Main Messages Last Class on Chemicals

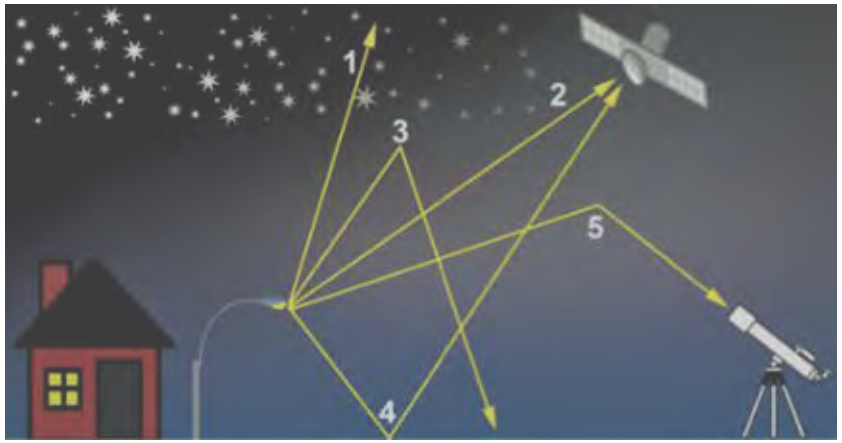
- Many tens of thousands of chemicals- everywhere, mixtures
- Chemical exposure through ingestion, breathing, contact and get into bloodstream
- Chemicals alter sensory system function and hormone system function
- Chemicals accumulate in us and wildlife and impacts are magnified

Some resources (in response to questions)

- A physiology tutorial: https://www.biologyonline.com/tutorials/the-human-physiology
- Chemical free lawn: https://www.sierraclub.org/maryland/pesticides-free-alternatives
- Pre-emergent: corn gluten meal…
- Others: vinegar



LLI Class 3: Artificial Light at Night (ALAN) and Noise Pollution





https://www.youtube.com/watch?v=InUPnPR1fTI

Today’s goals

- **Learn about circadian and circannual rhythms**
- **Impacts of artificial light**
- **Sound for communication**
- **Auditory System- focus on humans**
- **Impacts of human-produced noise**
- **What can we do?**

ALAN (Artificial Light at Night)

- **Affects spring and fall migration in birds, monarch butterflies, fish, marine mammals, sea turtles**
- **Light pollution, turbidity in aquatic environments: impact on fish vision, development, stress responses**
- **ALAN changes flowering and pollination**
- **ALAN reduces learning in birds, rodents, people**
- **ALAN linked to CV disease, decreased immune function**
- **Inadequate daytime light in humans: depression, sleep disturbances**

Rhythms and Sleep







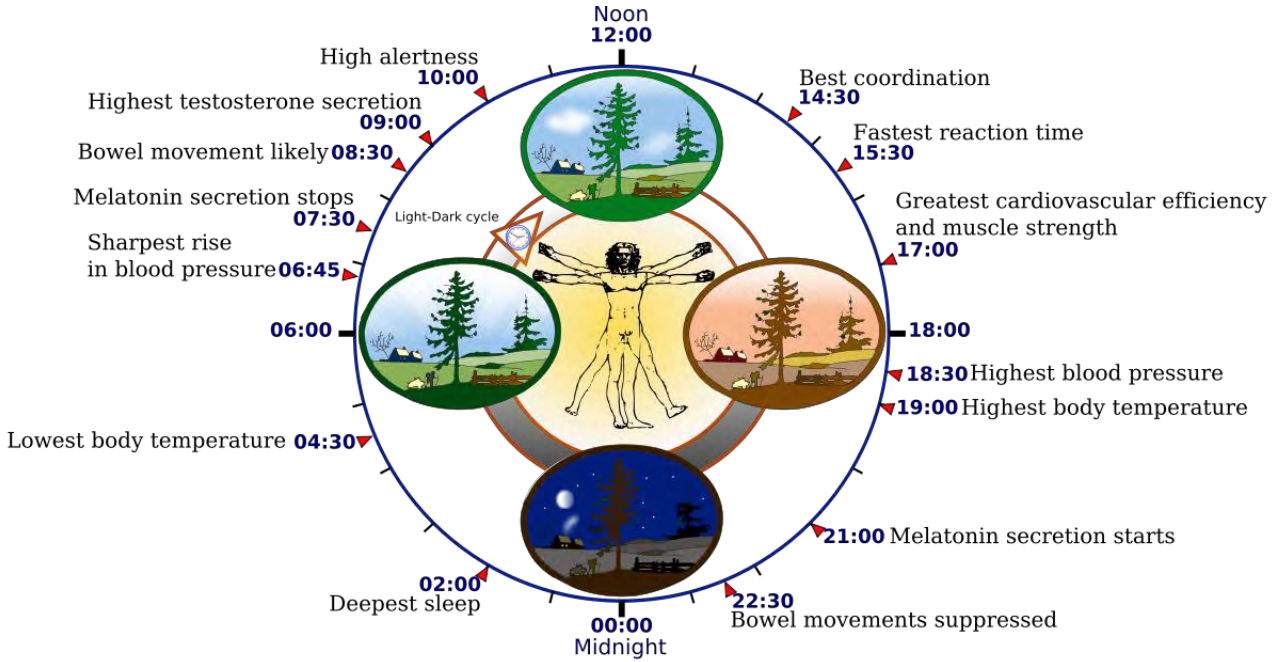


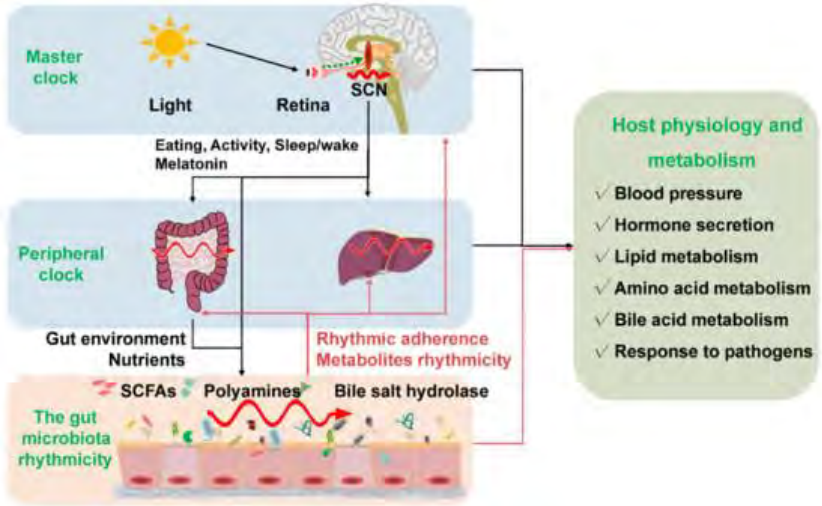




Circadian Rhythms

- Activity- locomotory, foraging
- Feeding, digestion
- Sleeping, arousal
- Skin
- Brain repair during sleep- CSF production, Aß
- Hormones: glucocorticoids
- Body temperature





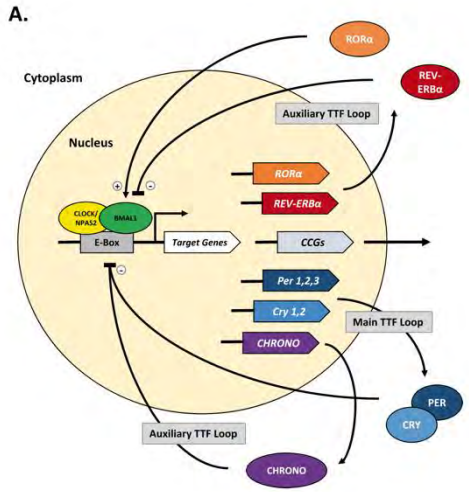
Dickmeis and Weger, 2013.Molec Cell Endocrin. DOI: 10.1016/j.mce.2013.05.012

Central pacemaker and peripheral pacemakers

- Suprachiasmatic nucleus of hypothalamus (SCN)
- Skin- daytime protection, nighttime repair (Dong et al, 2019)
- lung
- Liver- enzyme activity
- Ovaries
- Retina (melatonin fluctuations)
- Coordination through neural, hormonal, synchronized by stimuli (zeitgebers): light, temperature, food, social

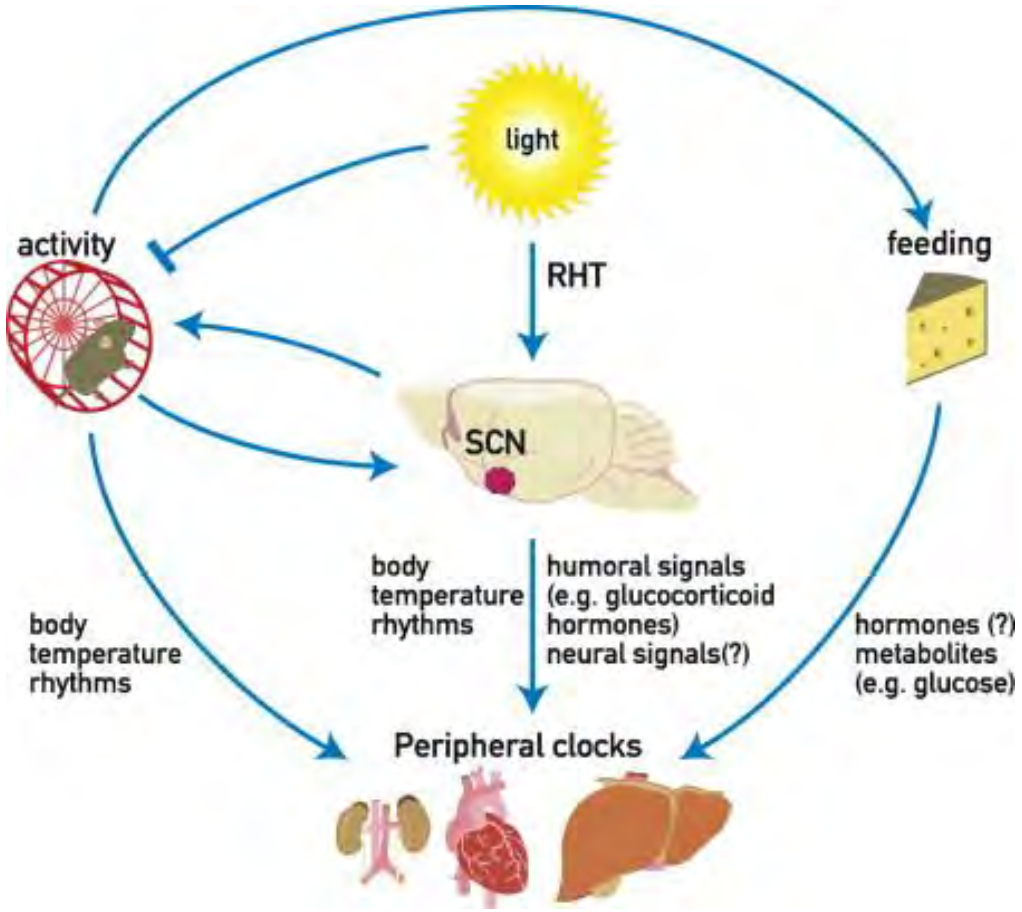
- Important to synchronize body functions, also time-memory stamp, predictions, esp. seasonality





Becker-Krail and McClung 2016 F1000Research5:59
https://doi.org/10.12688/f1000research.7608.1

