Infrasound:

Your ears “hear” it but they don't tell your brain.

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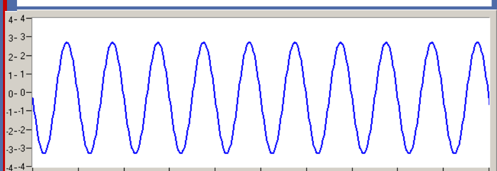
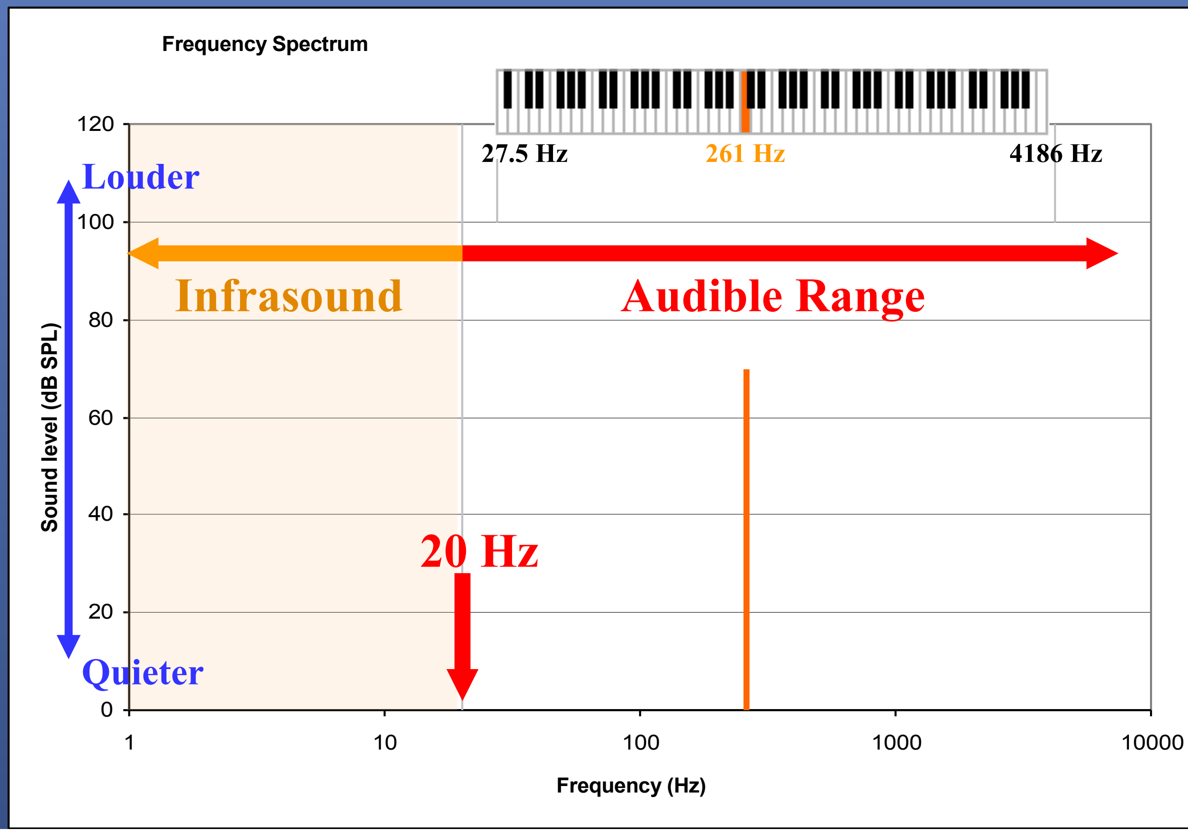
Introduction to Sound Spectrum Graphs

Middle C
261 cycles per second
= 261 Hz



Time



Infrasound frequencies are shown shaded orange on all subsequent graphs

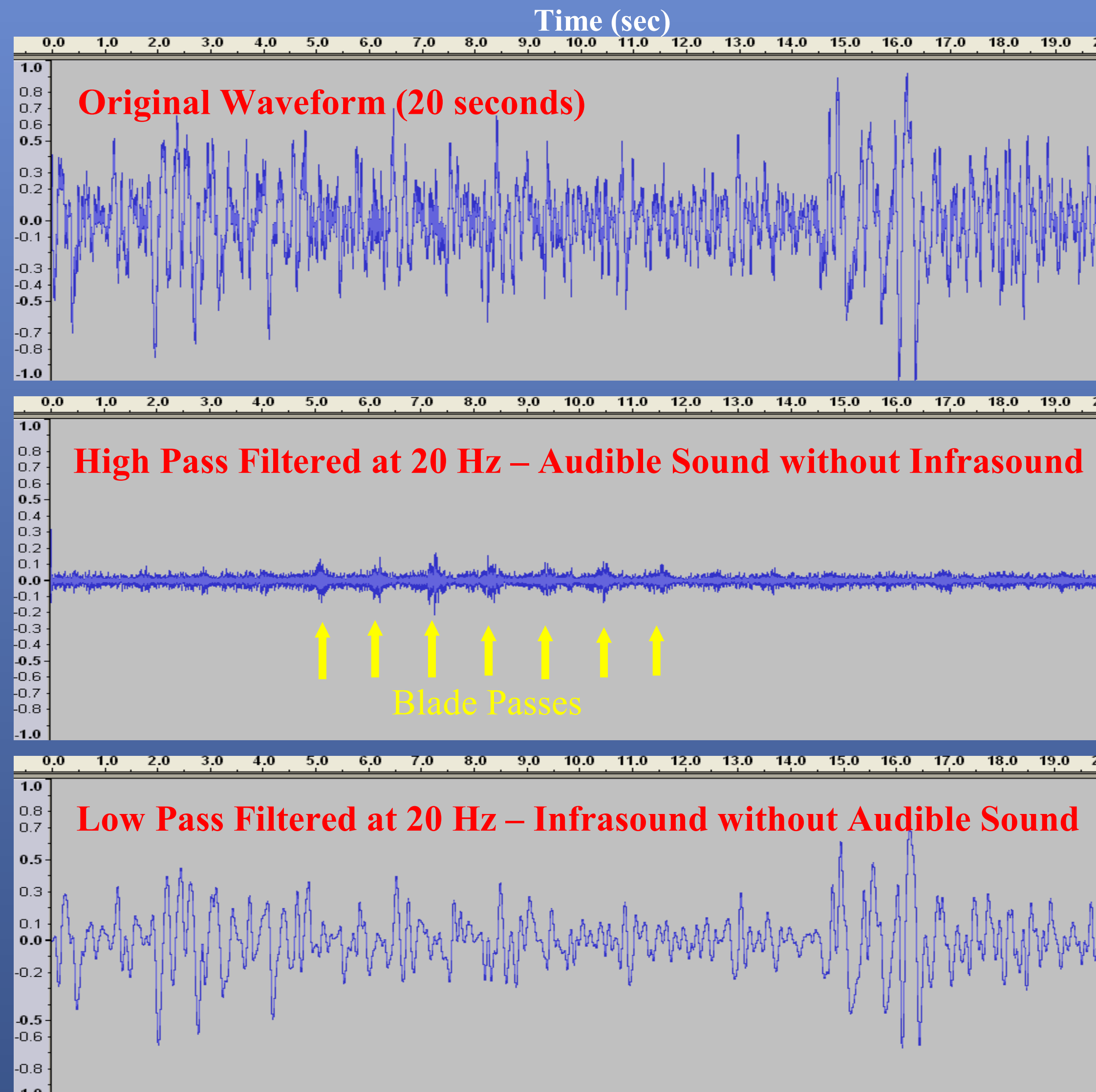
Wind Turbines Generate Infrasound

Sound recording courtesy of Rick James Recorded with 1Hz-capable microphone inside the vestibule of home with turbine 1500' downwind.

These two waveforms sound identical when played by the computer

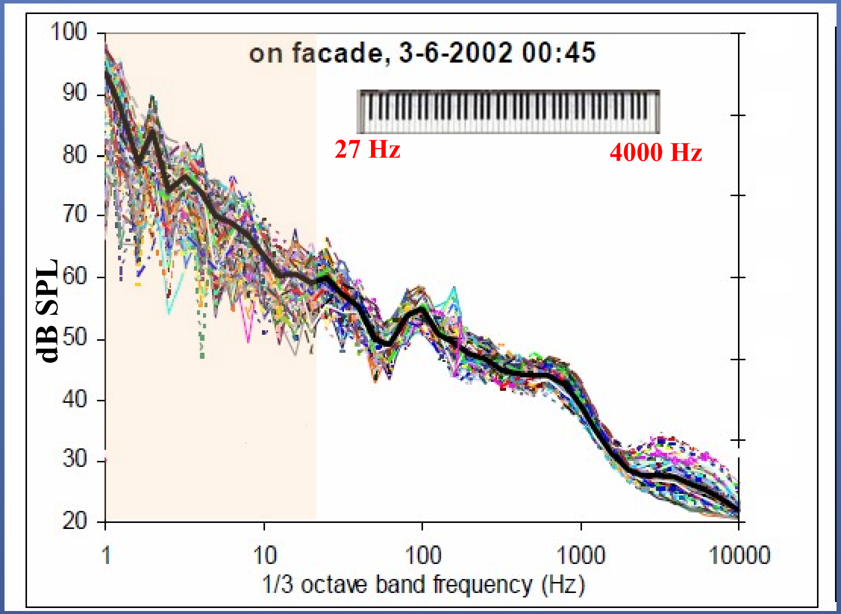
You hear nothing when this waveform is played.

