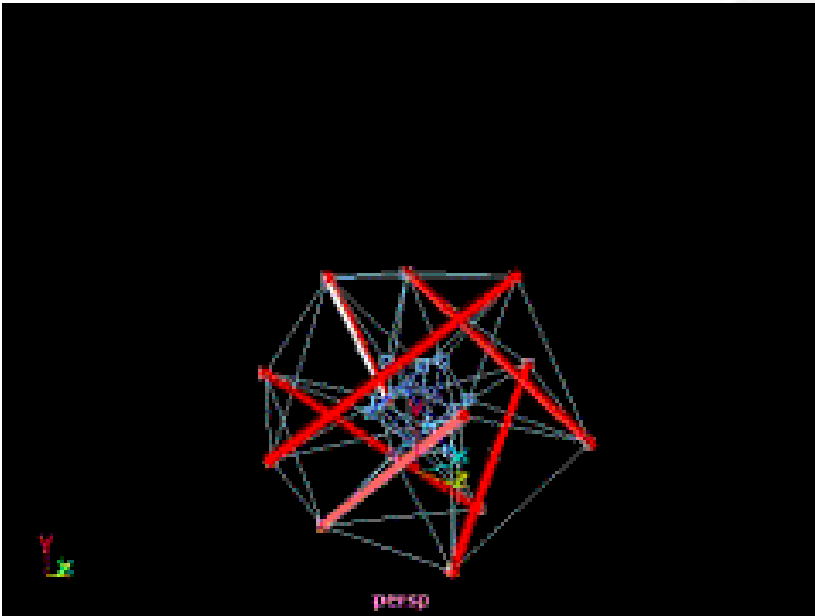
-- Cells are **not like elastic balloons** with floating organelles.

-- Cells communicate through biochemical and **mechanical signals**.



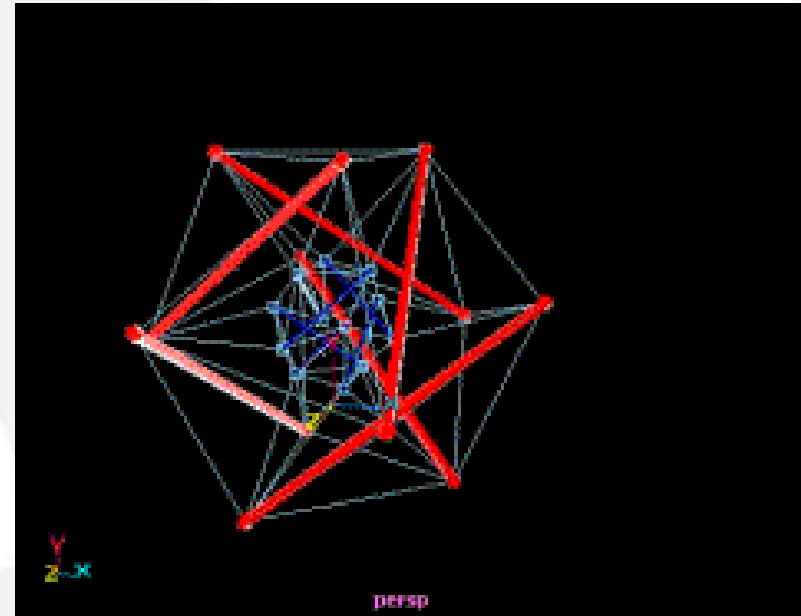
Tensegrity: Continuous Tension and Discontinuous Compression.

Tensegrity Structures

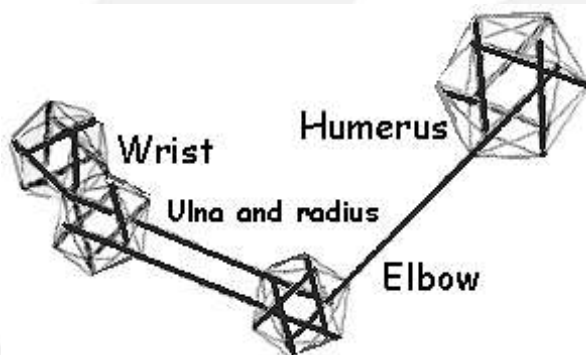


Ingber Lab
Harvard U.

Cellular response to force
along the vertical axis.

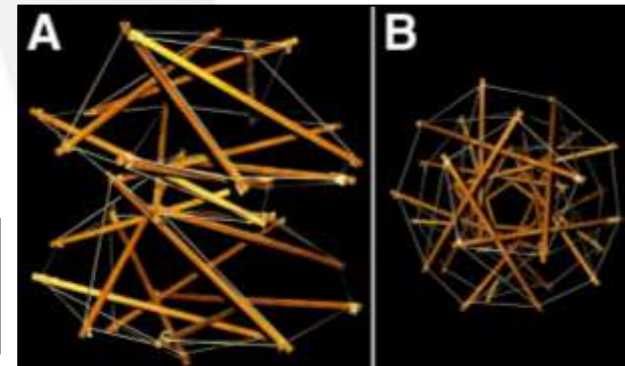


Cellular response to
laminar flow.



Human Arm

*Tensegrity model of
cellular membrane pore*



ILFN effects on hearing

- **ILFN-Exposed People:**

- Cannot stand any noise -- Say: “I hear too much” --
- Lower TV volume to where others cannot hear it -- Rage reactions -- Audiograms show losses at 250 Hz and 500 Hz

- **ILFN-Exposed Rats:**

Control rats respond to the sound of a blown kiss by becoming tense and frozen, while ILFN-exposed rats would develop a seizure-like episode, falling backwards while shaking.

VAD TEAM:

- Considers noise annoyance a **SUBJECTIVE PARAMETER;**
- In the presence of a “noise annoyed person”, prior noise exposure is suspected, and **OBJECTIVE MEDICAL TESTS** are provided.

Clinical Stages of Vibroacoustic Disease for Occupational Exposures (1999)

MILD

1-4 years of ILFN exposure

Slight mood swings, indigestion & heartburn, repeated mouth & throat infections, bronchitis.

MODERATE

4-10 years of ILFN exposure

Chest pain, back pain, fatigue, fungal & viral skin infections, allergies, blood in urine, inflammation of stomach lining.

SEVERE

> 10 years of ILFN exposure

Psychiatric disturbances, headaches, hemorrhages of nasal & digestive mucosa, duodenal ulcers, spastic colitis, varicose veins & hemorrhoids, decreased vision, severe joint pain, severe muscular pain, neurological disturbances.

Occupational vs Environmental

VAD Researchers' Experience:

- In-home ILFN levels have been *much lower* than within the occupational environments studied by VAD researchers.
- In-home time exposure patterns are different from occupational time exposure patterns: people *sleep* in ILFN-rich home environments.
- People most annoyed with in-home ILFN already have *non-trivial noise exposure histories* (fetal, childhood, leisure, previous or present occupations).
- The *work-at-home person* is more sensitive to in-home ILFN than other members of the family, unless these other members have additional ILFN exposure histories.