Central Pacemaker- Suprachiasmatic Nucleus



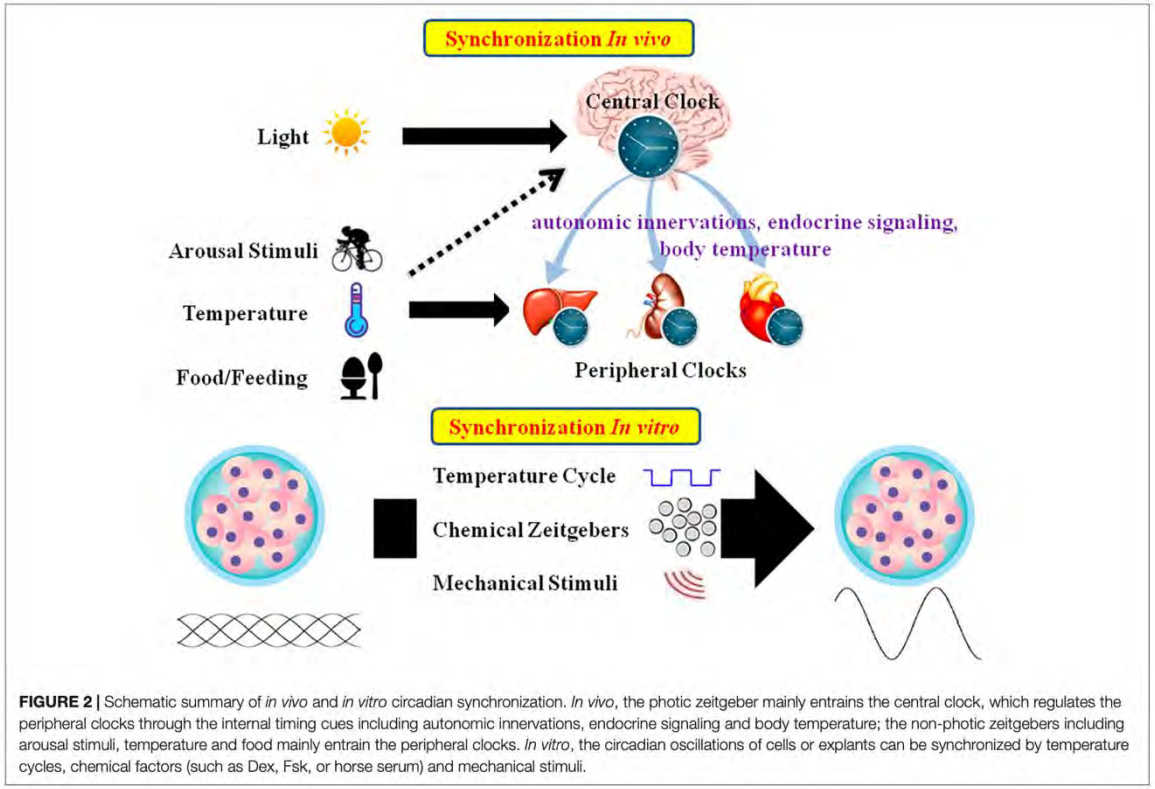
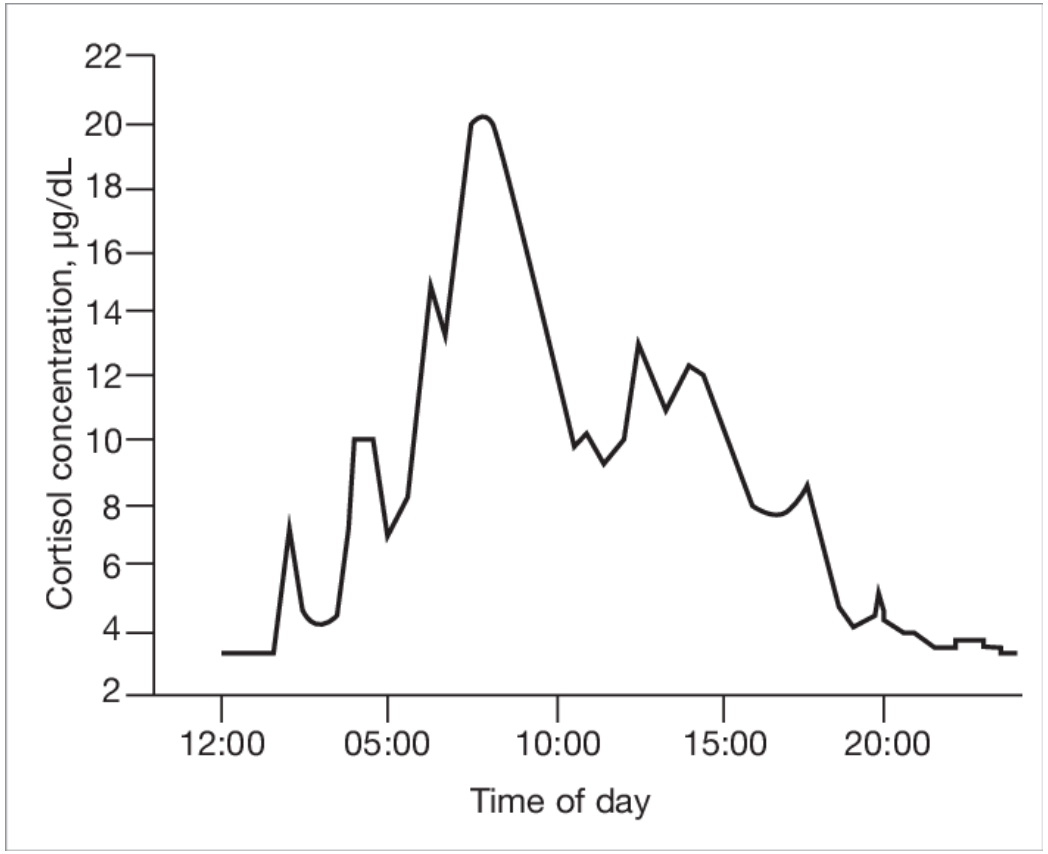
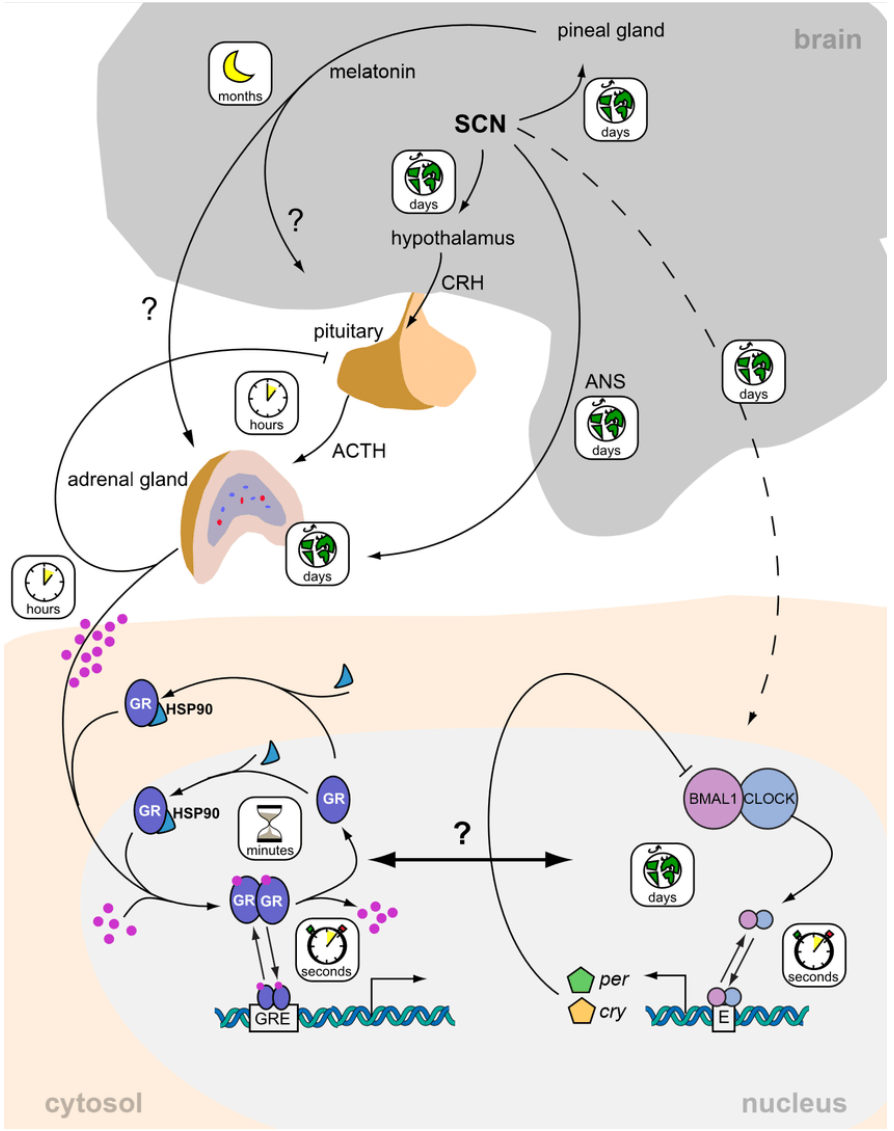


FIGURE 2 | Schematic summary of *in vivo* and *in vitro* circadian synchronization. *In vivo*, the photic zeitgeber mainly entrains the central clock, which regulates the peripheral clocks through the internal timing cues including autonomic innervations, endocrine signaling and body temperature; the non-photic zeitgebers including arousal stimuli, temperature and food mainly entrain the peripheral clocks. *In vitro*, the circadian oscillations of cells or explants can be synchronized by temperature cycles, chemical factors (such as Dex, Fsk, or horse serum) and mechanical stimuli.

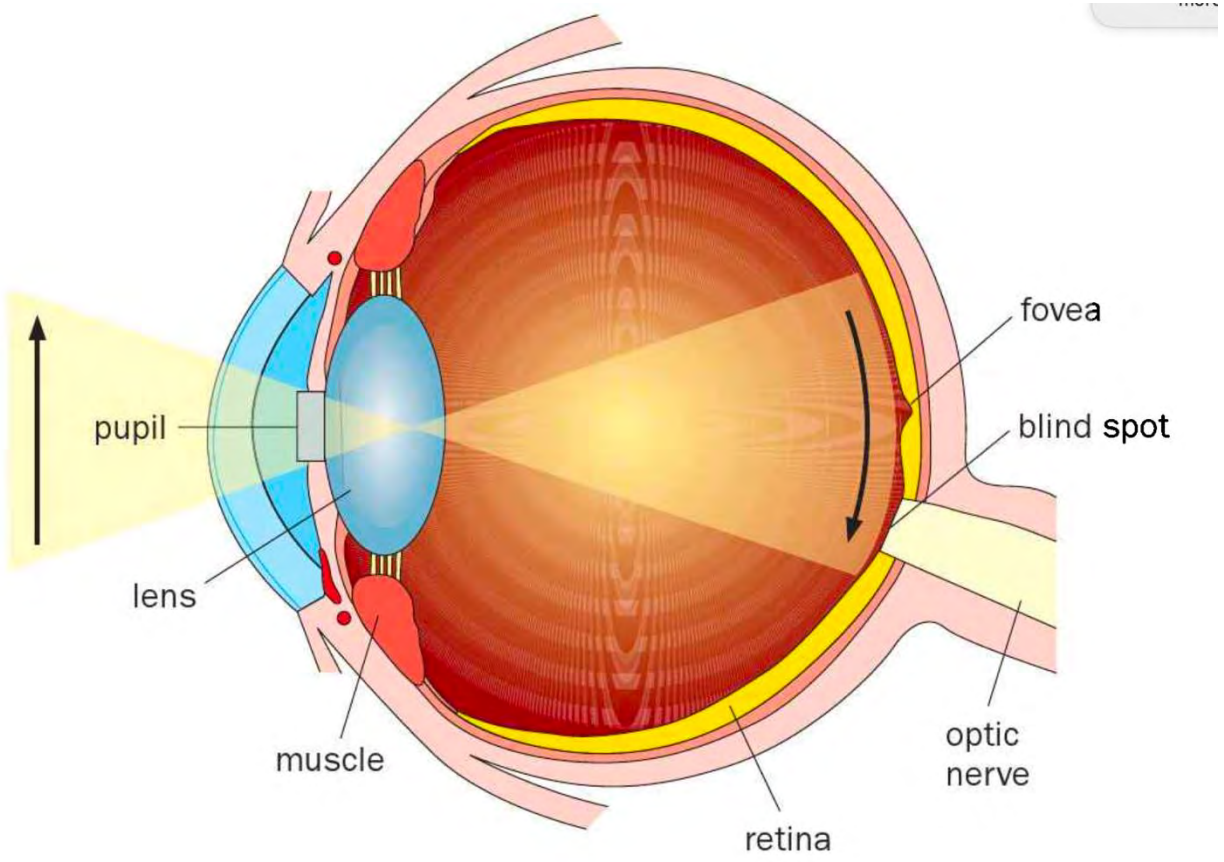
HPA (Hypothalamo-pituitary-adrenal axis) axis rhythms