1) The computer speakers cannot reproduce this sound.
2) Even if they did, you still couldn't hear it because it is infrasound.

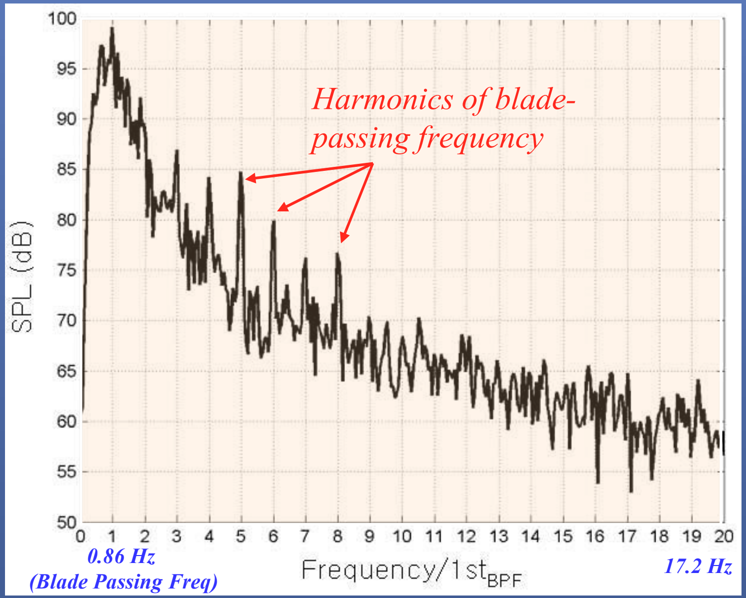


You cannot tell when infrasound is high based on audible sound.

Wind Turbine noise shown as a spectrum

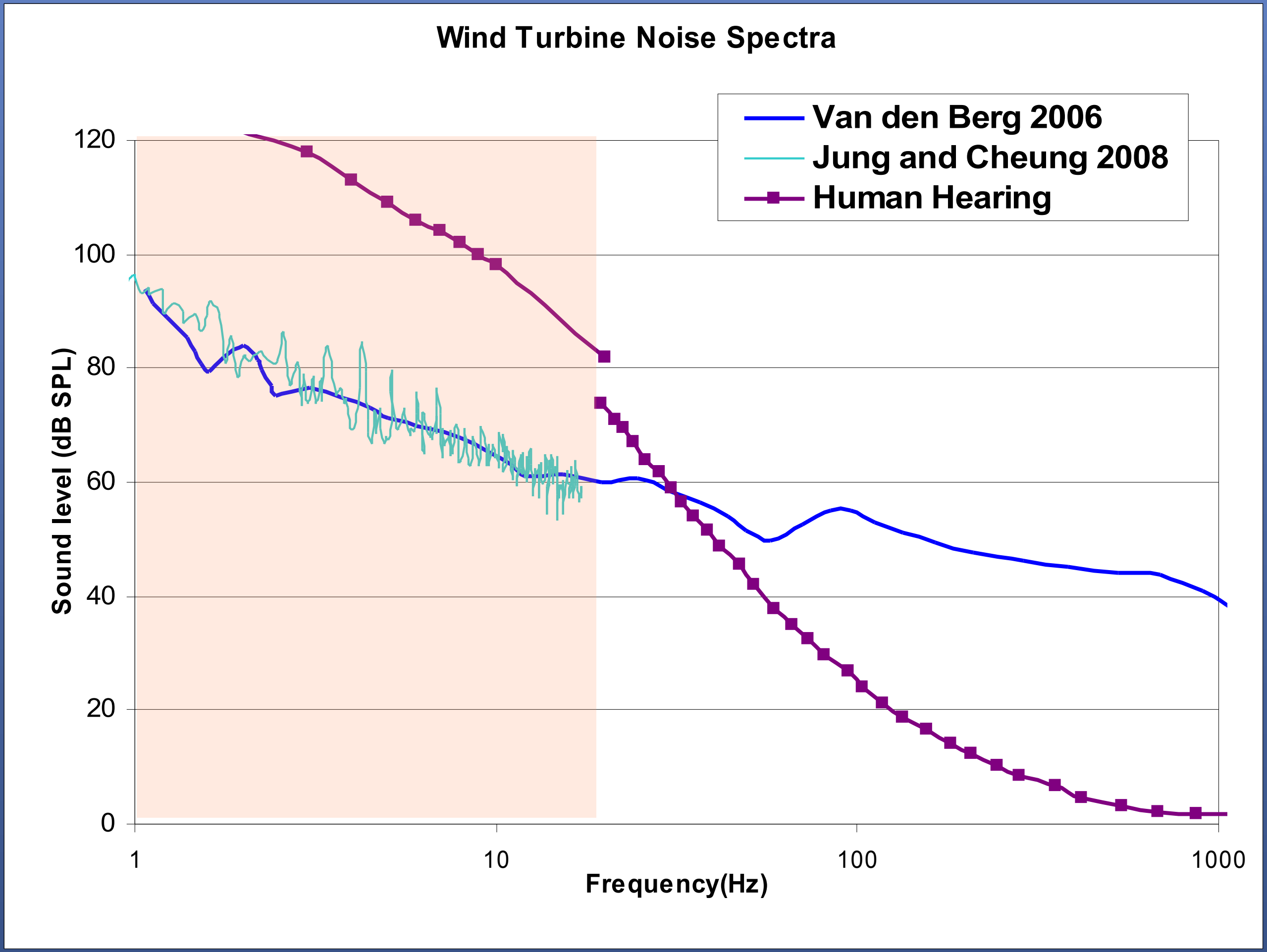


Van den Berg, 2004



Jung and Cheung, 2008

Wind turbine infrasound is at levels that cannot be heard



Widely Cited Interpretations

8. Unusual perception

The evidence is that the ear is the most sensitive receptor for infrasound and low-frequency sound, that if you cannot hear a sound you cannot perceive it in other ways and it does not affect you. However, unusual sensitivity is sometimes reported, for example by Feldmann and Pitten (2004). Here a family complained of disturbance at night, and consequent effects on health, allegedly caused by noise from a boiler house.

"If you cannot hear a sound…it does not affect you."

Leventhall G. What is infrasound?Progress in Biophysics and Molecular Biology 2007; 93: 130–137

The blade passing the tower has been mentioned as a specific source of low frequency noise. A theoretical study of this phenomenon has been conducted by RISØ DTU. The result is that this blade/tower interaction generates noise only at the lowest frequencies with a decreasing level with increasing frequency. The study confirms the findings from the measurements on large wind turbines and a literature study, that infrasound is negligible for this type of wind turbines.

DELTA

"Infrasound is negligible"

DELTA: Low Frequency Noise from Large Wind Turbines 2008

5 CONCLUSIONS

- Infrasound from wind turbines is below the audible threshold and of no consequence.
- Low frequency noise is normally not a problem, except under conditions of unusually turbulent inflow air

"Infrasound .. is below the audible threshold and of no consequence"

Leventhall G. Canadian Acoustics 2006; 34:29-36.

This logic seems to ONLY apply to hearing.

Consider other senses:

Taste : If you can't taste it, it can't affect you? Can you taste salmonella?

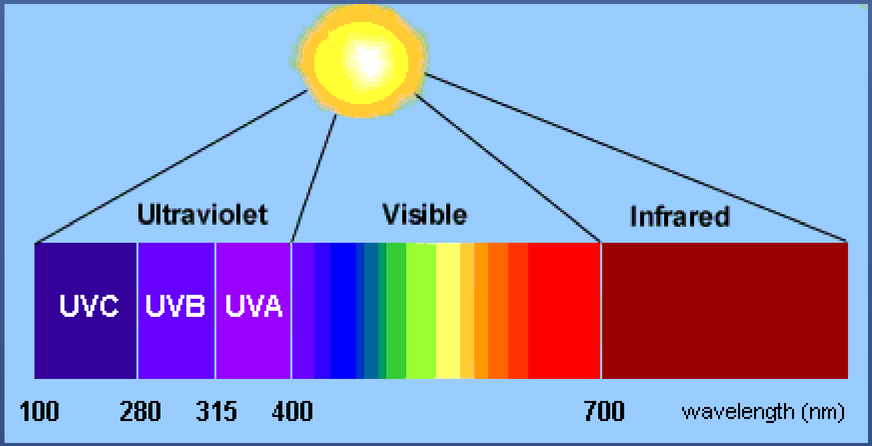
Smell : If you can't smell it, it can't affect you? Try breathing pure CO or CO_2

Sight : This will be used as a more detailed example.

Does the same logic work for sight?

If you can't see it, it cannot affect you

Ultraviolet (UV) light is invisible



Photokeratitis,
"snow blindness"
"welder's flash"
+
cataracts

Sunburn

Even though you can't see it:

UV does affect you.
UV can harm you.