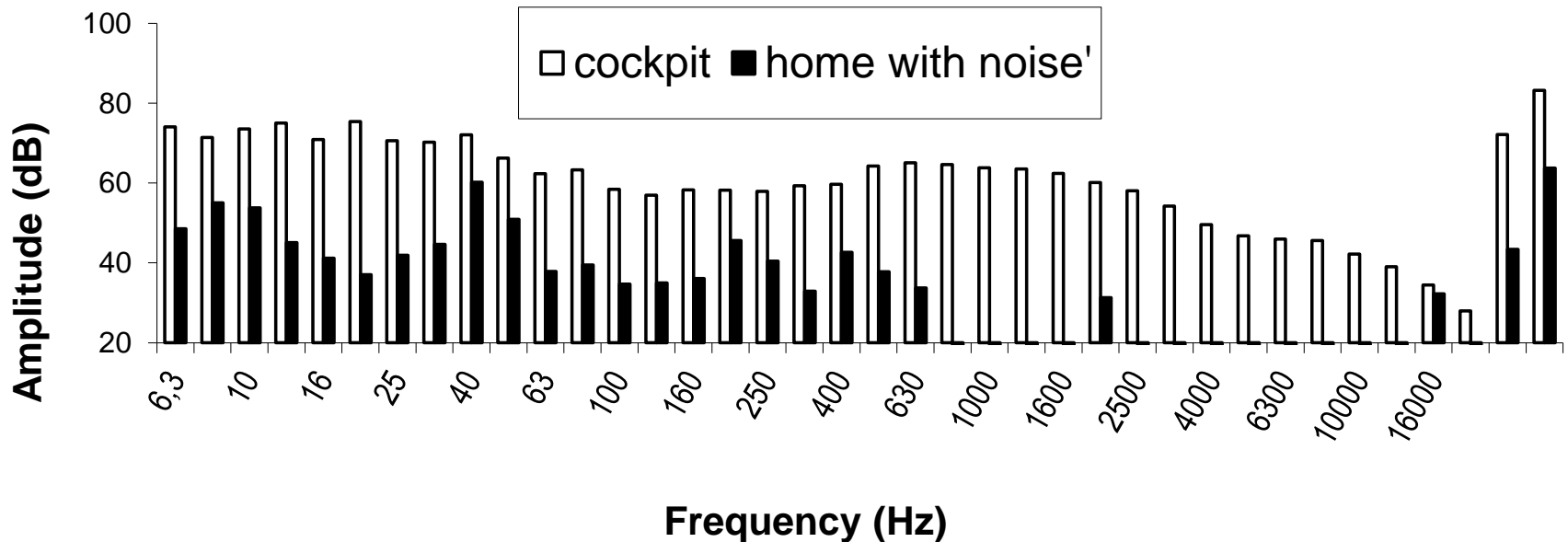
Cases of Environmental ILFN

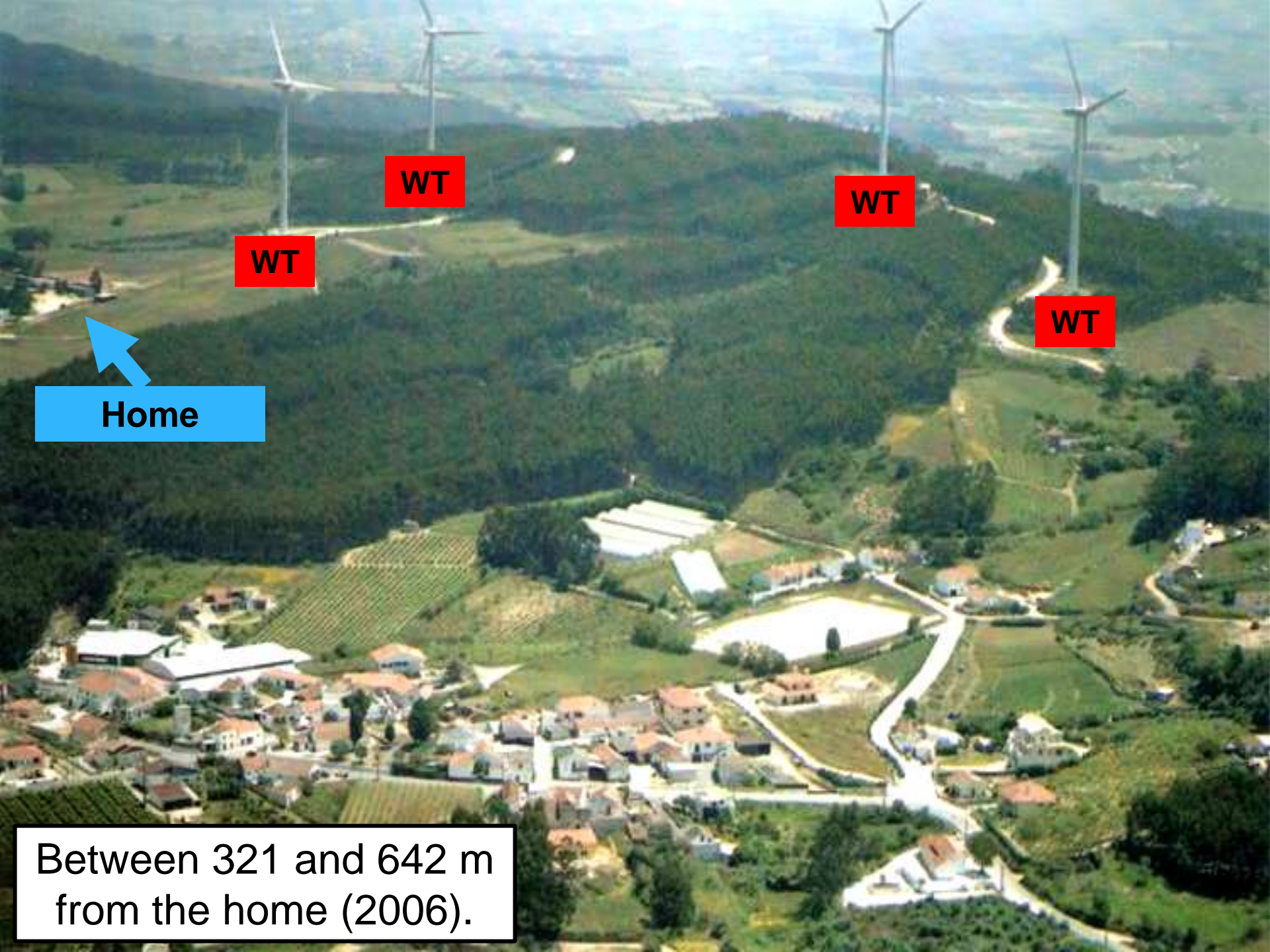


(2004)



Cockpit vs. Restelo Home With Noise





WT

WT

WT

WT

Home

Between 321 and 642 m
from the home (2006).

November 2006

- Four 2-MW wind turbines (WT) began operation.
- Located between 321 m and 642 m.
- Family seeks legal advice.



2 adults.

2 children.

Farm for breeding:

-- bulls for bullfights,

-- thoroughbred

Lusitanian horses.