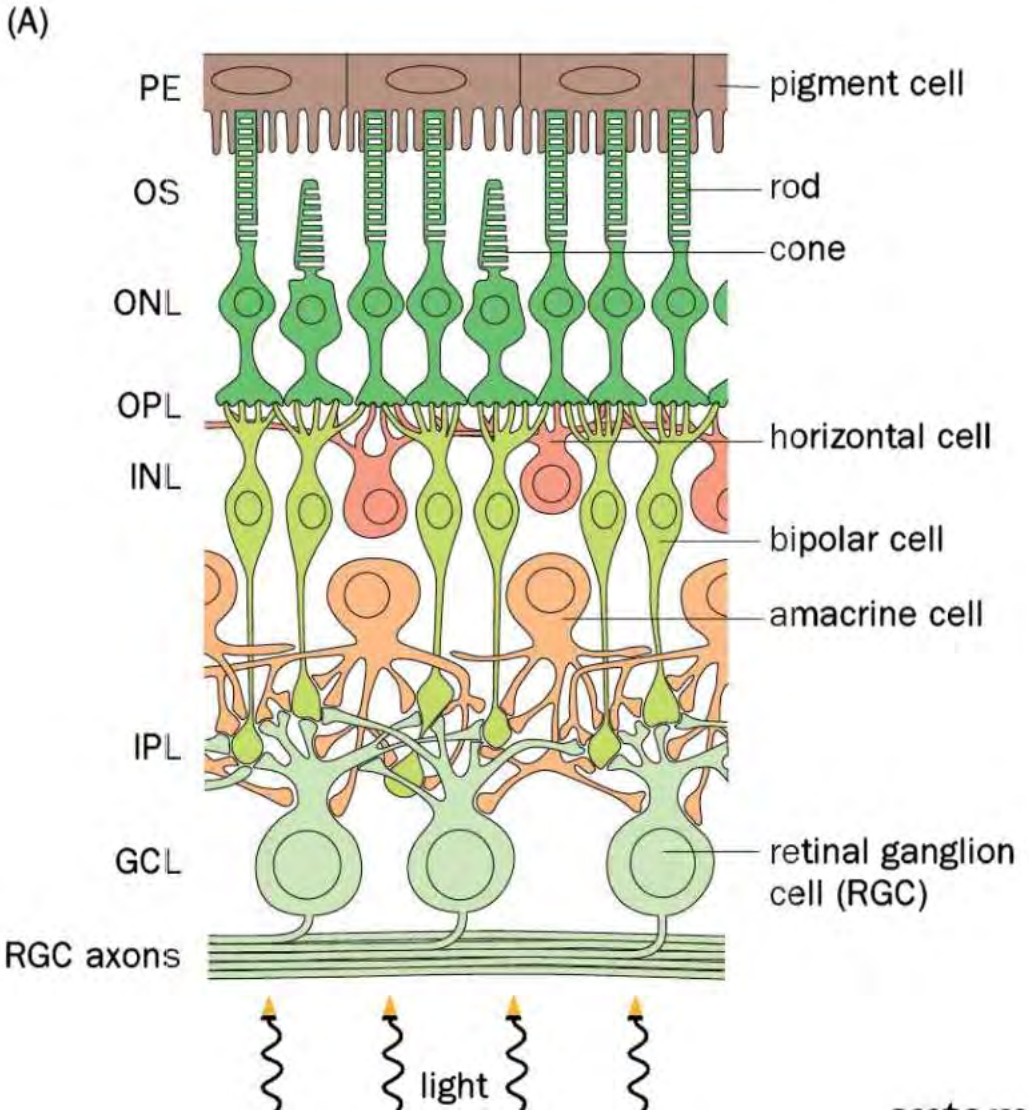




Dickmeis and Weger, 2013.Molec Cell Endocrin. DOI: 10.1016/j.mce.2013.05.012

Synchronzed by light input





LEDs- more harm than good?

- Cold-white LED emit more blue light- recommend amber
- Shape of lamp
- Off or reduced intensity periods with low traffic

Table 1. Artificial light's ecological and functional impacts.

Ecological Impacts	Functional Impacts
Mortality	Species attracted to light may be killed
Migration	Artificial light disturbs natural movement patterns, migration and orientation
Population size	Reduced or increased foraging because of presence of light
Indirect competition	Light can benefit certain species at the expense of others
Communication	Light can disturb species communication
Health and circadian rhythm	Light can influence various physiological processes that can impact health and circadian rhythm

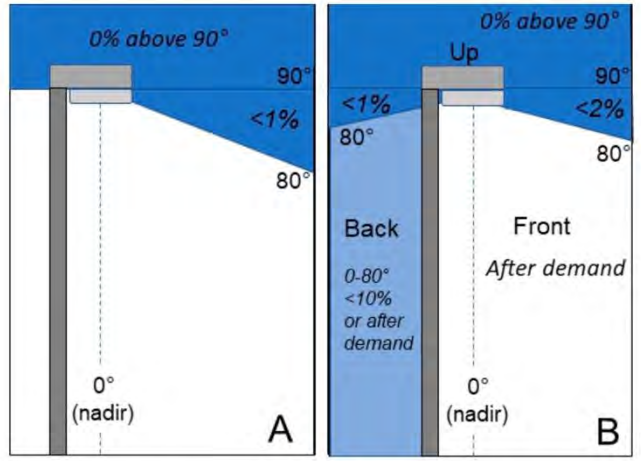
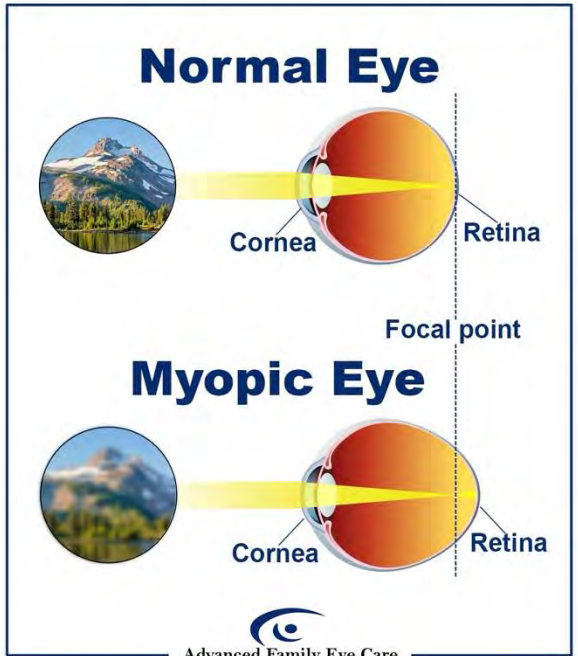


Figure 1. Examples of shielding of luminaries to reduce ecological light pollution in protected areas: (**A**) sharp cut-off, SCO (**B**) BUG system. Non-correct scales and angles.

Zhang et al 2022 Science of the Total Environment: Ubiquitous light-emitting diodes: Potential threats to retinal circadian rhythms and refractive development

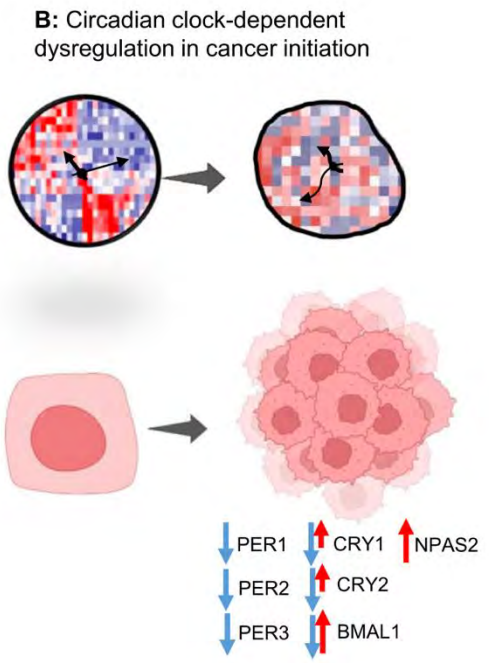
Myopia has increased substantially

- US From 25% in 1970 to 40% in 2000- theories: not enough outdoor light in day, too much blue light at night
- Genetics?, better eyecare?
- Indoor environments- dimmer days and brighter nights
- Lifestyle- blue light, LEDs, electronics



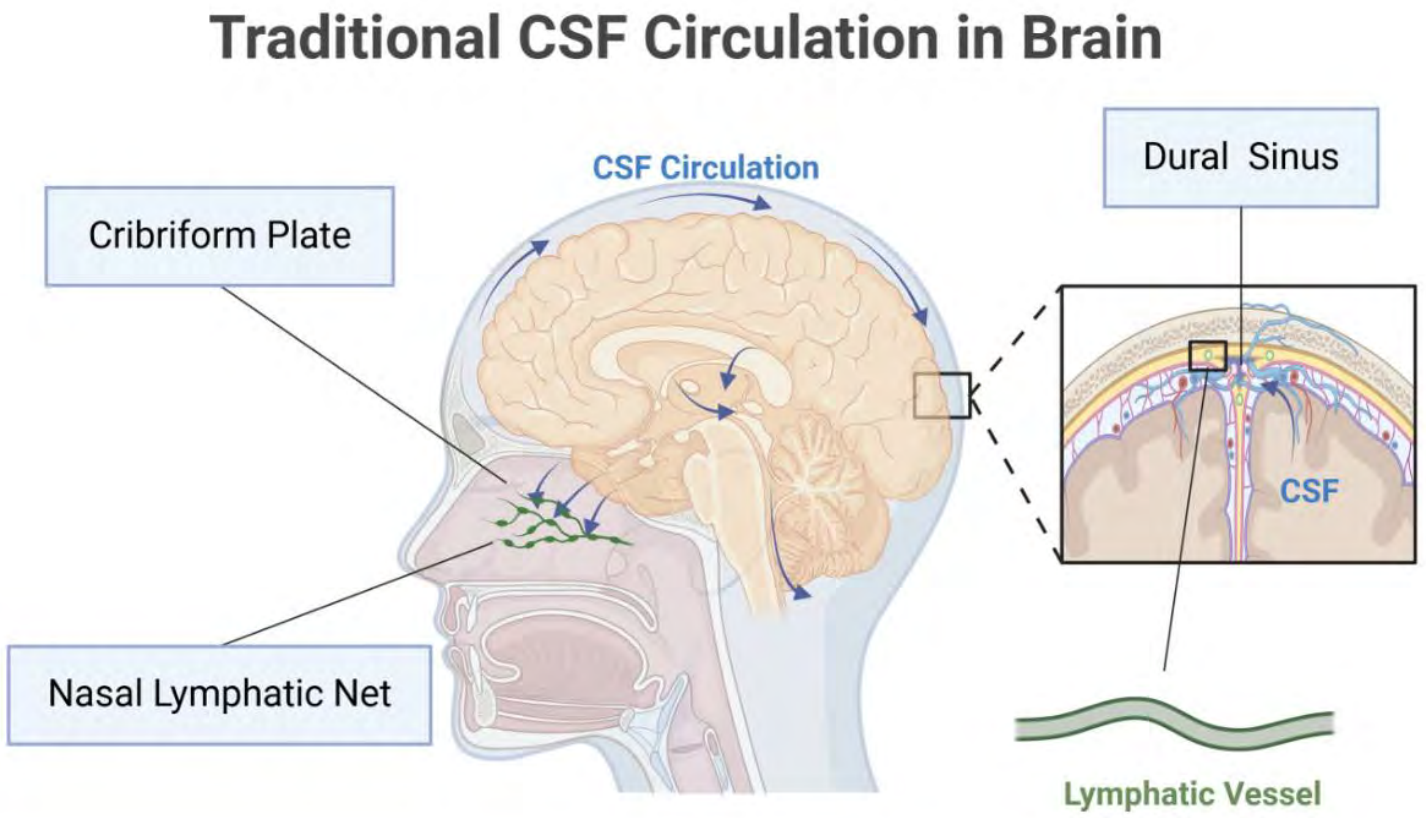
Rhythm dysfunction and disease/dysfunction