If you can’t hear it, it can’t affect you

is only true:

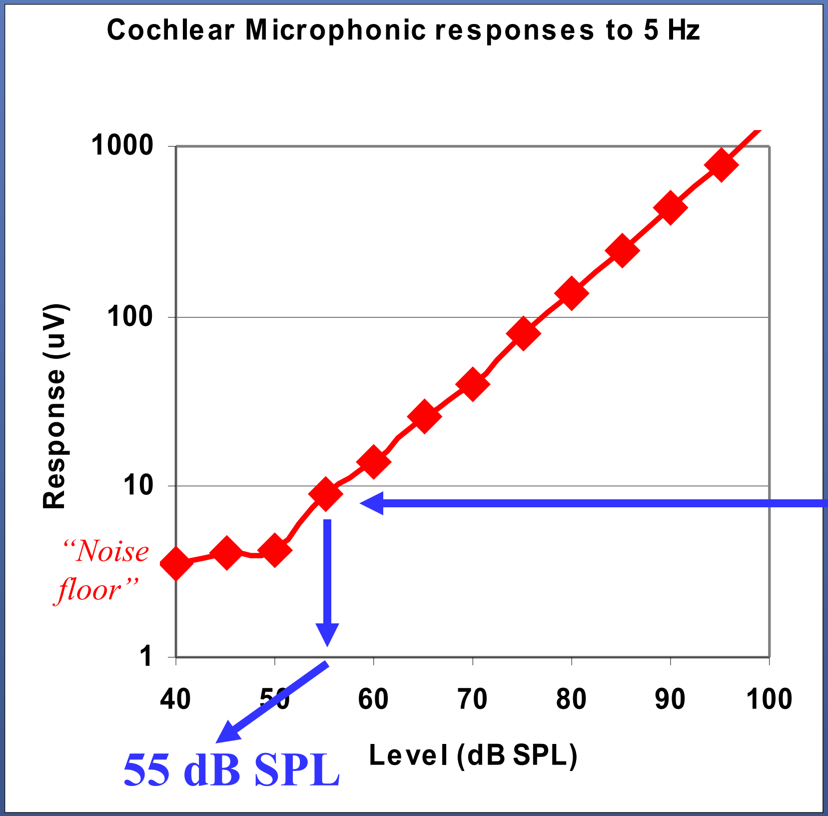
If no other part of the ear is more sensitive than HEARING…

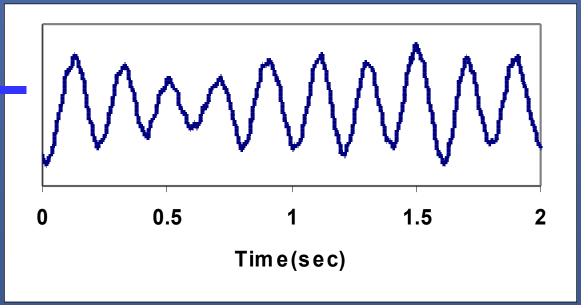
And if no other part of the body is more sensitive than HEARING…

……and I will show this is NOT true

Infrasound at moderate levels is detected by the ear ….

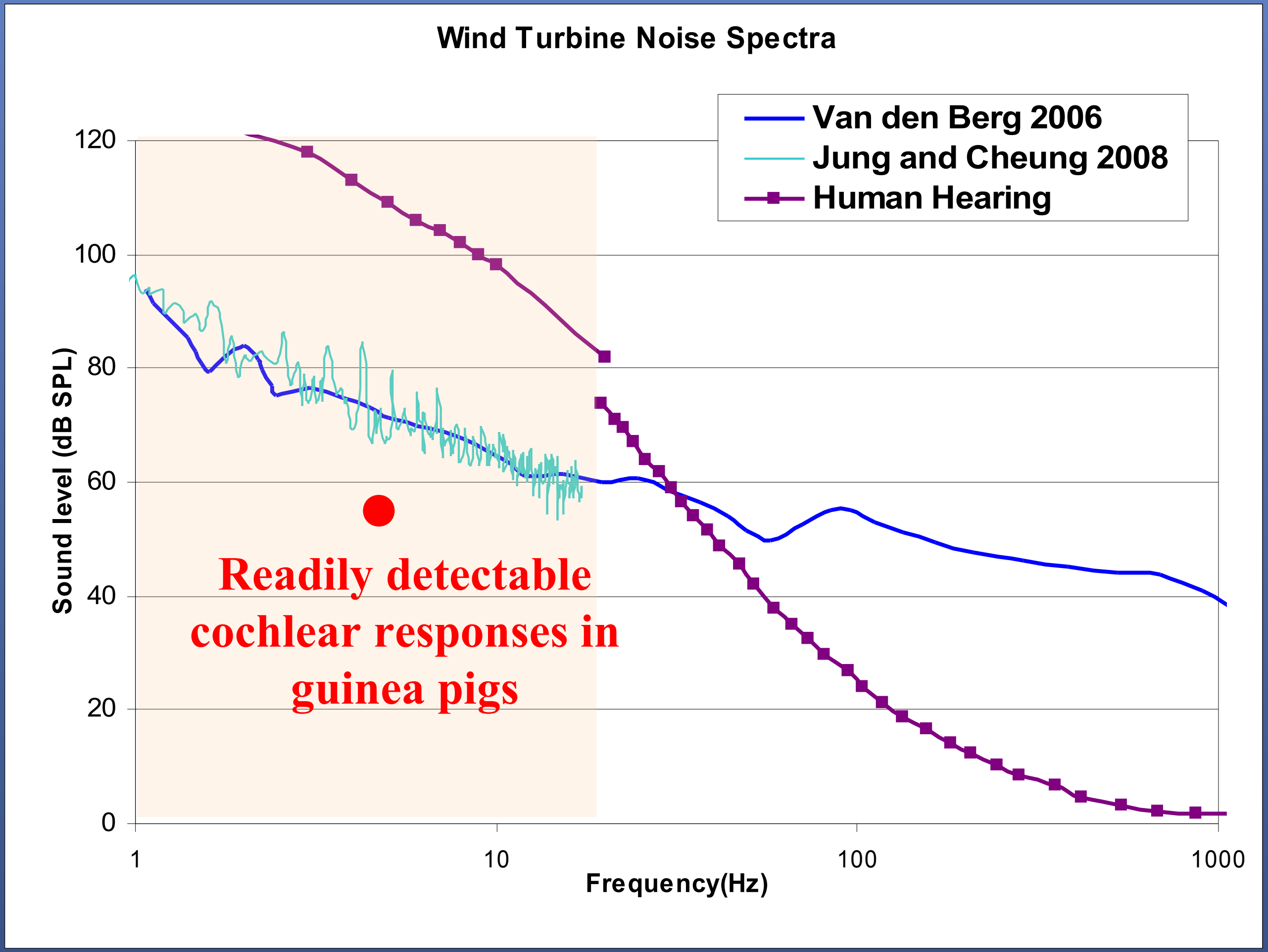
Measured responses to infrasound (5 Hz) in animals



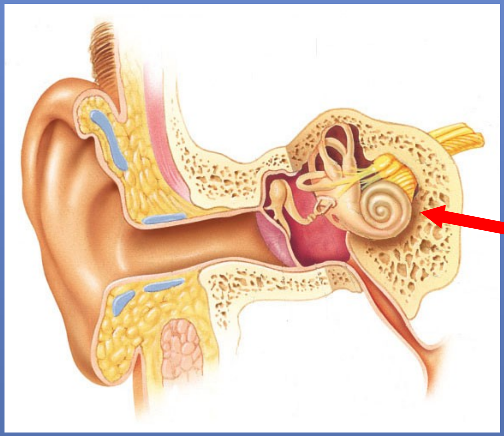


Symbols show the pk/pk amplitude of averaged responses from scala media in turn 3 of the guinea pig cochlea. Responses to20 stimuli averaged in each case.