March 2007

Letter from school-teacher:

“... it seems that [the child] has lost interest, makes a lesser effort, as if he were permanently tired. In Physical Education, an abnormal amount of tiredness is also observed. Is [the child] leading a healthy life? Does he sleep sufficient hours during the night?”

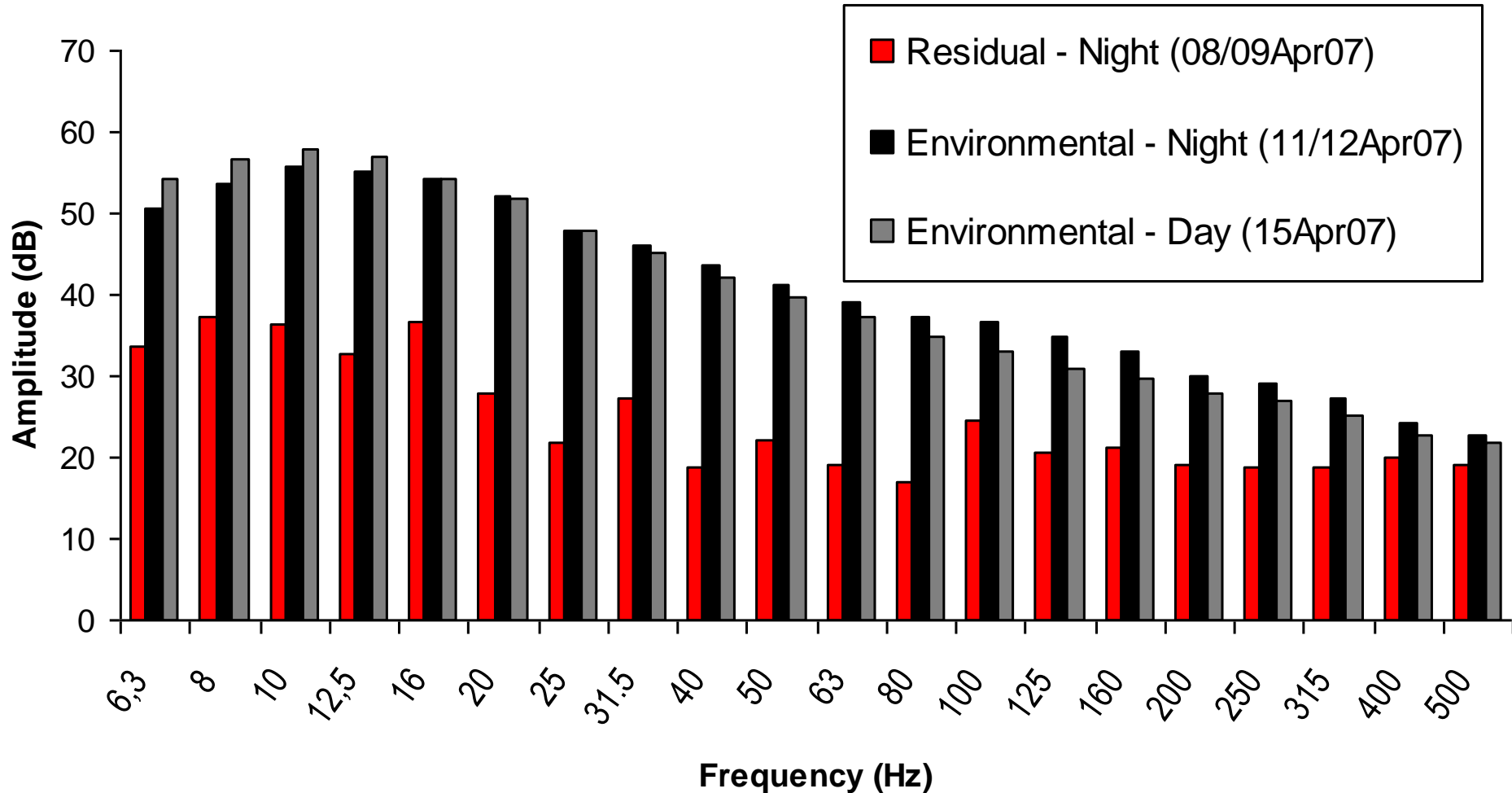
VAD TEAM is contacted by “Family R.”:

“... Inability to obtain restful sleep, increased irritability ... Odd behavior of dogs, horses and ants ... like an airplane flyover that never ends...”

In the Master Bedroom

(2007)

Wind Turbine Home With Same Wind Speed (5.4 Km/h)



Clinical Evaluation

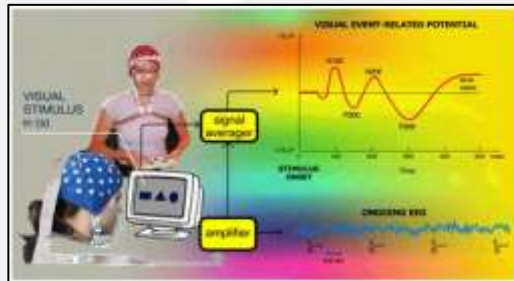
P300 event related potentials in child

Jun 2007: **352 ms**

Sep 2007:
(after 2 mo. Holiday)

322 ms

(norm: 300 ms)



PCO₂ respiratory drive

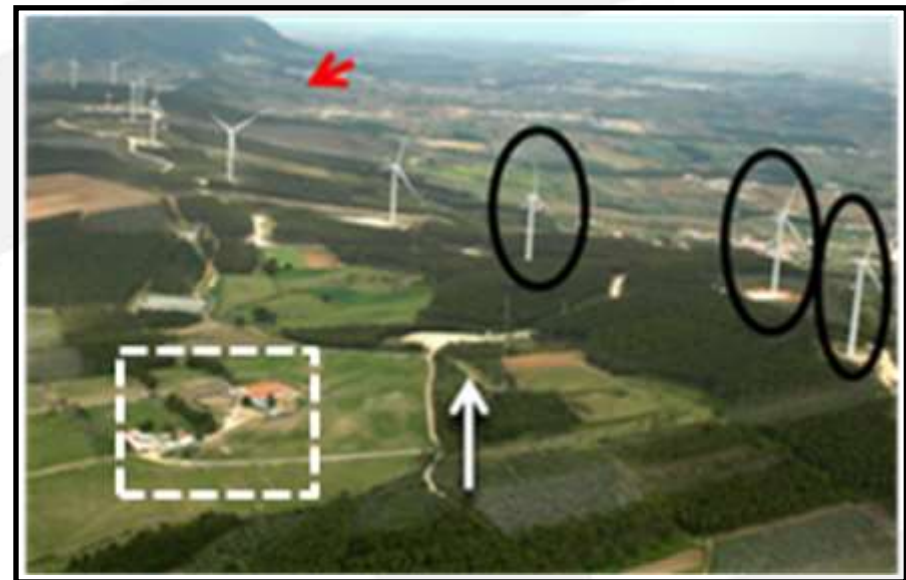
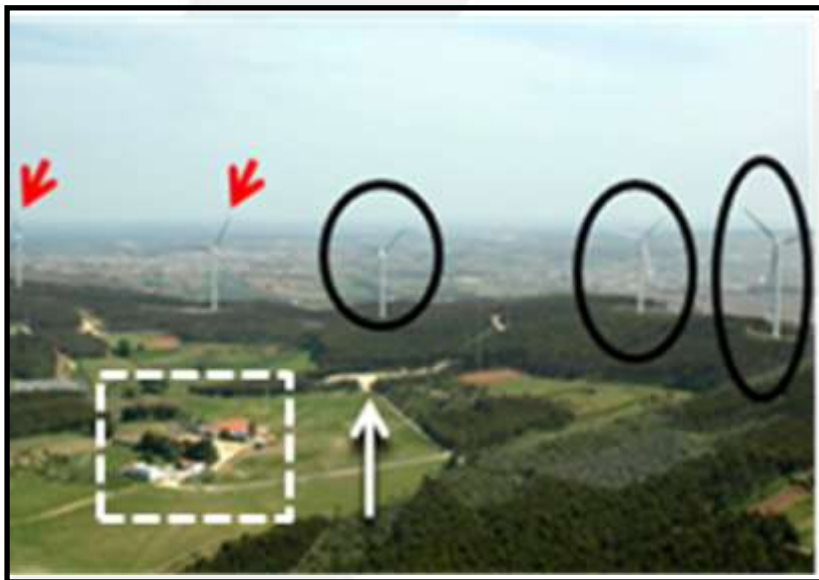
39-year-old father: **46%**