- Parkinson's disease: doubled in the past 25 years (WHO)
- Medical complaints of sleep problems have doubled in middle-aged Europeans since 1960's (Rowan et al, 2010. J. Sleep Research)
- Inadequate sleep linked with CV disease, stroke, chronic depression, anxiety
- Circadian disruption linked with cancer



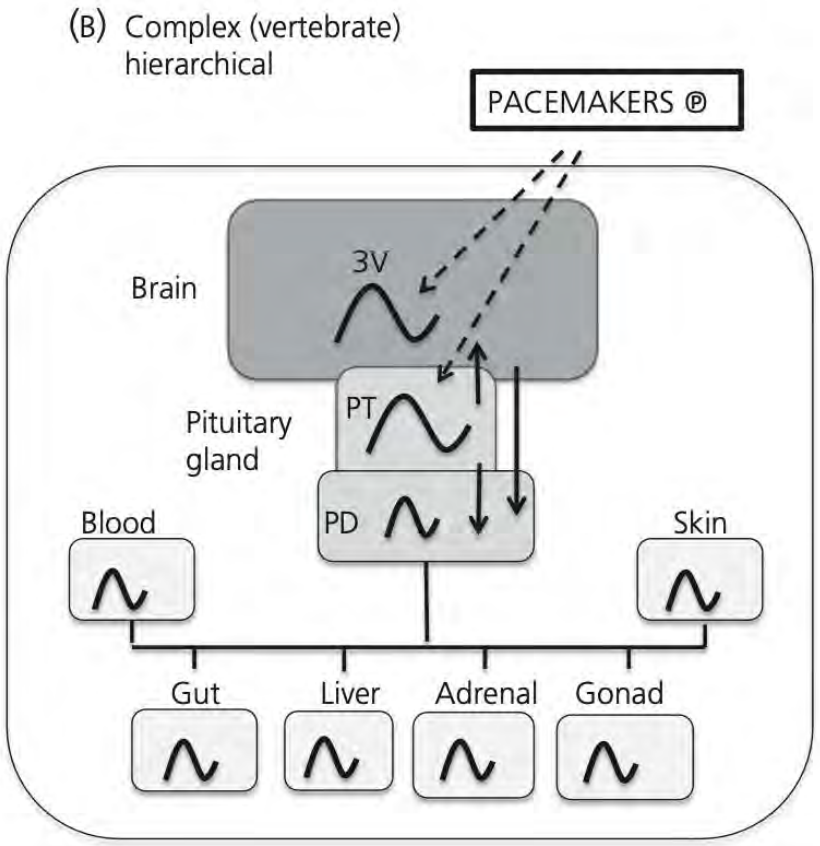
Fekry and Eckel-Mahan, 2022 J. Biochem *https://doi.org/10.1093/jb/mvac017*

Brain repair during sleep? Glymphatic system and Cerebrospinal fluid



Circannual Rhythms

- Evolved for switching from growth and dormancy
- Seasonal physiology and behavior



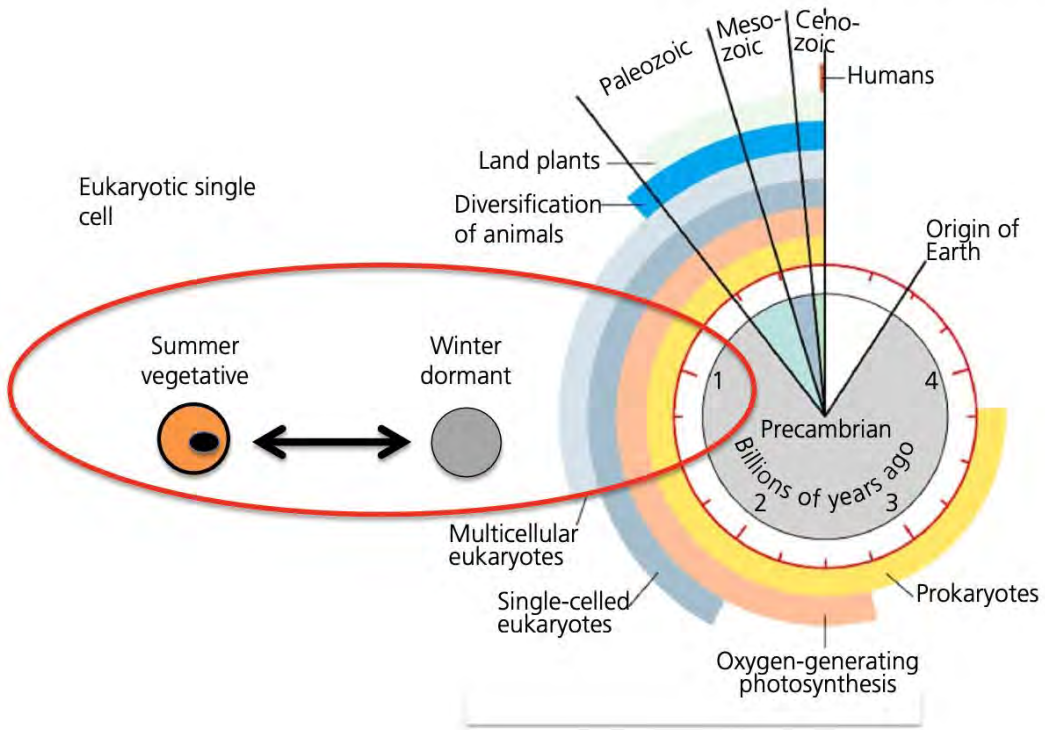
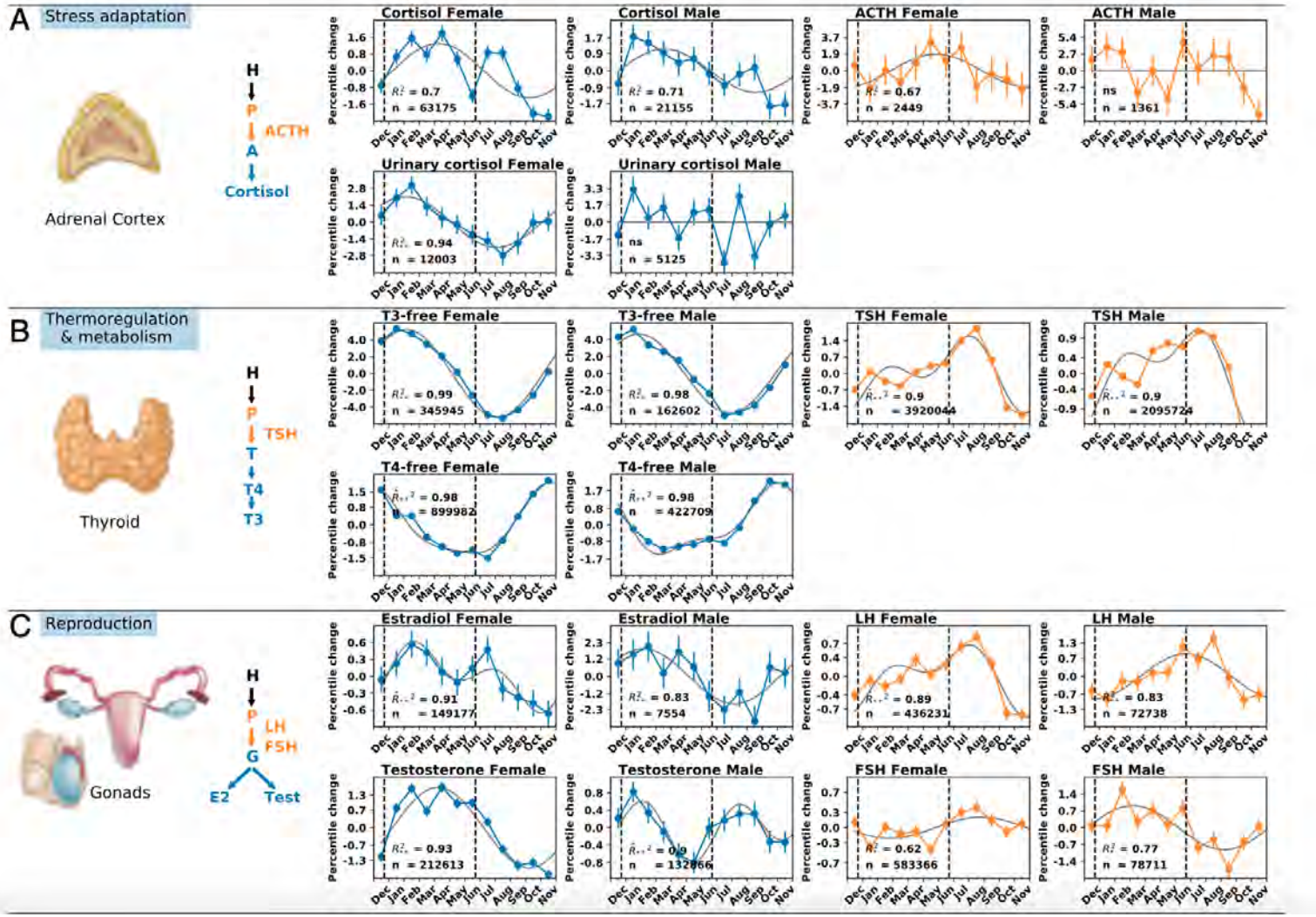


FIGURE 2 Ancient origins of circannual clocks. The prediction is that circannual timing first evolved in free-living eukaryote cells as an adaptation to survive the winter. These organisms alternate between growth and dormancy across their life history, and circannual control of a specific life-history phase is adaptive, irrespective of the short lifespan of the individual. This requires that circannual clocks are genetically regulated, cell autonomous and transgenerational

Lincoln, 2018. J. Neuroendo. DOI: 10.1111/jne.12694

Humans might have circannual patterns too



Tendler et al, 2021 PNAS 2021 Vol. 118 No. 7 e2003926118

Take-aways and actions you can take

- Light at the wrong time interferes with circadian rhythms and sleep
- Rhythms important for many behaviors: feeding, movement/activity
- Rhythms important for hormones, brain activity/repair

- Home exterior/interior lighting- intensity, wavelength, time
- Local/neighborhood exterior lighting, streetlighting

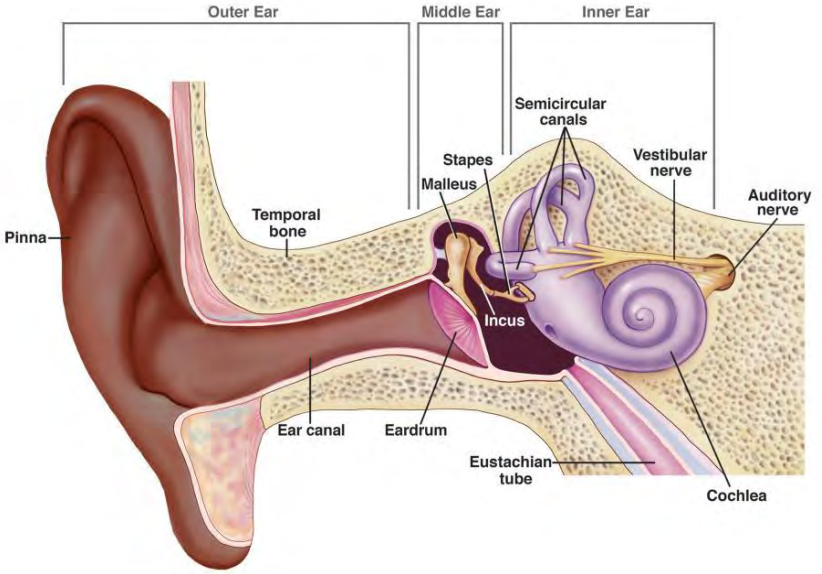


Sound, Auditory Neurobiology











https://www.youtube.com/watch?v=3N-enduqQCg

Animals use sound for:

- Avoidance of predators- eg. Deer (https://www.youtube.com/watch?v=wjMPA4bKAnU)

Play around 4min

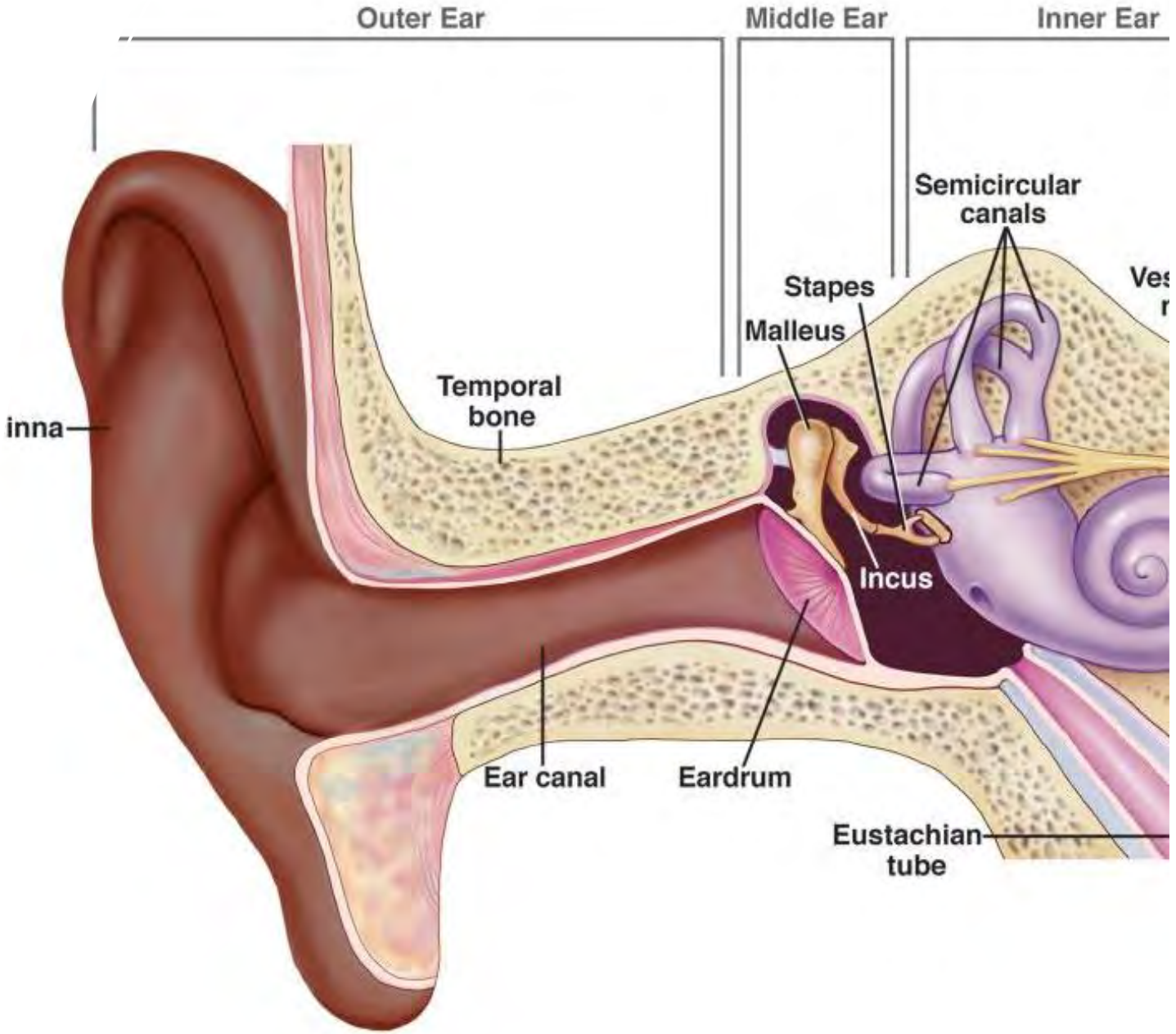
- Navigation- bat echolocation (https://www.youtube.com/watch?v=kp5jyZtoTIg&t=39s)

- Detection of prey- eg. Barn owls (around 4 min) (https://www.nathab.com/blog/video-owls-have-heads-designed-for-hearing/)

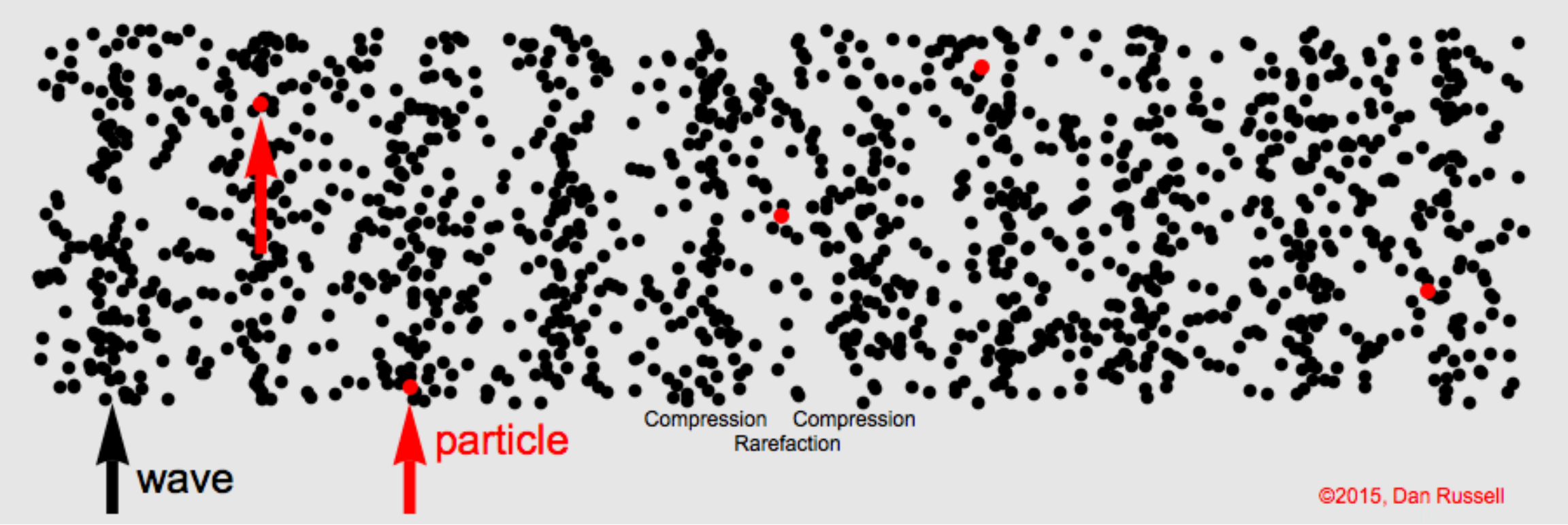
- Intraspecies communication- dolphins (https://www.youtube.com/watch?v=gbYjM1KlFrE)

Sensing Sound- very general principles

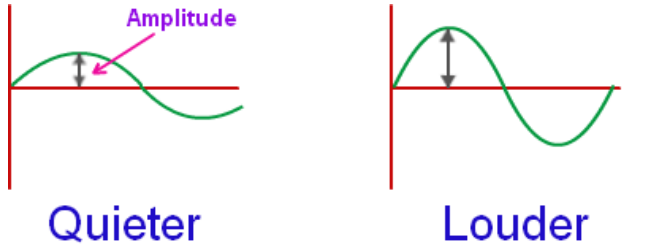
- Frequency range
- Detection
- Amplitude/Intensity
- Spatial localization

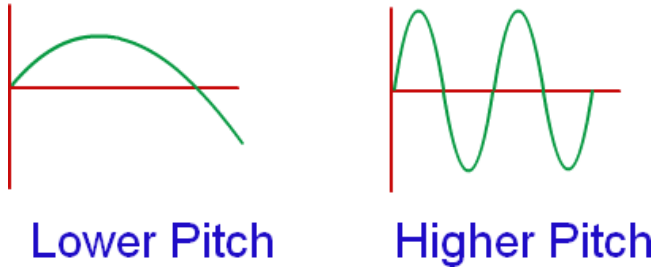


Sound is a longitudinal wave of high/low pressure



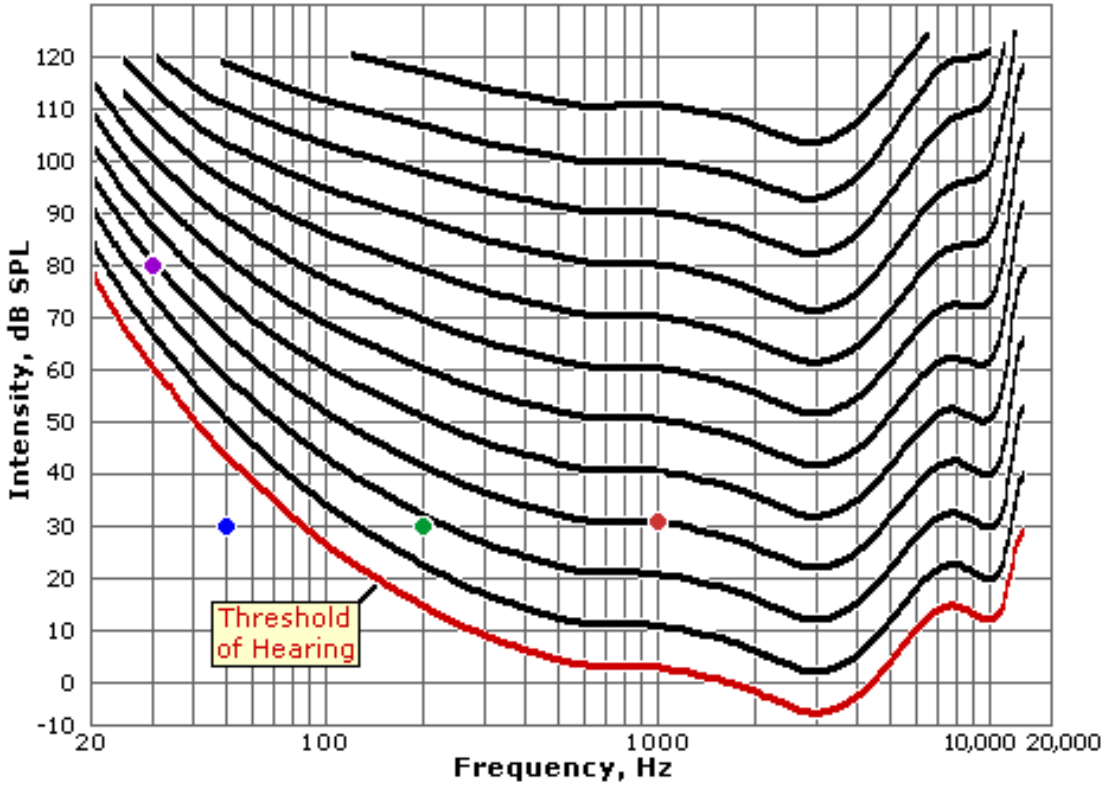
Amplitude, intensity = loudness
Frequency = pitch





Frequency range….