Infrasounds at levels generated by turbines DO affect the ear

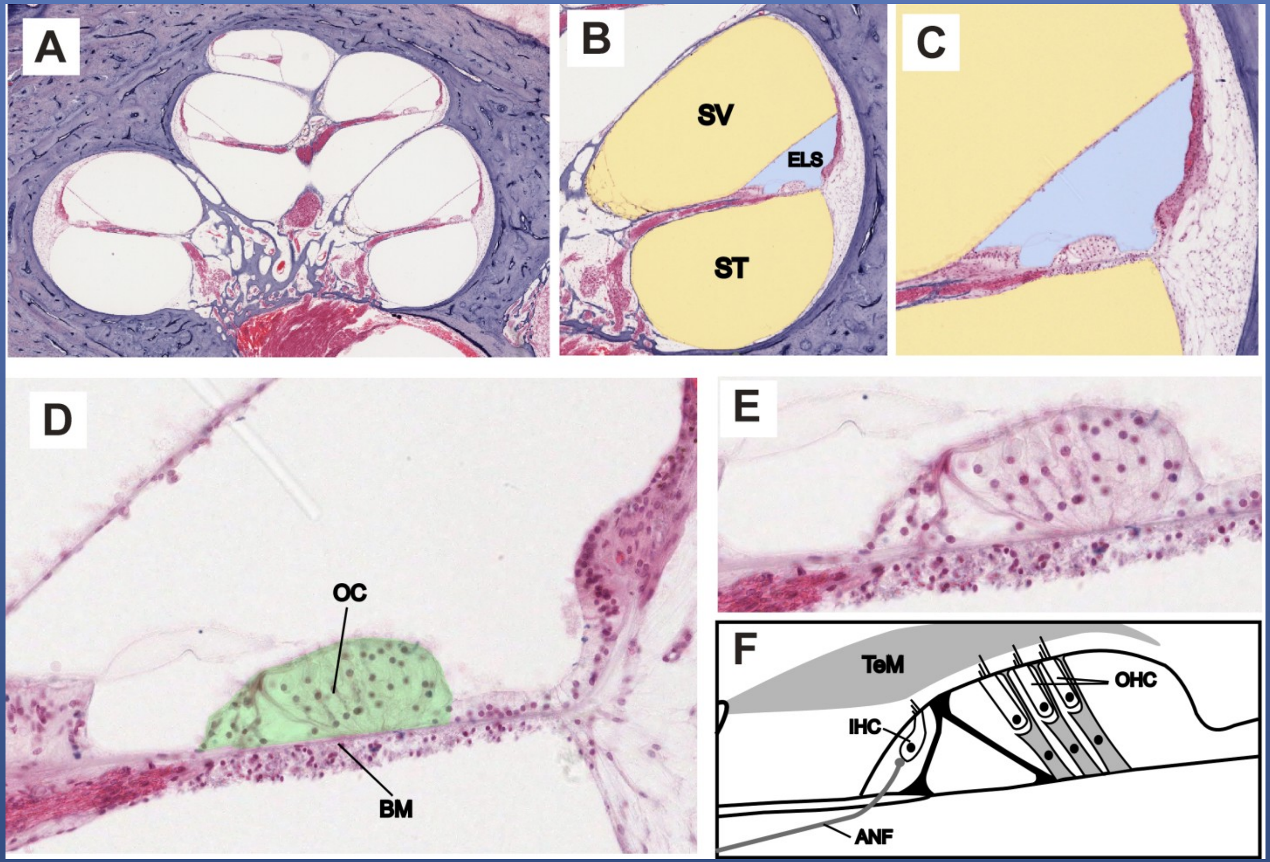


And guinea pig hearing is LESS sensitive than humans to low frequency sounds

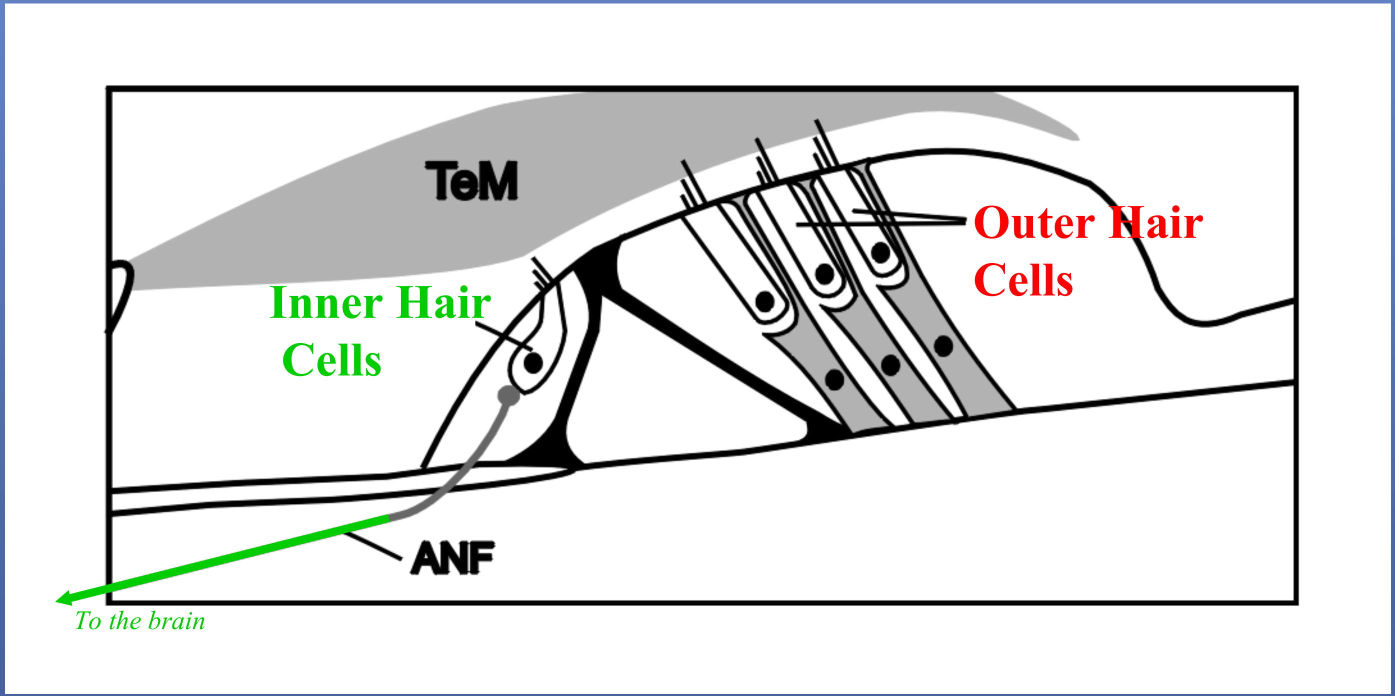


Explanation of how the ear responds to low frequencies you cannot hear

Inside the cochlea



Sensory cells of the ear



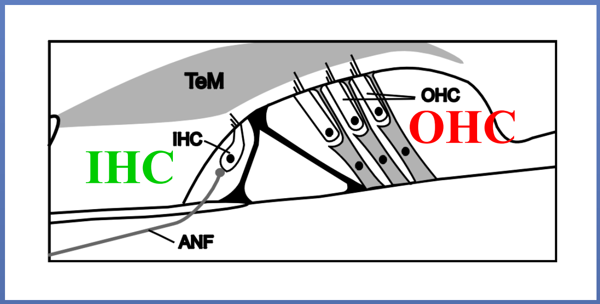
Vibrations cause a bending of the sensory hairs.
The inner hair cells are connected to auditory nerve fibers (ANF) that send signals to the brain.

You "hear" with your inner hair cells

How it works is best seen with a movie **0914345107_SM1.mov**

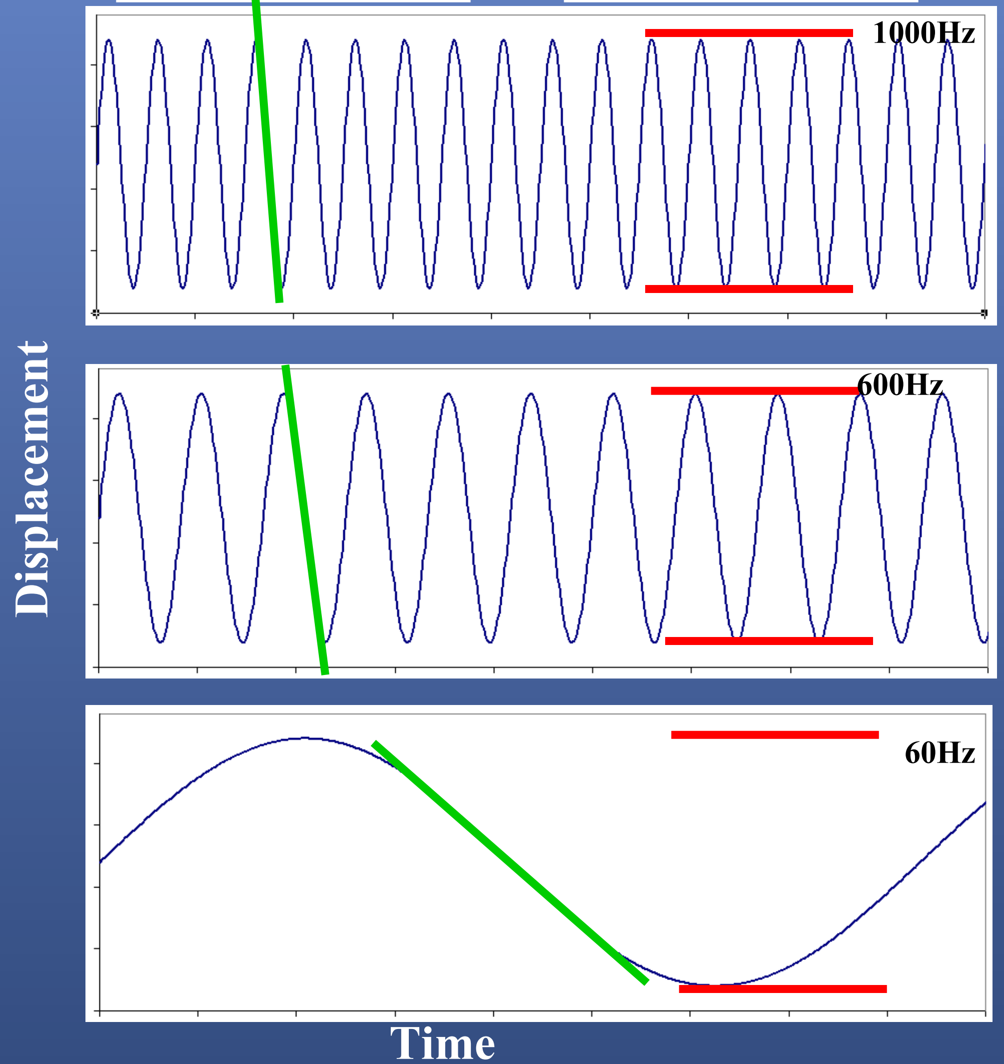
Reichenbach & Hudspeth 2010.