42-year-old mother:
53% (norm: >60%)



Legal Proceedings - 2007

- WT No. 2, closest to home, at 322 m was ordered shut down.
- All other (3) WTs were ordered to be shut down during the evening (8-11 pm) and night hours (11 pm – 7 am).
- Meanwhile, the installation of WT continued in the contiguous vicinity of the R family home.



Situation in 2010



- Child has normal P300 values.
- Mrs. R and the children have moved out of the home.
- Mr. R. must stay to care for Lusitanian horses.
- Mr. R's health is visibly deteriorating, with increased cognitive impairment and severe noise intolerance.
- Between 2000 and 2006, 13 healthy thoroughbred Lusitanian horses were born and raised on Mr. R's property.
- Horses raised after 2007 developed asymmetric *equine flexural limb deformities* (EFLD).
- Four were studied plus 1 control.

EFLD Study



Normal forelimb:
Hoof wall-to-floor angle $>115^\circ$



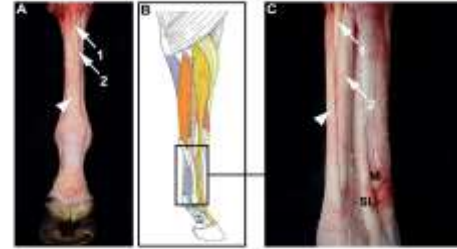
Espartaco – Case 4
Born: 02May09 and raised on R's Farm.



Engenheiro – Case 5
Born: 17May09 and raised on R's Farm.

EFLD forelimb:
Angle $<115^\circ$

Corrective Surgery:



During corrective surgery, fragments were removed for histological analyses. Results were the same as those from ILFN-exposed humans and animal models:

Thickened vascular structures due to abnormal growth of collagen in the absence of an inflammatory process.

Today

May 2013-- Supreme Court of Justice Decision:

All 4 WT must be permanently removed;
Increased monetary compensation.

Living arrangements:

Mrs. R & children still live in separate home.

Mr. R's health:

-- PCO₂ value at **28%**

(norm: > 60%; 46% in 2007)

-- Balance disturbances with loss of consciousness, apparently causing falls leading to facial and rib fractures. Suspected late-onset epilepsy.

Limb Deformities



VAD Team
Laboratory
Rat exposed
in utero



Chicken exposed to Infrasound
and Low Frequency noise
generated by coal mining
operations before hatching

Wind Turbine Home Horses

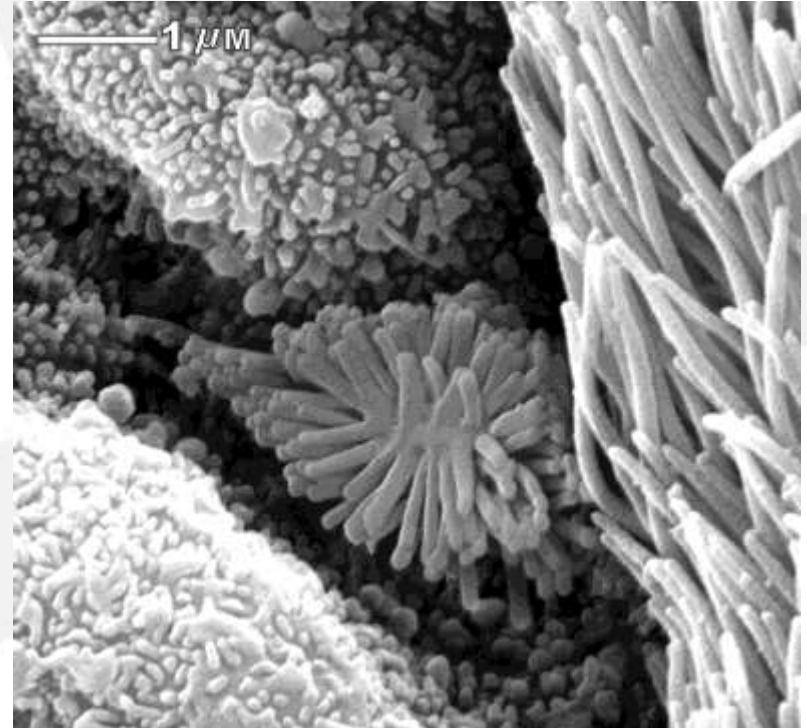


Thank you for your attention!

m.alvespereira@gmail.com



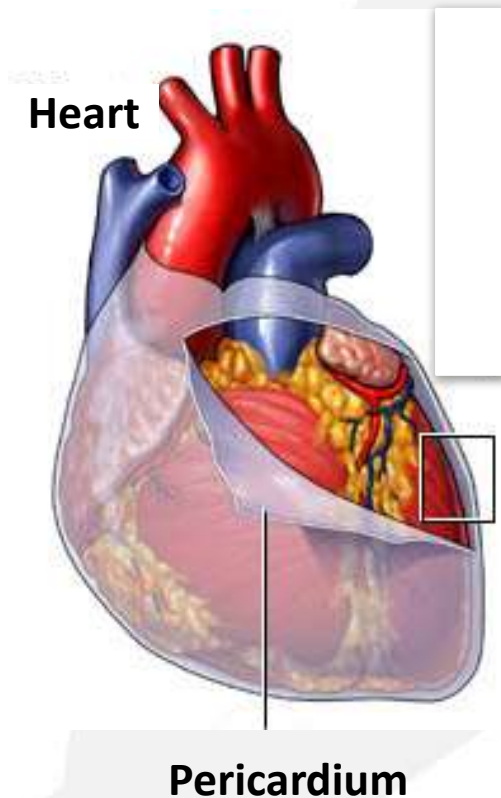
Succulent plant exposed to Northern winds on Madeira Island – North Atlantic Ocean.