Humans 20-20,000 HZ (opt. 1K-5K)



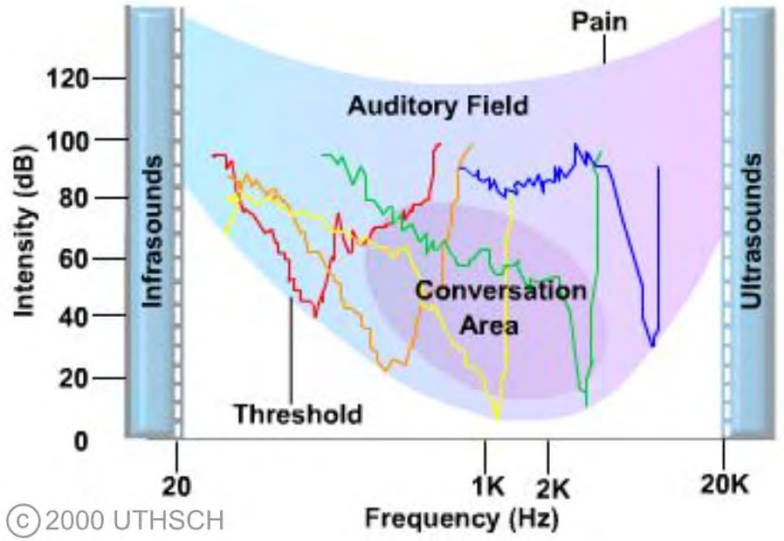
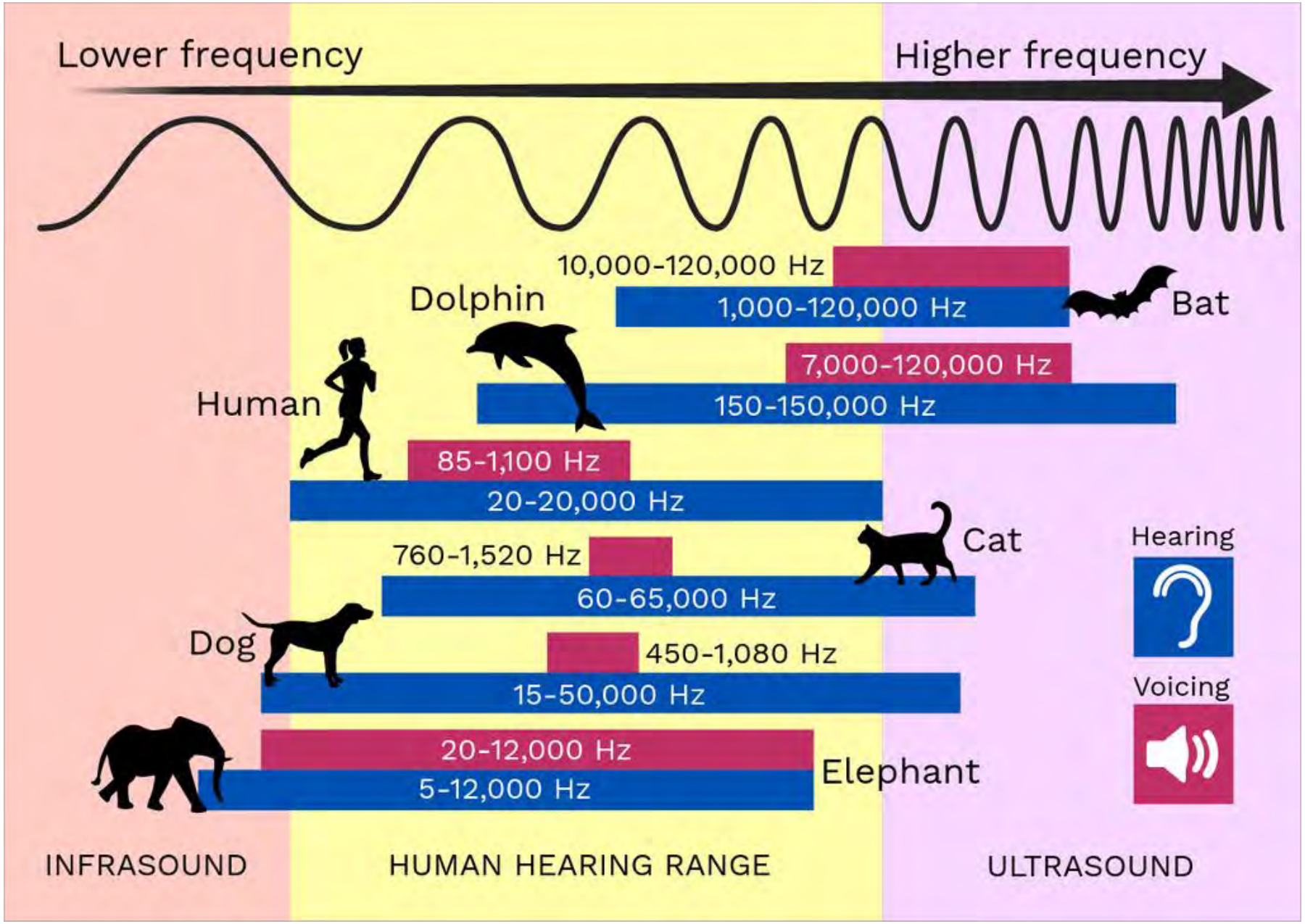


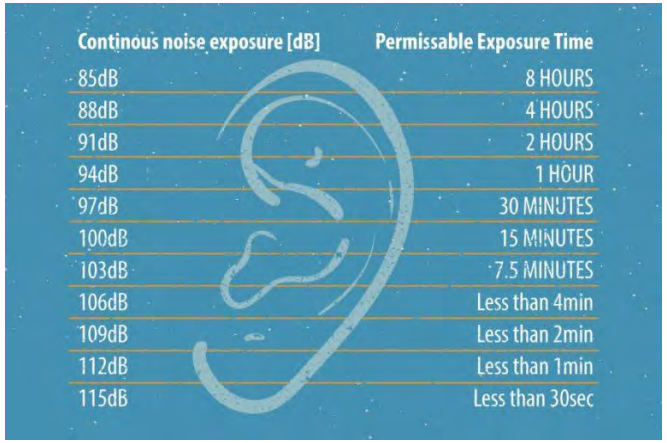
Figure 12.8
Audiometric curve for a normal hearing subject and some neural tuning curves.

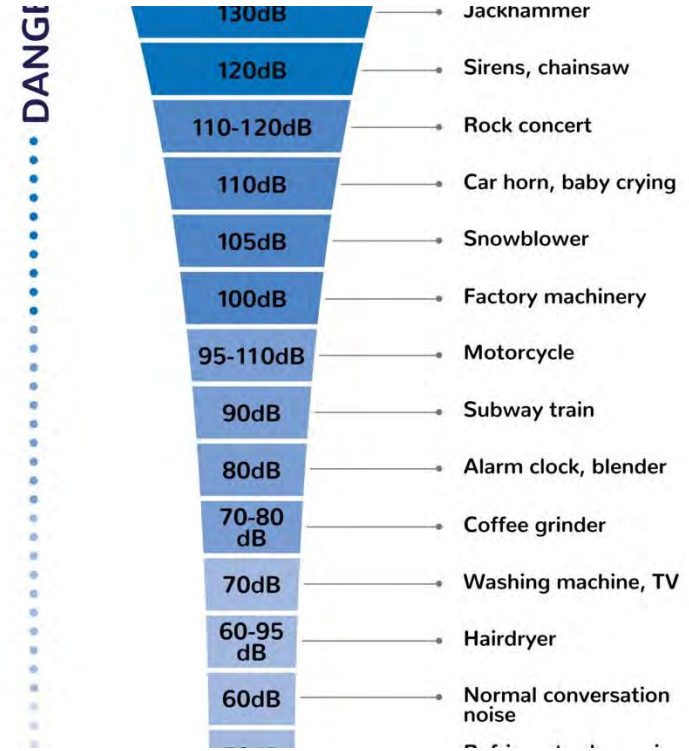
Just a few different animals- Frequency ranges

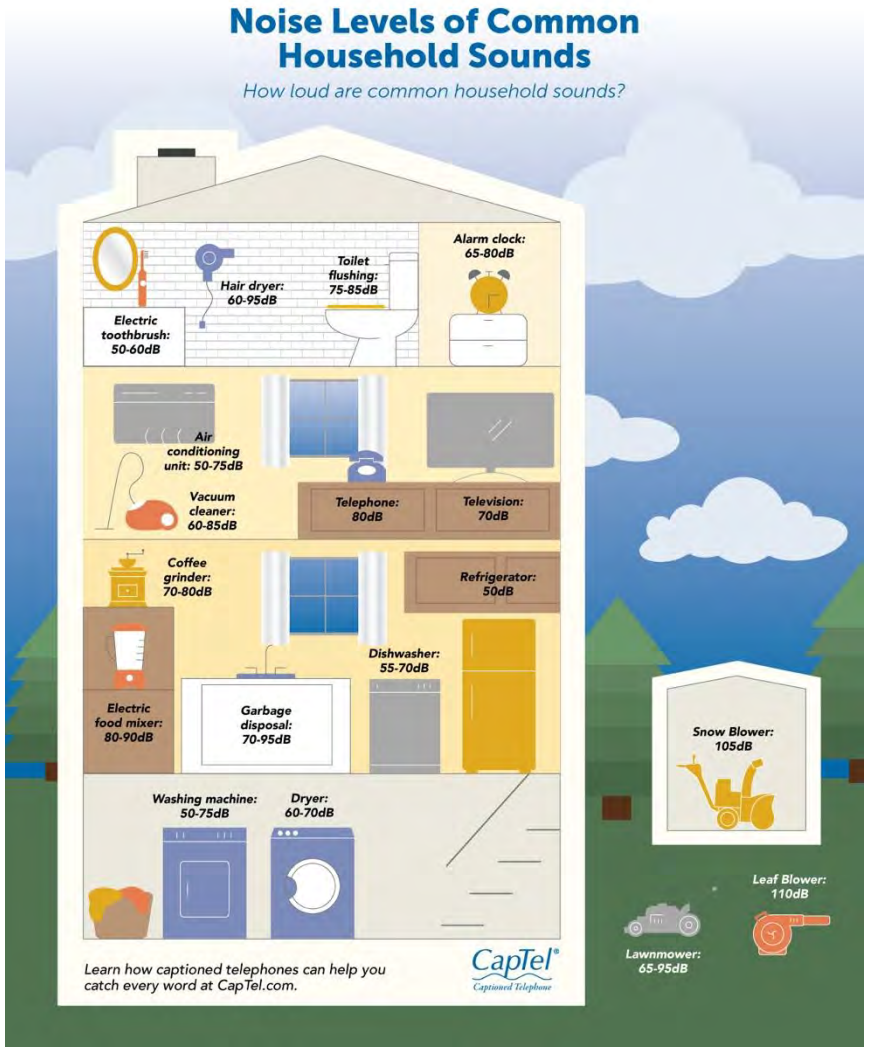


Species	Approximate Range (Hz)
human	64-23,000
dog	67-45,000
cat	45-64,000
cow	23-35,000
horse	55-33,500
sheep	100-30,000
rabbit	360-42,000
rat	200-76,000
mouse	1,000-91,000
gerbil	100-60,000
guinea pig	54-50,000
hedgehog	250-45,000
raccoon	100-40,000
ferret	16-44,000
opossum	500-64,000
chinchilla	90-22,800
bat	2,000-110,000
beluga whale	1,000-123,000
elephant	16-12,000
porpoise	75-150,000
goldfish	20-3,000
catfish	50-4,000
tuna	50-1,100
bullfrog	100-3,000
tree frog	50-4,000
canary	250-8,000
parakeet	200-8,500
cockatiel	250-8,000
owl	200-12,000
chicken	125-2,000