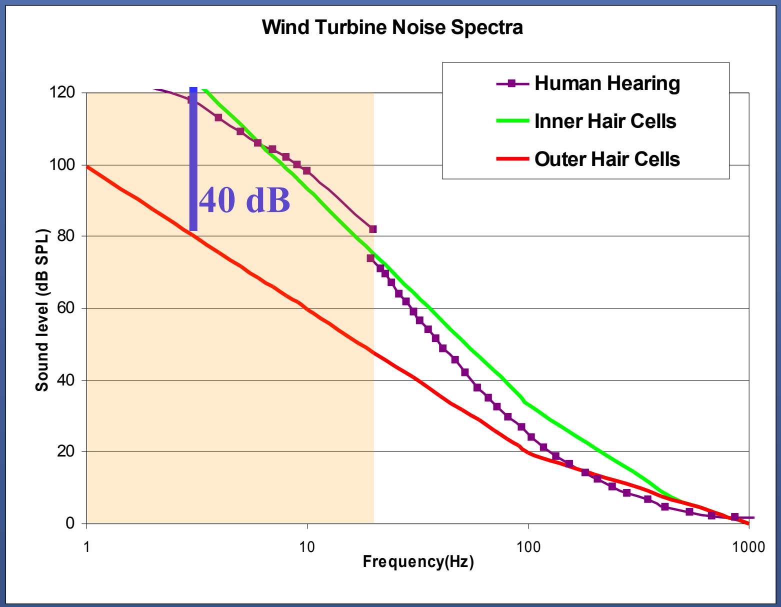
IHC and OHC respond differently as sound frequency is changed



IHC respond to velocity

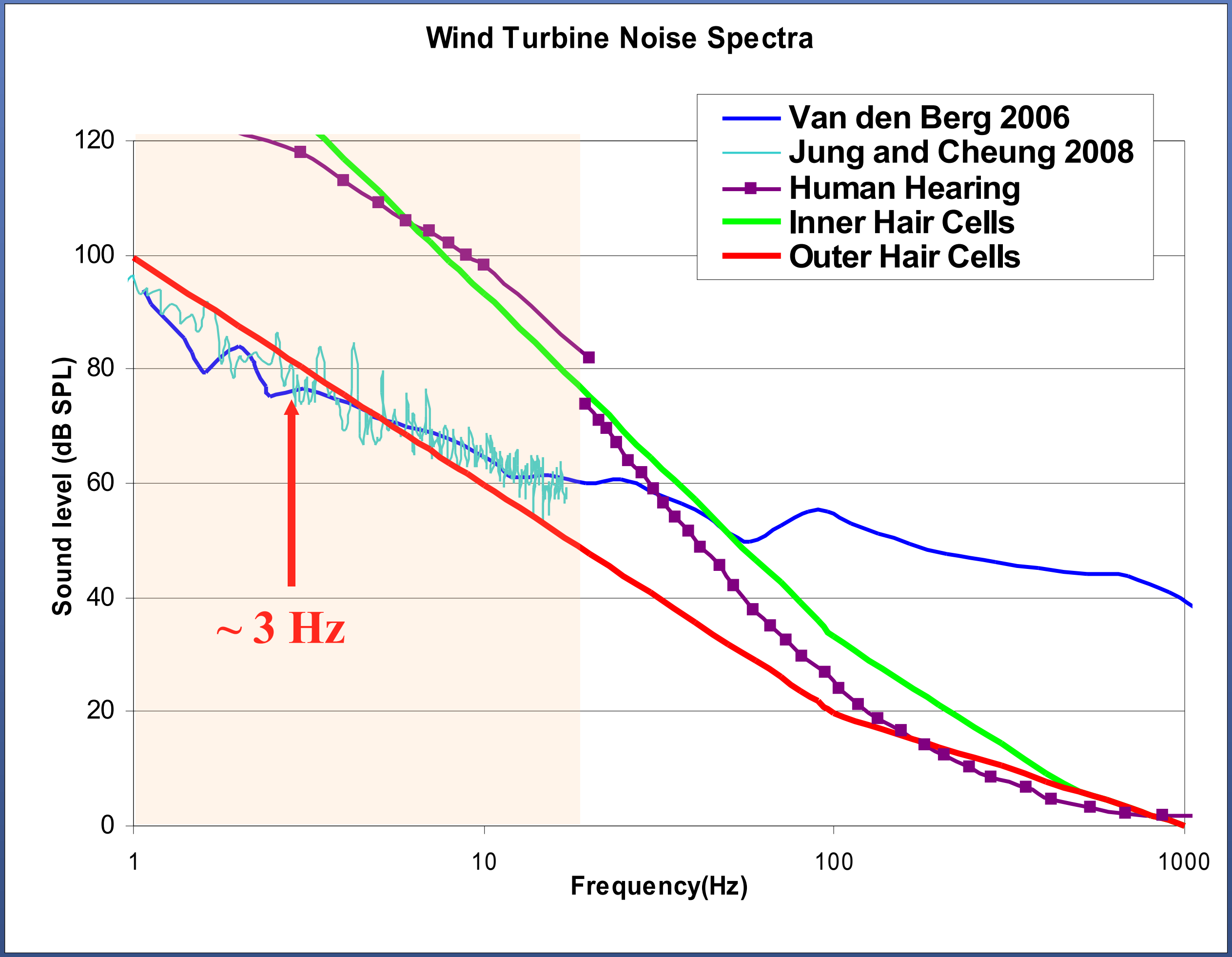
OHC respond to displacement





OHC respond at ~ 40 dB BELOW IHC sensitivity at 2 Hz

Outer hair cells will be stimulated by wind turbine noise



Outer Hair Cells do not just detect sound

Sound/ Vibration → **Hair cells** → Electrical Signal to the Brain

It is not so simple !

Low-level sound/ Vibration ↔ **Outer Hair Cells** ↔ Detect & Mechanically Modify Vibrations → **Inner Hair Cells** → Electrical Signals to the Brain

Amplify *high frequencies*

Cancel *infrasonic frequencies*

Ashmore: Movie

Outer Hair Cell from the ear contracting like a muscle with electrical stimulation.

Outer hair cells active responses

Reichenbach T, Hudspeth AJ.
Proc Natl Acad Sci U S A. 2010

0914345107_SM1.mov

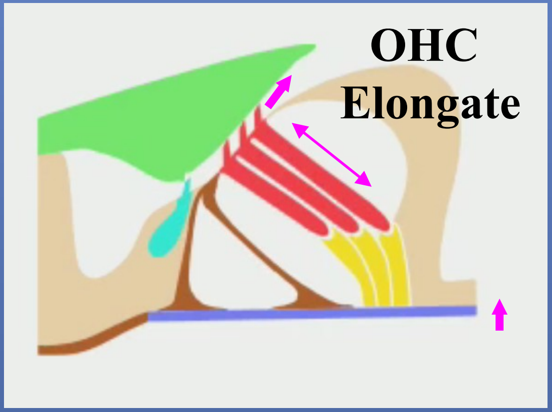
Hudspeth's most recent model
For low-amplitude, high frequencies, OHC ELONGATE when hairs are bent outwards, which makes stimulus greater for IHC (amplifies signal).