Bronchial brush cell of Rat exposed to infrasound and low frequency noise.

Cardiovascular Thickening

Autopsy revealed thickening of cardiovascular structures -- Pericardium and Blood Vessel Walls



Normal pericardium

- <math><0.5\text{ mm}</math> thickness
- **Three layers** of tissue:
 - Serous
 - Fibrous
 - Epipericardium

Echocardiography



Top: Echo-image with GAIN = 67 showing pericardial echogenicity.

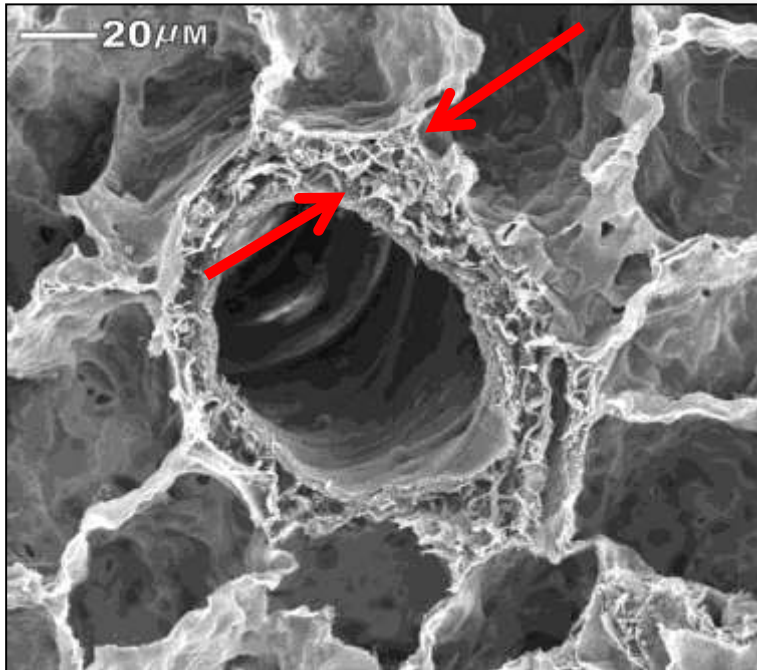
Bottom: Echo-image with GAIN = 39 showing *persistent* pericardial echogenicity

| | |
|-----------------------|--------|
| Diastolic function: | normal |
| Inflammatory process: | absent |

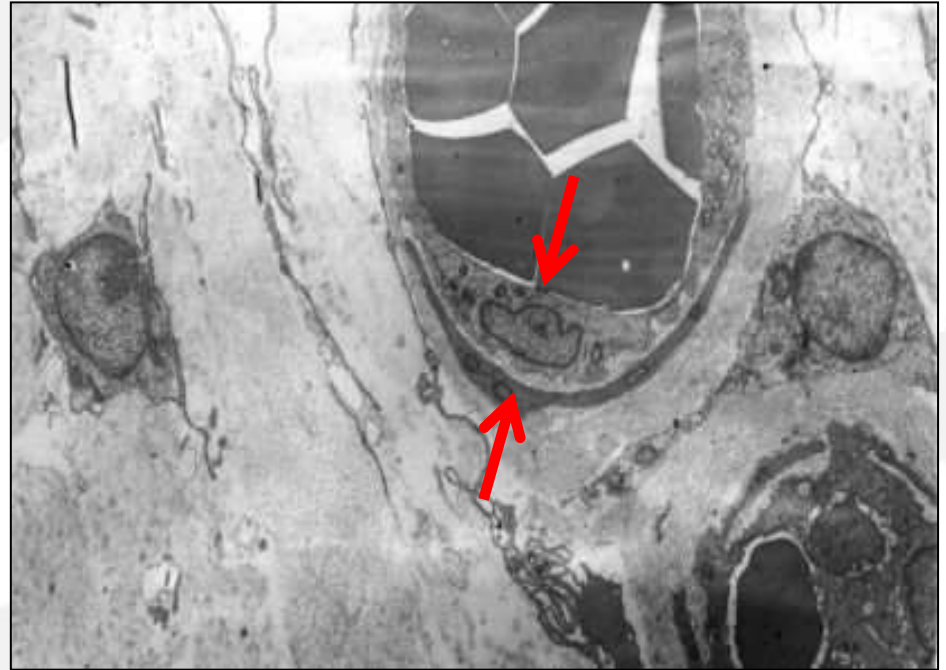
Pericardial thickening in ILFN-exposed workers:

- first observed in autopsy (1987),
- confirmed through echocardiography (1991-2016)
- anatomically confirmed in VAD patients submitted to cardiac surgery for other reasons (1996-

Thickened Blood Vessel Walls



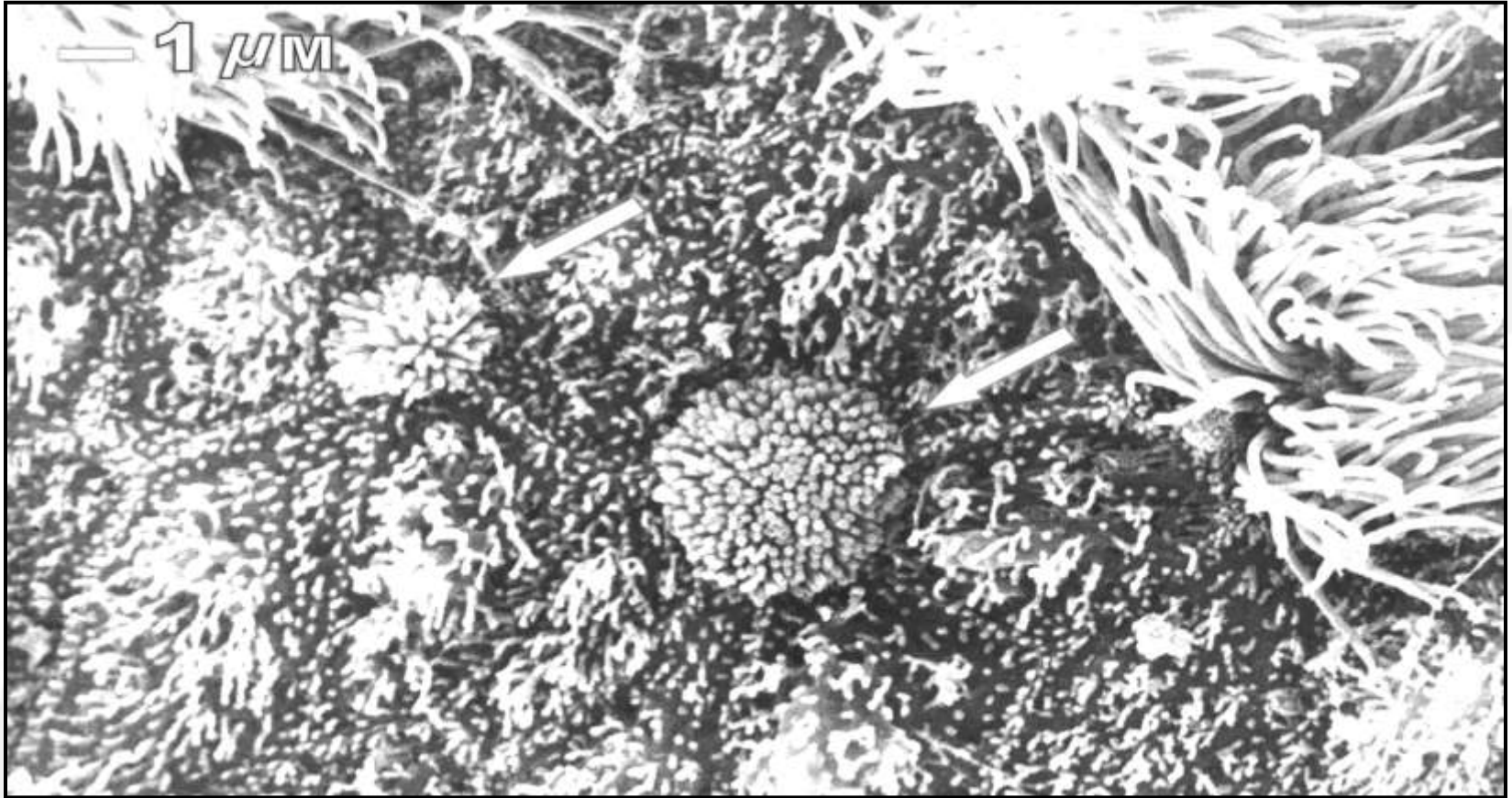
Thickened artery wall
in LFN-exposed rat.