Very loud sounds are damaging

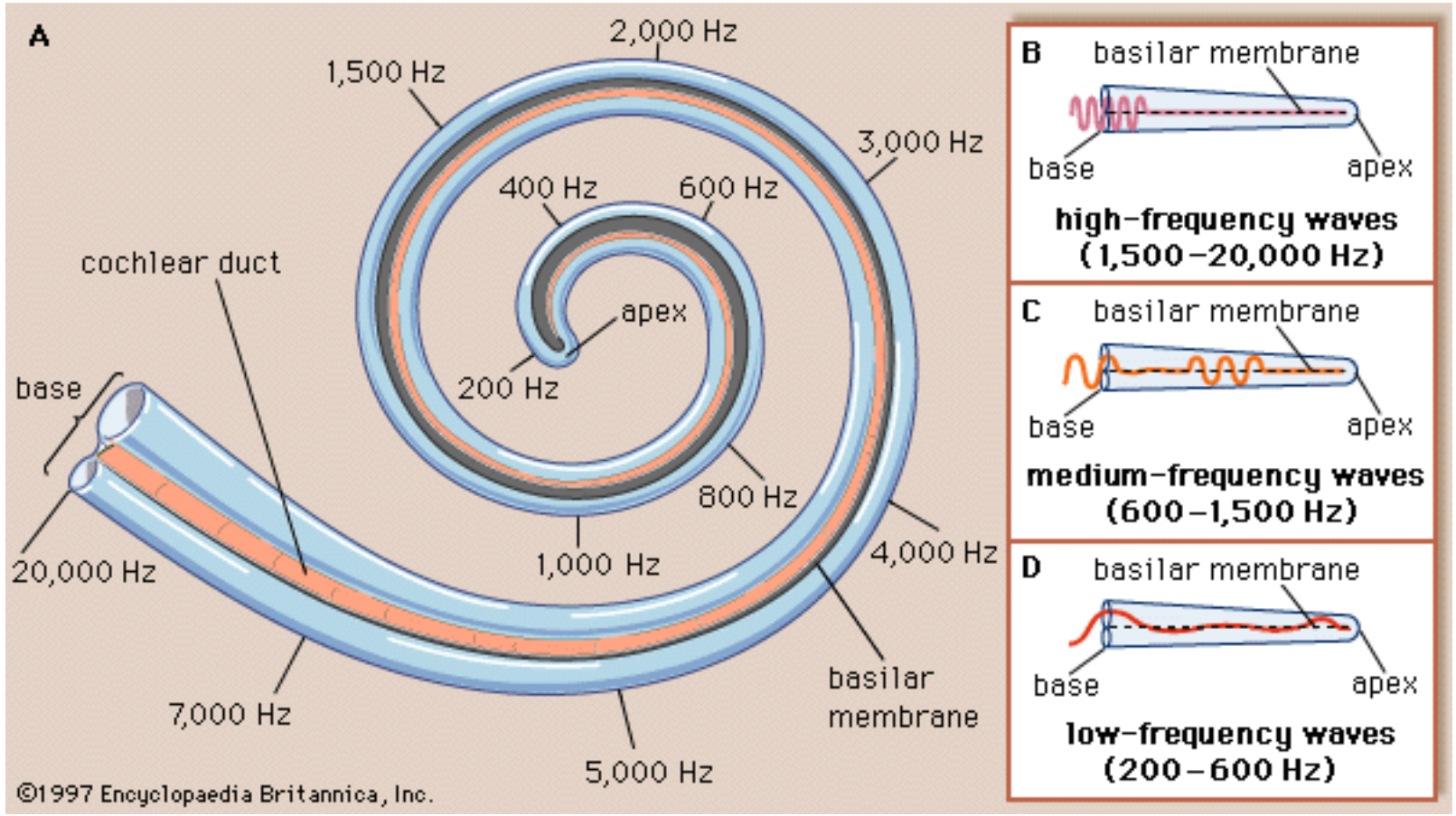


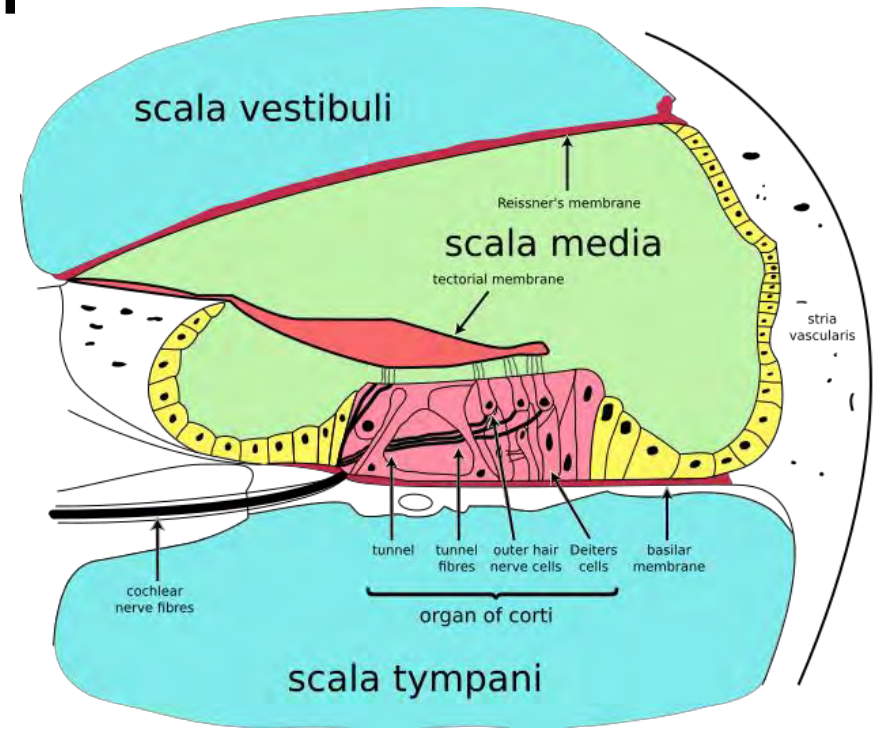


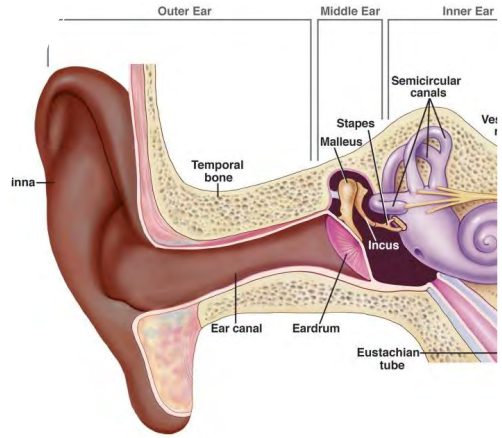


Low frequency sounds penetrate walls

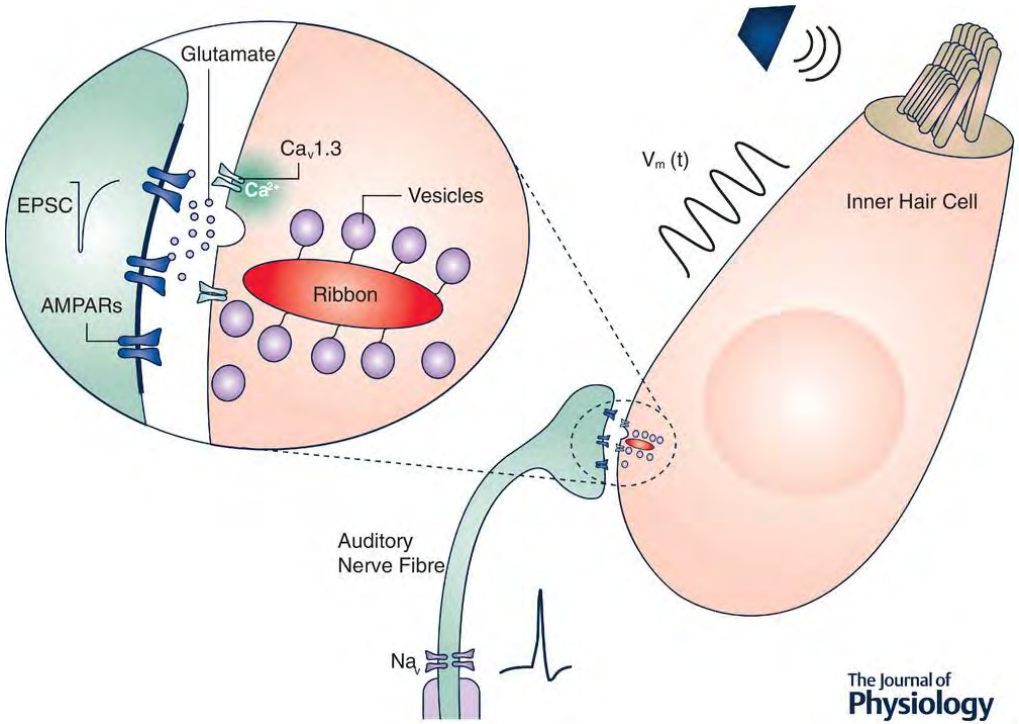
Frequency (pitch) coding in tympanic membrane