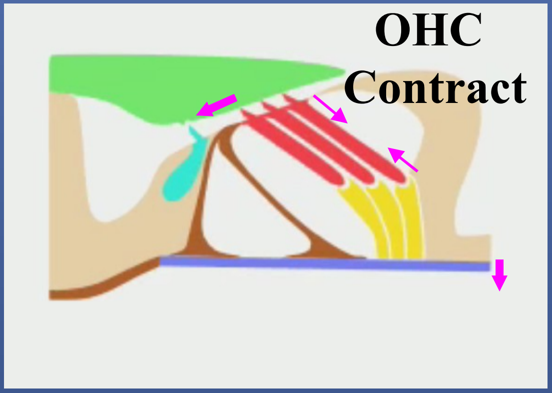
Amplifier becomes less effective (less necessary) for higher level sounds, ineffective about 40 dB above threshold

Hudspeth Model, 2010

At very low frequencies, we know that bending the hairs laterally causes OHC to CONTRACT

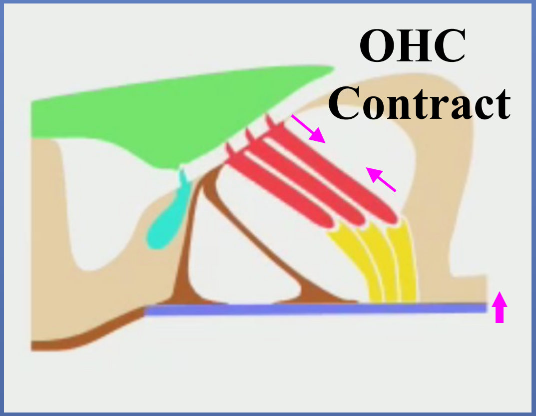
High Frequency Stimulus

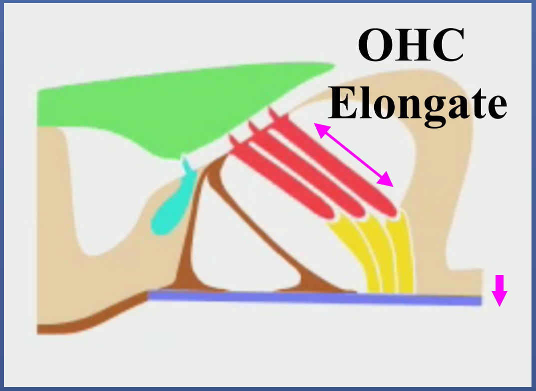




Vibration amplitude at the IHC is AMPLIFIED

Infrasound Stimulus

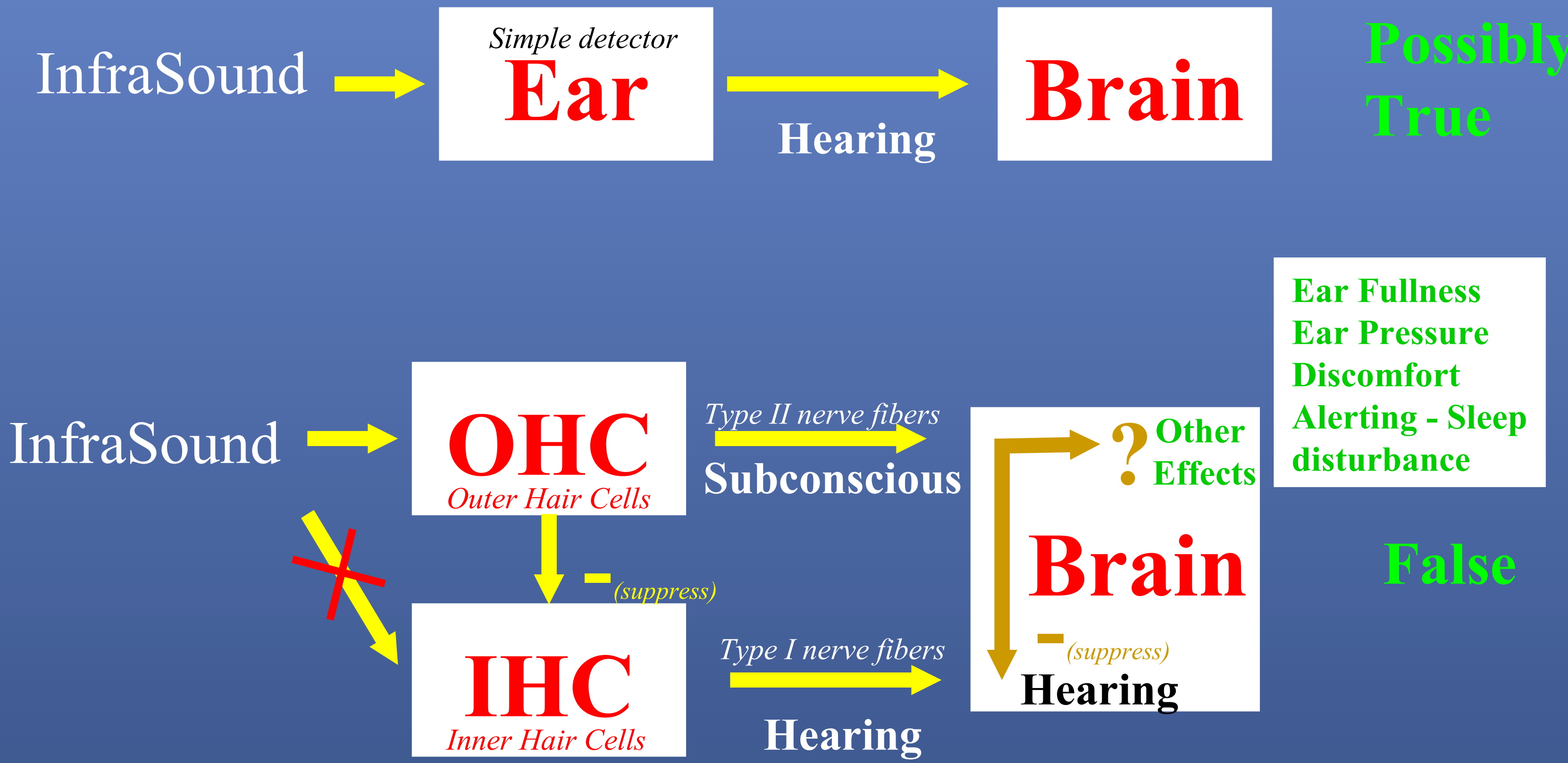




Vibration amplitude at the IHC is REDUCED

OHC are detecting low-level infrasound and actively canceling it for the IHC

If you can't hear it, it doesn't affect you?

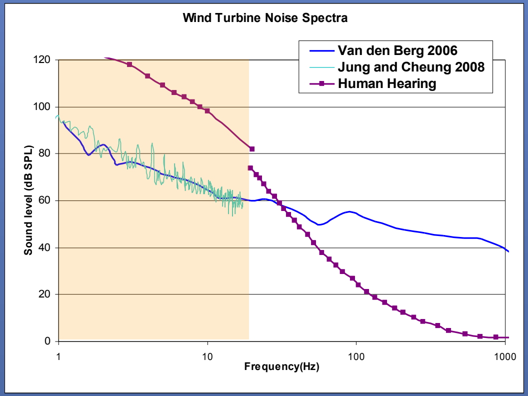


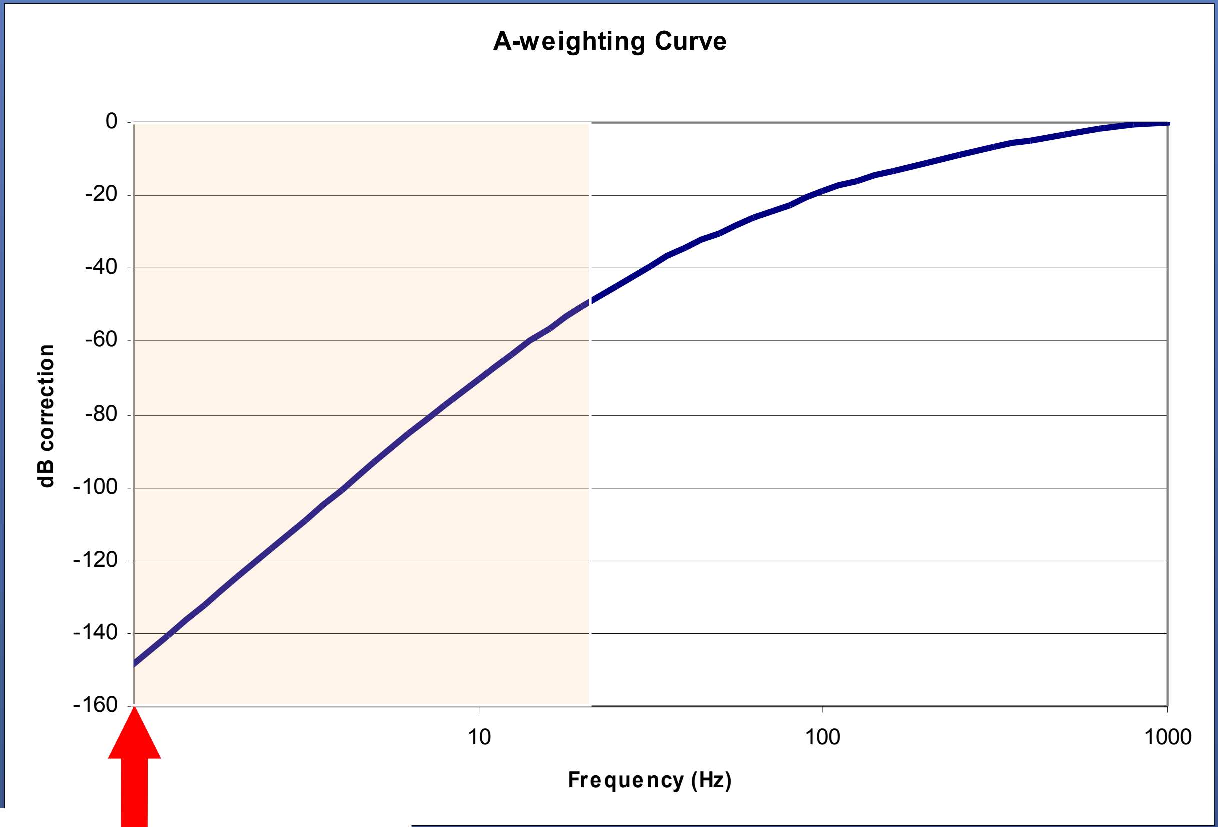
Physiologic pathway exists for infrasound to affect the brain at levels that are not heard.