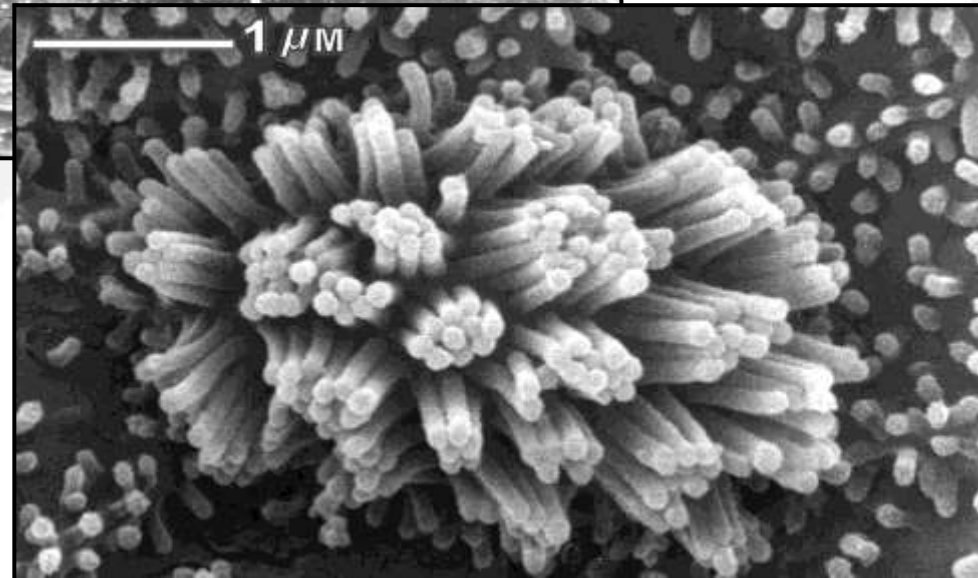
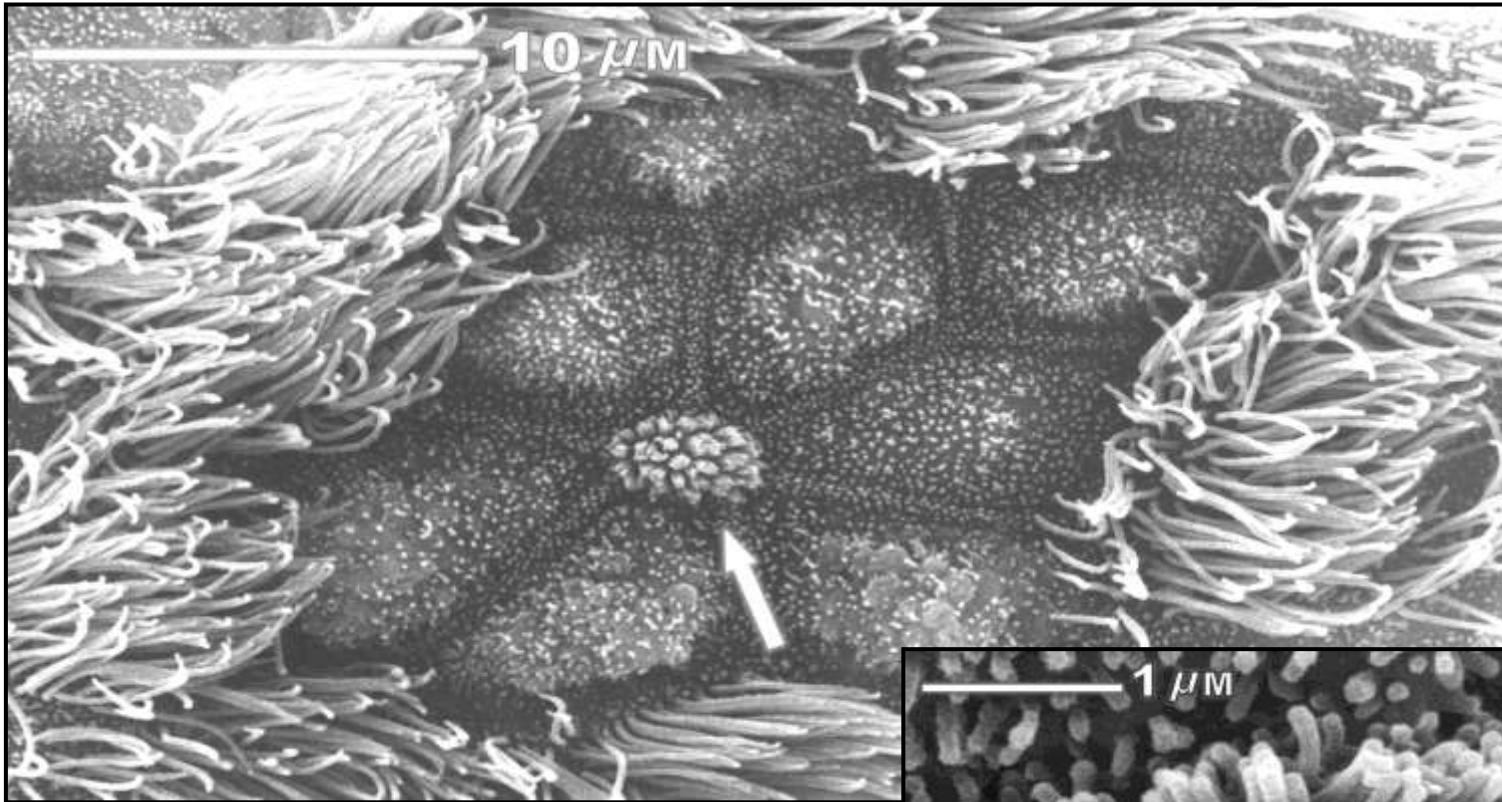
Thickened artery wall in VAD-patient
pericardial loose-tissue layer.