The idea that infrasound effects can be dismissed because they are inaudible is INCORRECT.

A-weighting sound measurements

Corrects a sound measurement to represent what is HEARD, based on the human audibility (40 phon) curve.



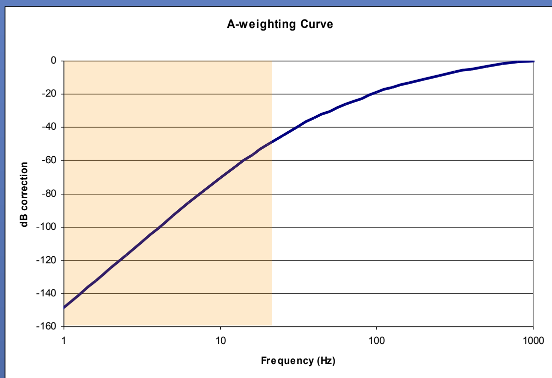


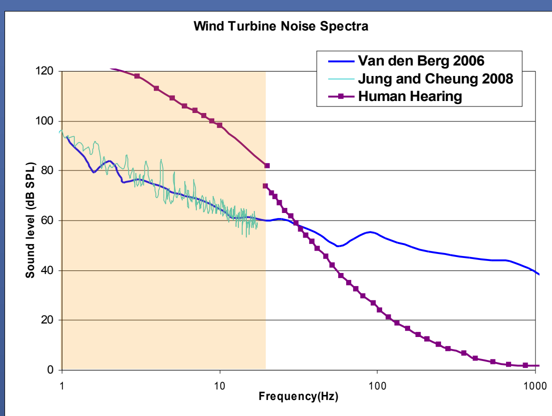
1 Hz

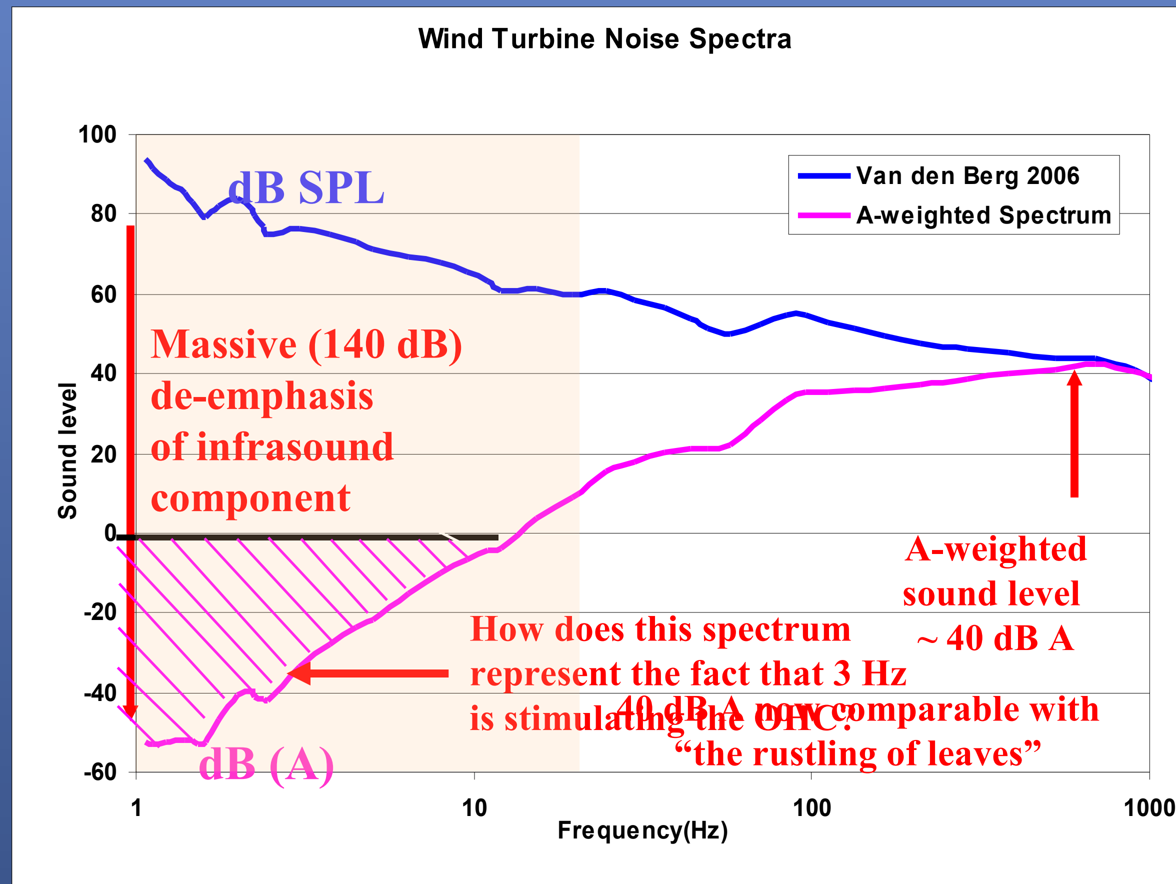
-148 dB Correction

Equivalent to dividing by 25 million

Effect of A-weighting wind turbine noise

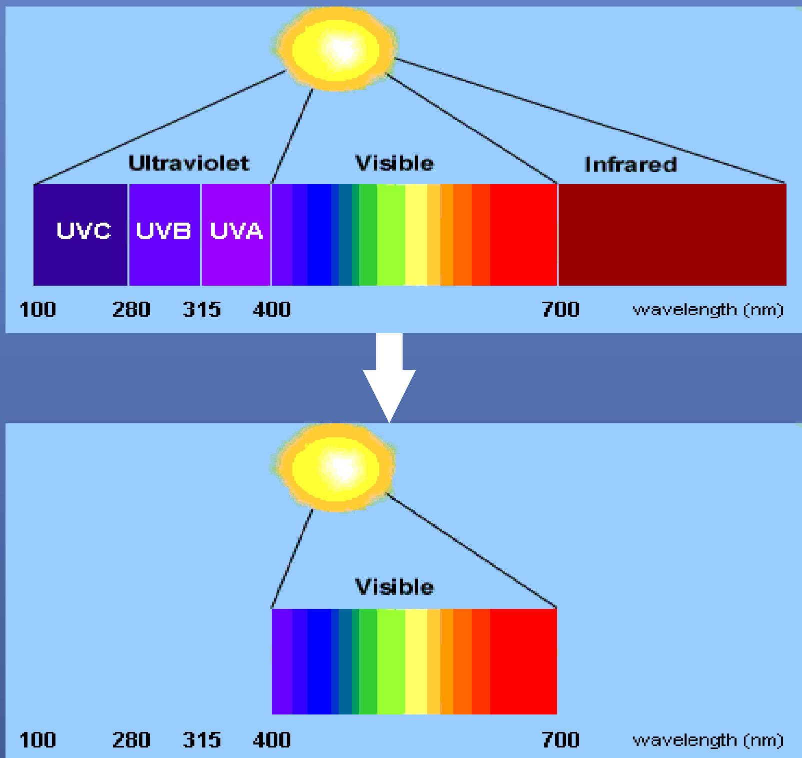






A-weighting may represent what you hear – but hearing does not give a reliable indication of whether the infrasound is affecting your ears

"A weighting" principle applied to UV light



Is equivalent to adjusting sunlight spectrum for what is VISIBLE

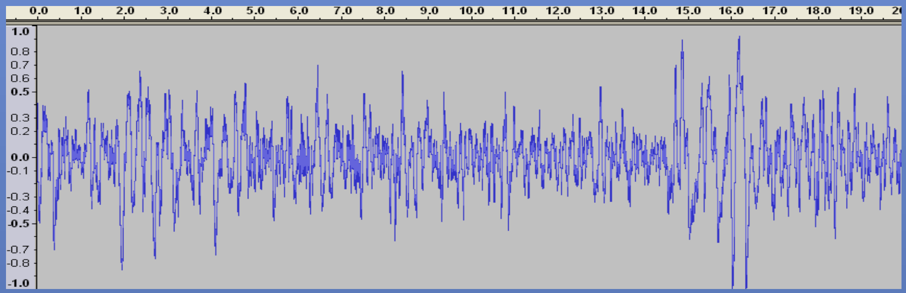
And then saying:
"There is nothing here that can harm you.
You don't need sunscreen.
You don't need sunglasses.
Go spend all day laying out in the sun. ☺ "

This approach isn't rational when applied to light,
So why do we accept similar logic applied to sound ???

Measuring visible light (e.g. photographs) tells you NOTHING about UV content.
Similarly, A-weighted measurements tell you NOTHING about infrasound content.

A-weighting

- A-weighted spectra totally misrepresent the effects of wind turbine noise (that includes infrasound components) on the ear.
- A-weighted level readings (e.g. 42 dB A) are totally meaningless for assessing whether turbine noise is affecting the ear.