This abnormal collagen growth **is not** triggered
through auditory stimuli alone.

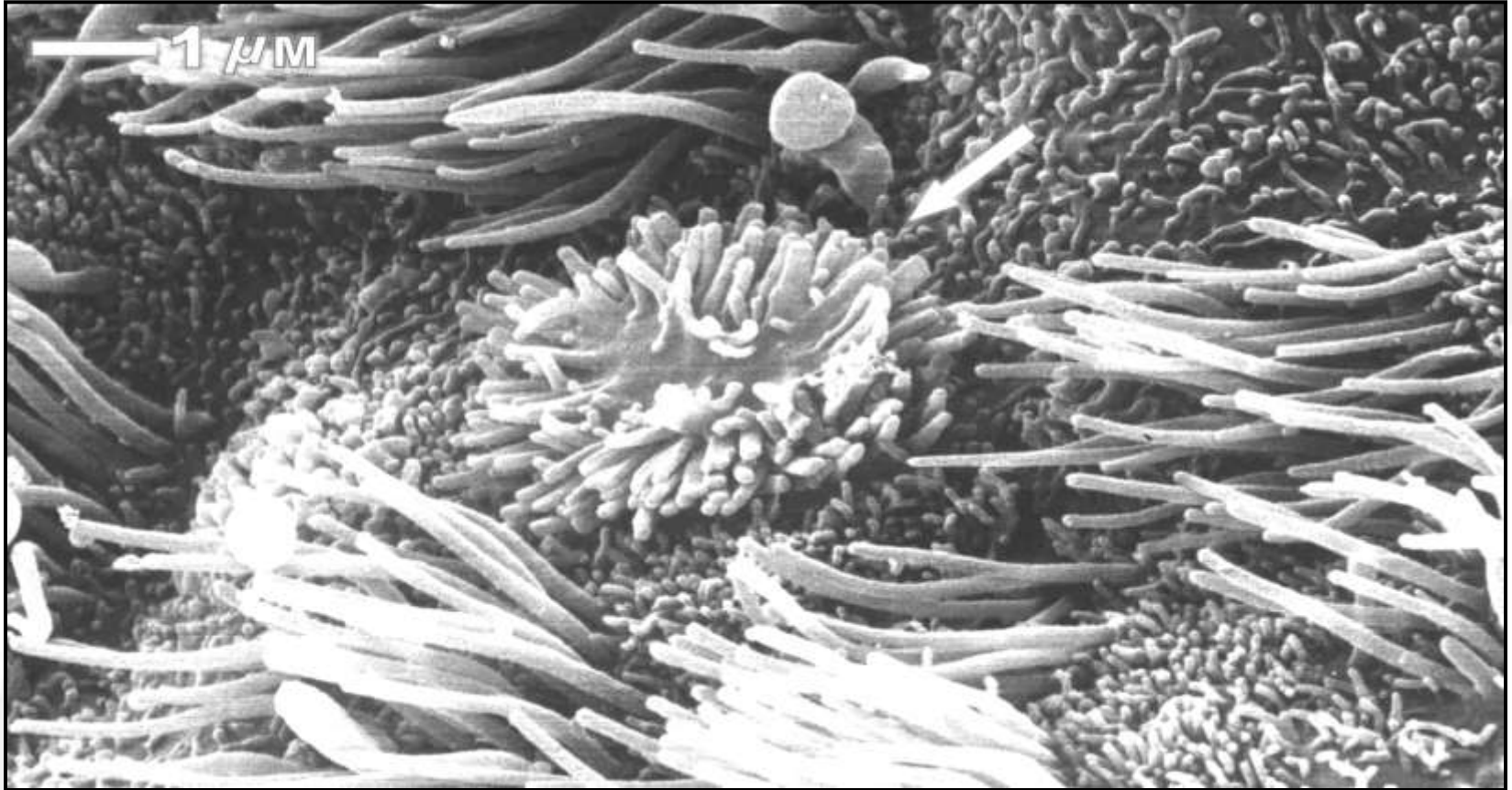
Normal Trachea – Brush Cell



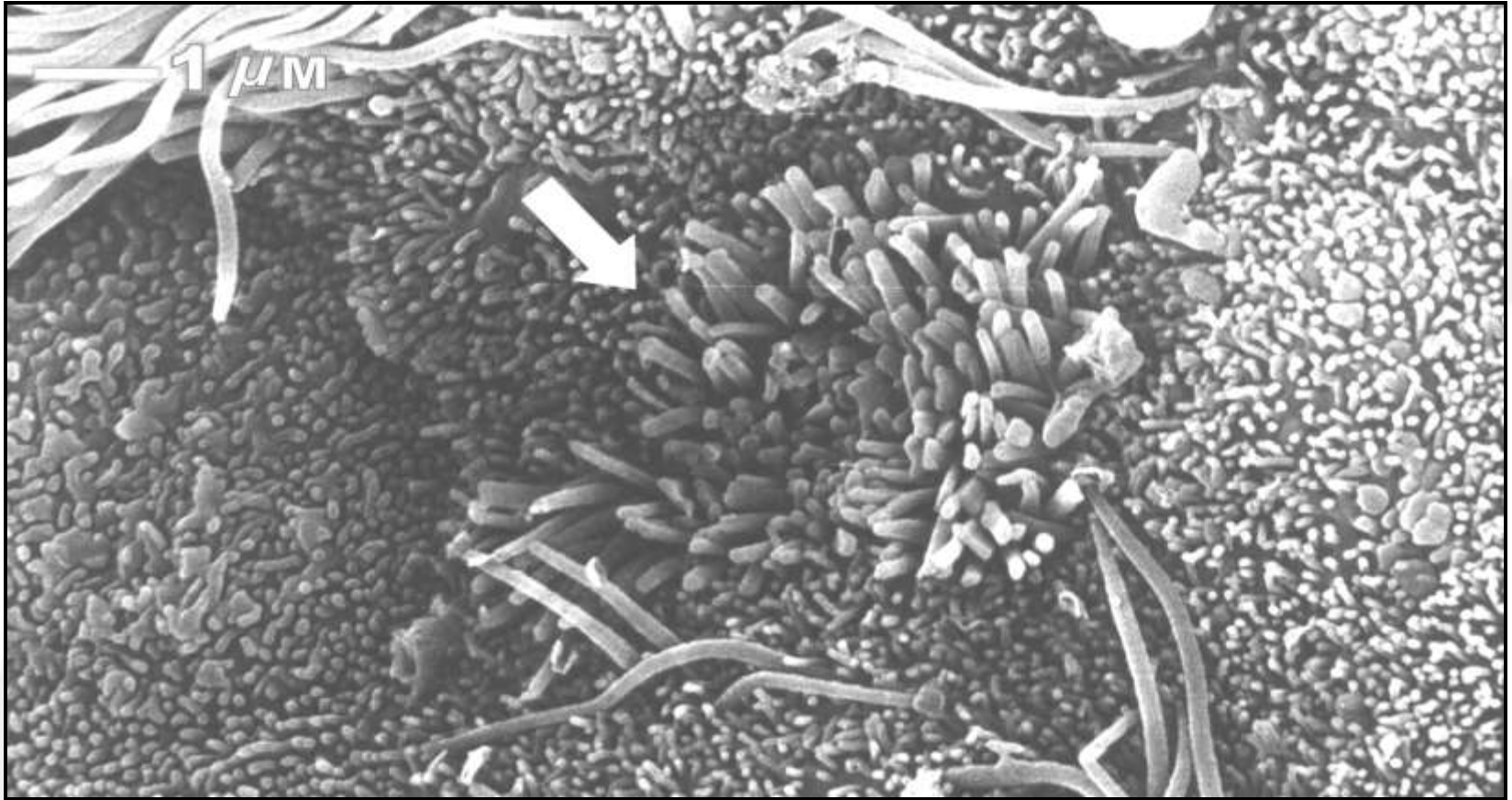
Trachea – Brush Cell – 235 hrs



Trachea – Brush Cell – 4399 hrs

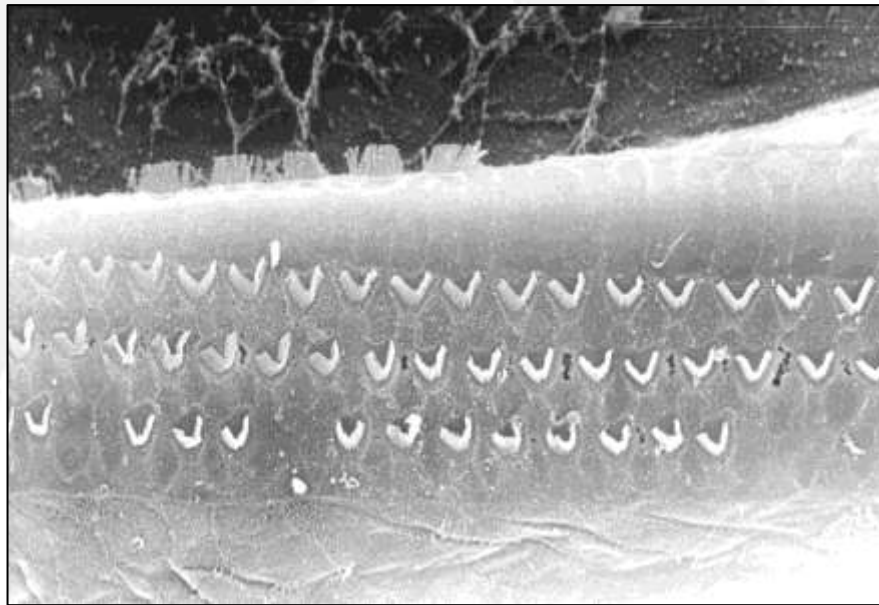


Trachea – Brush Cell – 5304 hrs



Normal Rat Cochlea

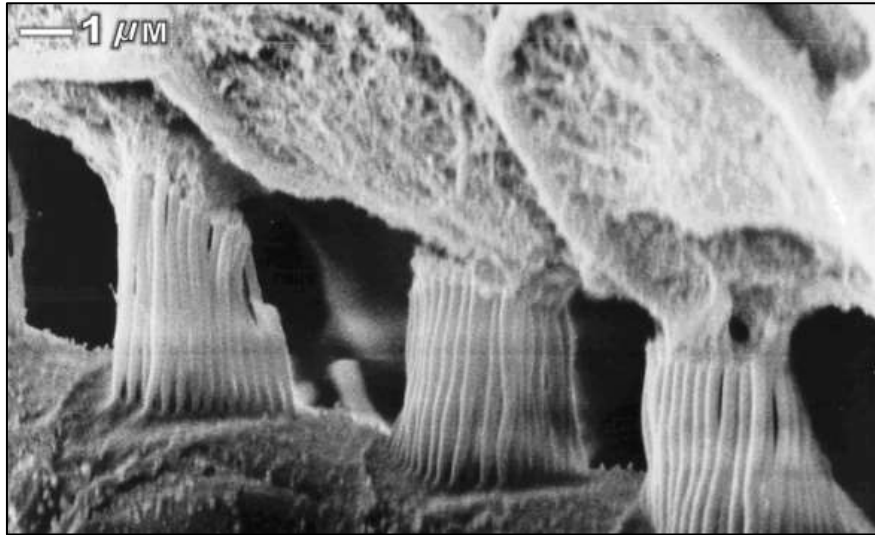
The cochlea of ILFN-exposed rats were studied using light and electron microscopy, and compared to controls.



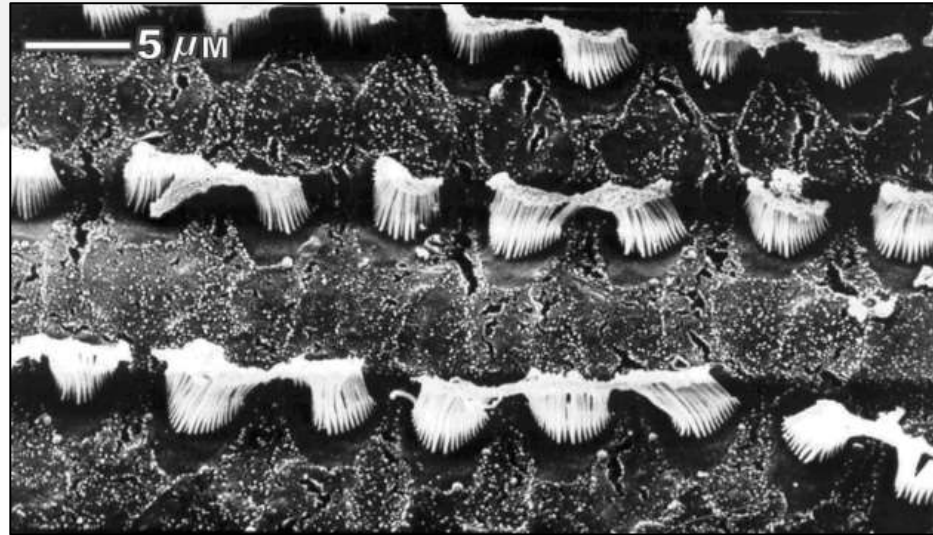
Normal rat hair cells of ear.

- Upper tectorial membrane was completely removed to show independent tufts of cilia.
- Missing cilia is due to normal aging process.

Exposed Rat Cochlear Cilia



Upper membrane is fused with cilia and not easily removed. Cilia are fused amongst themselves.



Upper membrane is removed revealing cilia tufts fused amongst themselves. No missing cilia tufts due to natural aging process.

Given the function of actin-based stereocilia in relaying acoustical signals into electrical inputs to the brain, VAD researchers suspect that this ciliary fusion, if it occurs in humans, may be an organic explanation for noise annoyance.