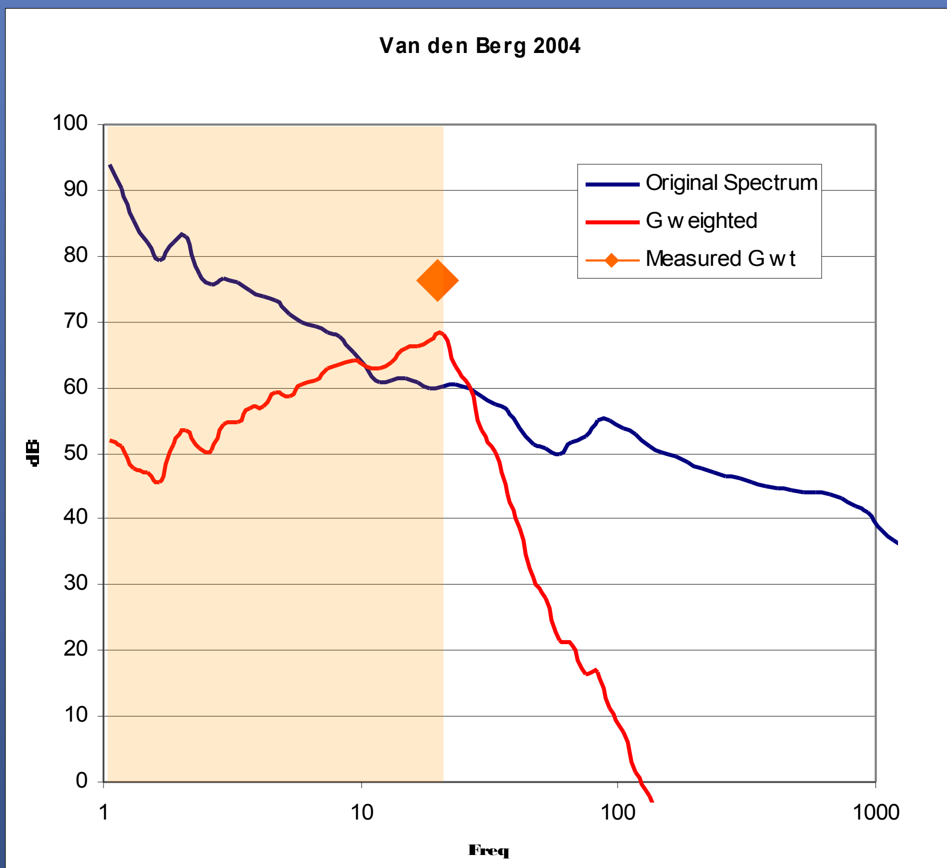


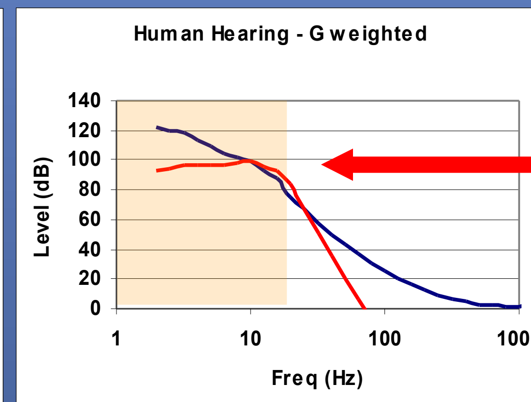
Documenting Wind Turbine Sound

- Most video cameras DO NOT record the infrasound component of wind turbine noise.
- Speaker systems in TVs and computers cannot play back the infrasound component.
- Even if they did – you can't hear it!
- Video recordings of wind turbines give NO INDICATION of the infrasound level being produced.
- Infrasound can only be measured with specialized instrumentation capable of detecting sounds down to ~ 1 Hz.

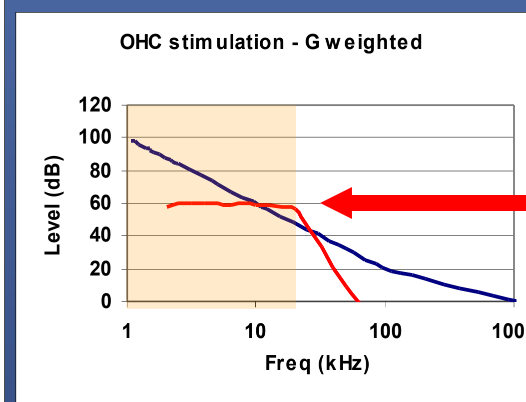
G-weighting

Weights infrasound components (excluding higher frequencies) according to human sensitivity curve





Hearing
95 dB G



OHC Stim
60 dB G

G-weighted Turbine Measurements

Table I. Summary of infrasound measurements on wind turbines

Wind Turbine	Rated power	Distance	Infrasound level	Conditions	Ref.
Monopteros 50	640kW	200m	84 dB (G)	11 m/s	[10]
Enercon E-40	500kW	200m	56 – 64 dB (G)	8 m/s	[10, 11]
Vestas V66	1650kW	100m	70 dB (G)	(723 kW)	[12, 13]
(Anonymous)	2000kW	200m	59 dB (G)	6 m/s	[13]
-	-	200m	65 dB (G)	12 m/s	-
Bonus	450kW	80m	65 dB (G)	9 m/s (4 turb.)	[15]
-	-	100m	71 dB (G)	8 m/s (1 turb.)	-
-	-	200m	63 dB (G)	10 m/s (1 turb.)	-
-	-	100 – 200m	70 dB (G)	9 m/s (4 turb.)	-
-	-	(n.a.)	67 dB (G)	Background, 9 m/s	-
MOD-1	2000kW	105m	107 dB (G)		[8]
-	-	1000m	73 - 75 dB (G)		-
WTS-4	4200kW	150m	92 dB (G)		-
-	-	250m	83 - 85 dB (G)		-
MOD-5B	3200kW	68m	71 dB (G)		-
USWP-50	50kW	500m	67 - 79 dB (G)	(14 turbines)	-
WTS-3	3000kW	750m	68 dB (G)		-
-	-	2100m	60 dB (G)		-

Hear:
95 dB G
OHC Stimulation:
60 dB G

For MOST of these conditions, the ear WILL BE STIMULATED by the turbine noise.

Jakobsen, J., 2005 Infrasound emission from wind turbines
Journal of Low Frequency Noise Vibration and Active Control 24, 145-155

Other ways that infrasound could affect the ear

- **Stimulation of vestibular hair cells** (saccule, utricle).
  - Vestibular hair cells are "tuned" to infrasonic frequencies.
  - No-one has ever measured sensitivity to acoustic infrasound.

  Symptoms : Unsteadiness, queasiness

- **Disturbance of inner ear fluids** (e.g. endolymph volume).
  - Low frequency sound at non-damaging levels induces endolymphatic hydrops (a swelling of one of the fluid spaces).
  - Infrasound does affect endolymph volume – is the basis of a treatment for hydrops in which infrasound is applied by the Meniett
  - No one has ever measured what level of infrasound causes hydrops.

  Symptoms : Ear fullness, unsteadiness, tinnitus

Infrasound - Ranked by Sensitivity

Ranked Sensitivity	Structures	Long-term Exposure Effect	Sensation
1	Outer Hair Cells	"overworked, tired, irritated" OHC, Type II fiber stimulation	Ear pressure or fullness, discomfort, arousal from sleep
2?	Inner Ear Fluid Homeostasis	Volume disturbance - Endolymphatic hydrops	Ear fullness, tinnitus, unsteadiness
3?	Saccular Hair cells	Stimulation	Unsteadiness
4?	Other, non-ear receptors	Stimulation	Stress, Anxiety
5	Inner Hair Cells / Hearing	*None*	

You cannot hear what causes the symptoms !

Sensitivity and sensations remain to be quantified.

"Wind Turbine Syndrome"

WE NEED MORE RESEARCH TO DEFINE THE SENSITIVITY OF THESE PROCESSES

Sounds you cannot hear…..

1)	cannot affect you.	**False**
2)	can affect you.	**True**
3)	can disturb you.	**True**
4)	can harm you.	**True** *in some cases*
5)	can hurt you.	**? False** *(no blood or pain)*
6)	can cause disease.	**True** ***Although for the ear: probably False.*** Auditory and balance disorders, effects of sleep deprivation are serious (hypertension, diabetes, mortality).

Conclusion and Recommendations

For years, people have been told that infrasound you cannot hear cannot affect you. This is completely **WRONG**.

As the inner ear **DOES** respond to infrasound at levels that are not heard, people living near wind turbines are being put at risk by infrasound effects on the body that no-one presently understands.

Until a scientific understanding of this issue is established we should not be dismissing these effects, but need to be erring on the side of caution.

For industrial turbines a cautious approach could require :

1) Setbacks of at least 2 kilometers (1 ¼ miles).

2) In-home monitoring of **both** A-weighted (audible) **and** G-weighted (infrasound) noise levels 24 hrs/day for all dwellings within 2 miles.

3) Health monitoring studies for those living within 2 miles (with consent).

And Finally……

We need to stop ignoring the infrasound component of wind turbine noise and find out why it bothers people !!

Wind turbine noise is NOT comparable to the rustling of leaves.