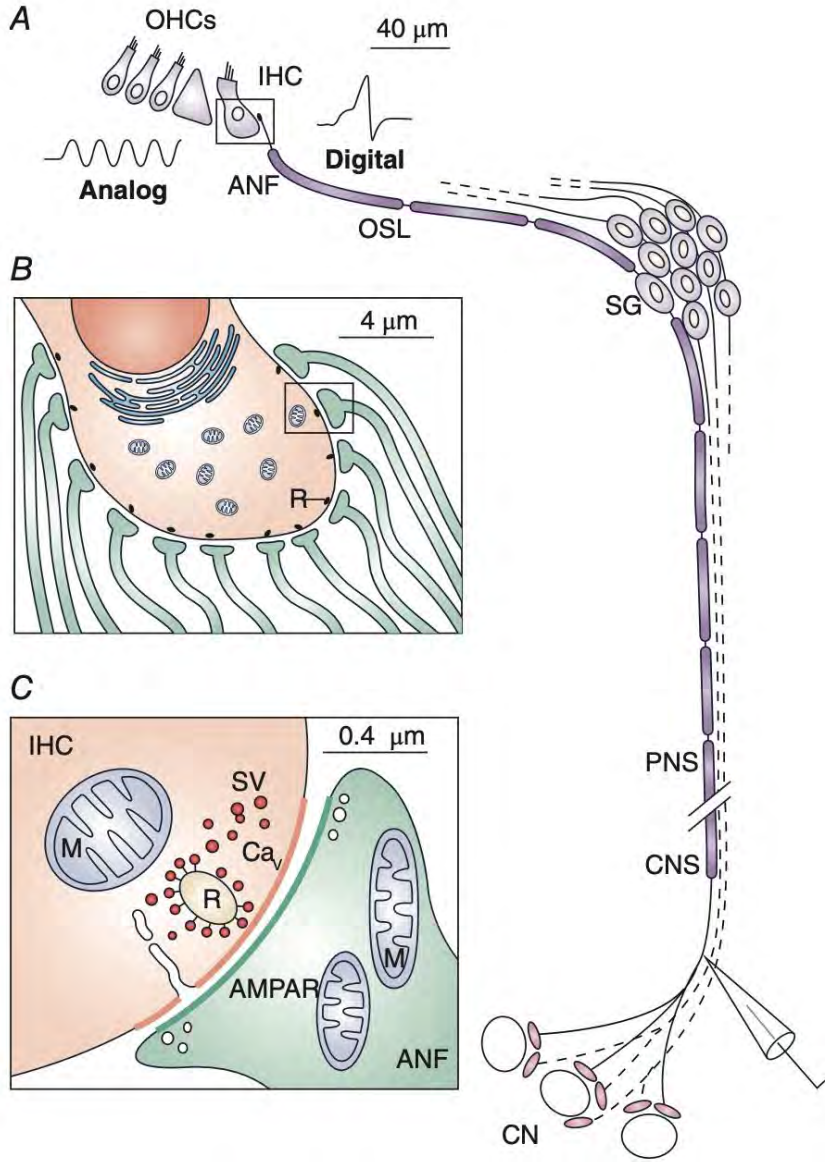






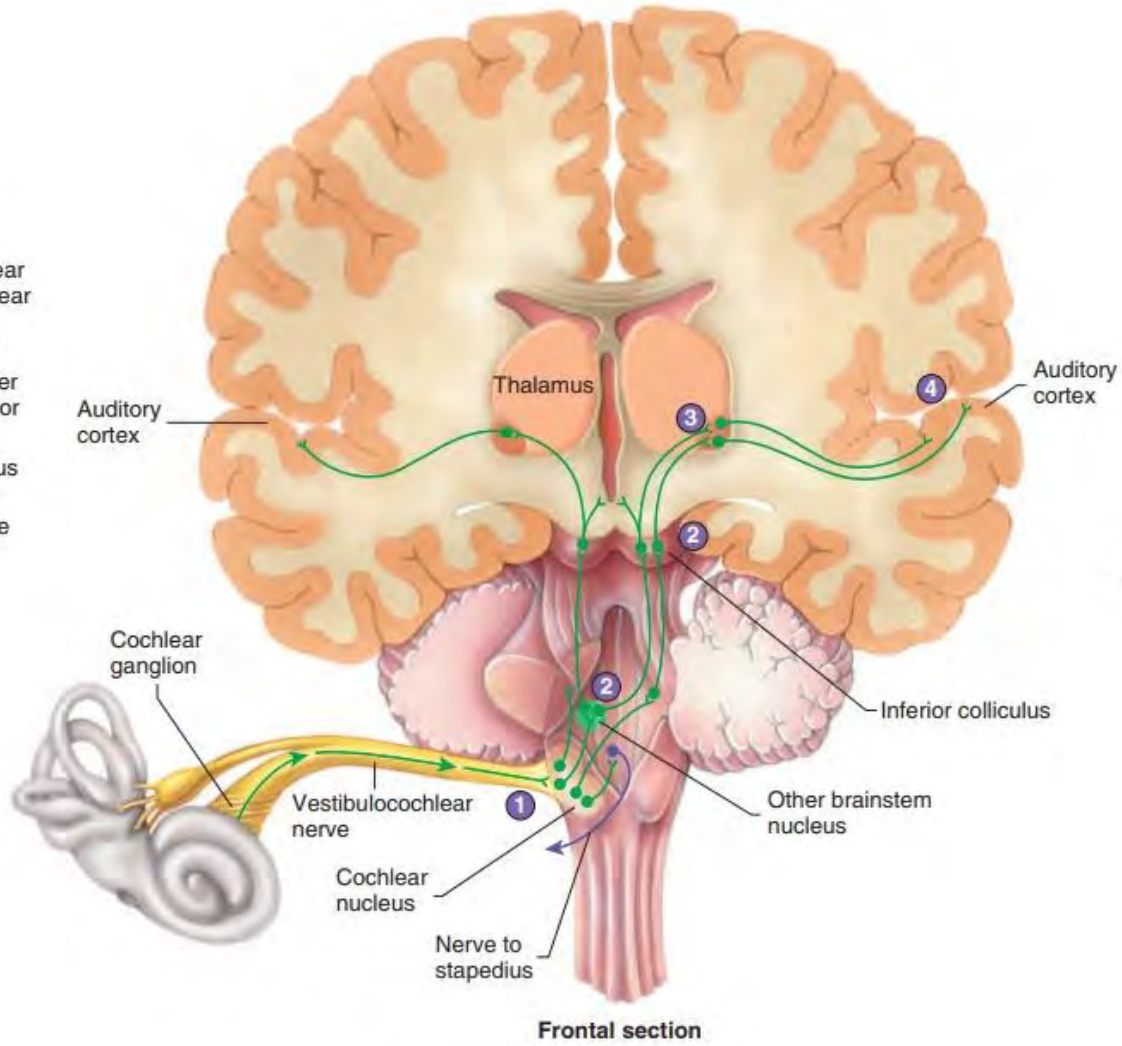
Signal transduction: hair cell to auditory nerve



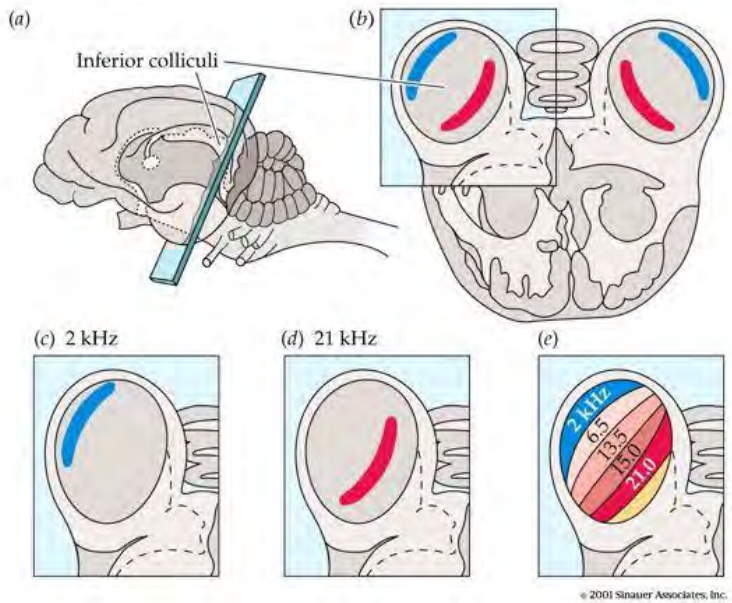


J Physiol 599.10 (2021) pp 2527–2557

1. Sensory axons from the cochlear ganglion terminate in the cochlear nucleus in the brainstem.
2. Axons from the neurons in the cochlear nucleus project to other brainstem nuclei or to the inferior colliculus.
3. Axons from the inferior colliculus project to the thalamus.
4. Thalamic neurons project to the auditory cortex.

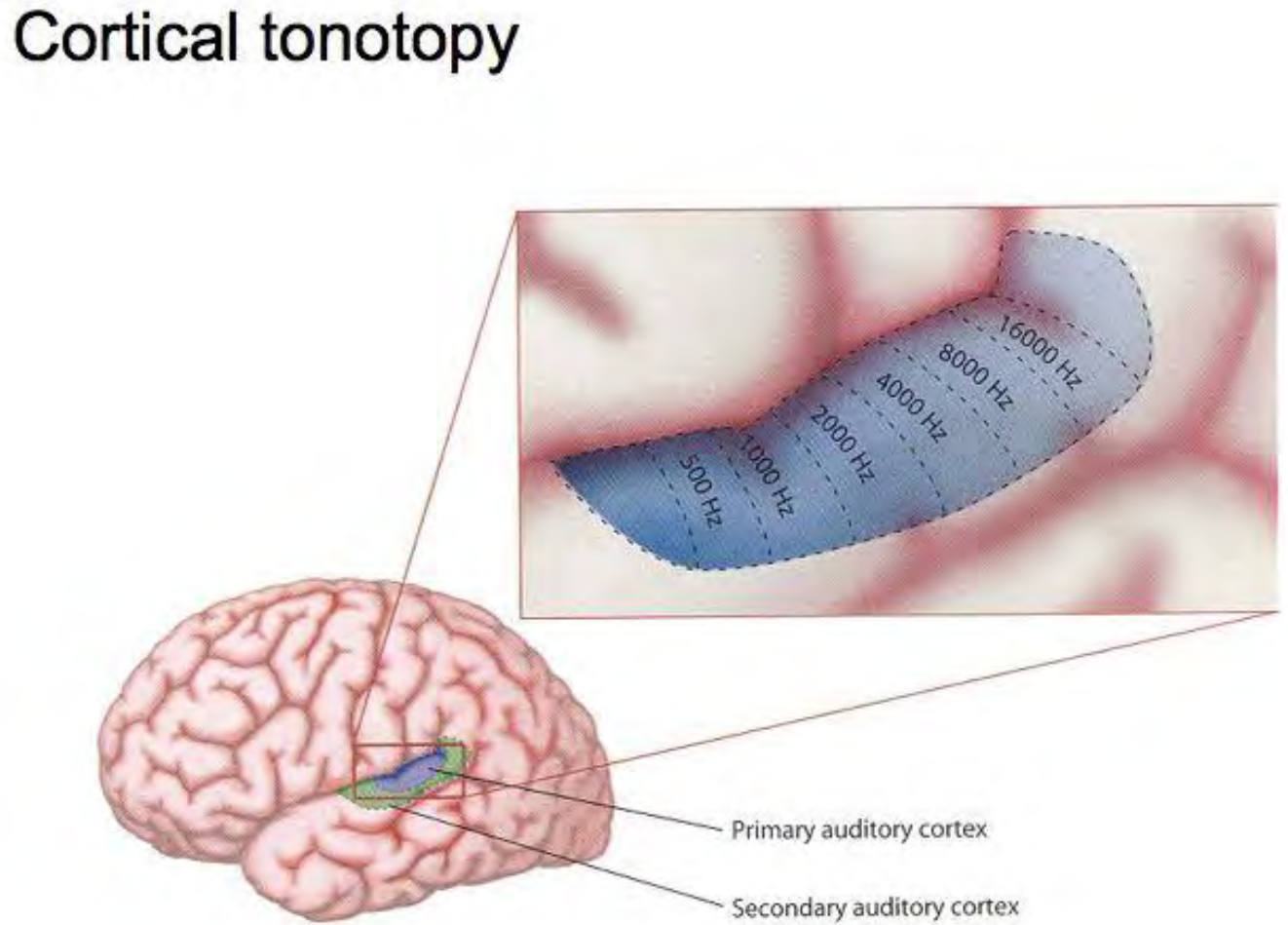


Tonotopic organization



https://www.cns.nyu.edu/~david/courses/perception/lecturenotes/localization/localization.html

Tonotopic map in Auditory Cortex



Sound and cortex, neuroendocrine

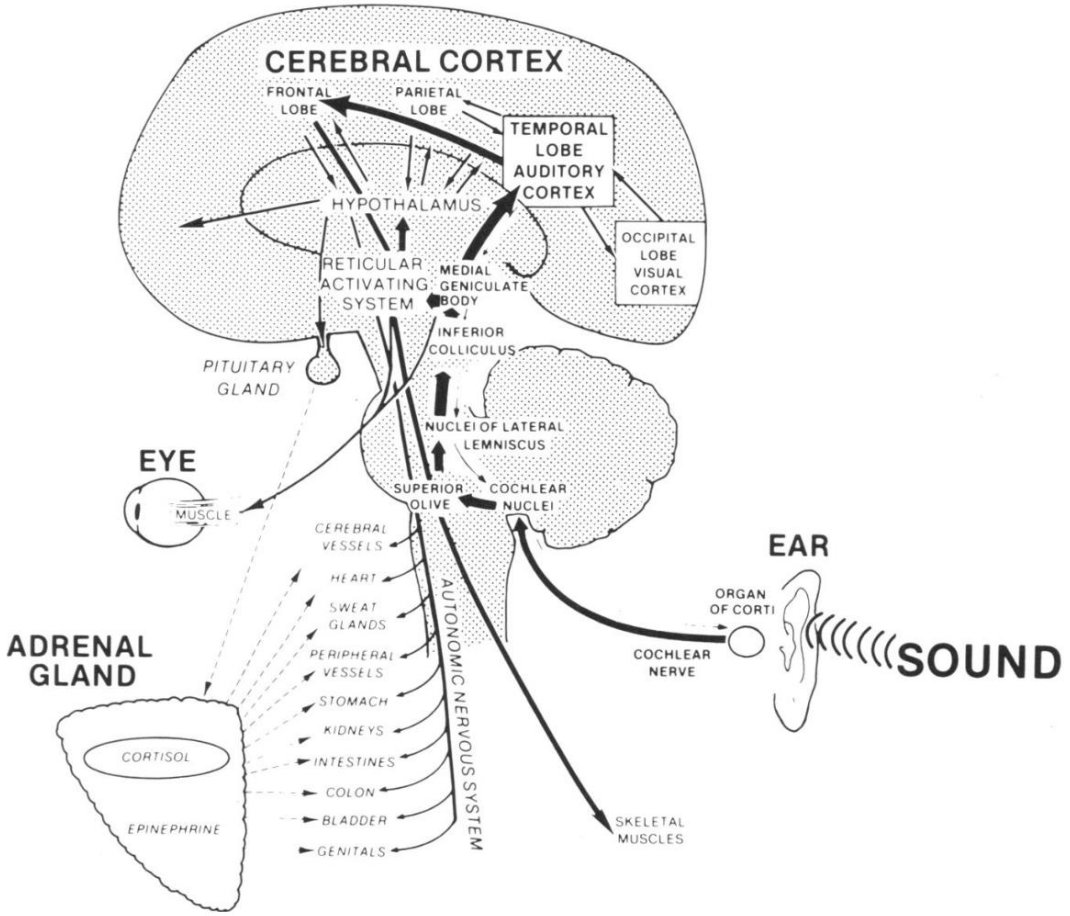


FIGURE 1. Processing of sound by the brain.

Westman and Walters, 1981 Noise and Stress: A comprehensive approach. Environ. Health Perspec 41:291

Hearing damage in humans

- Noise-induced hearing loss. 2017 CDC Study: 40 million adults have NIHL (and 17% of teens!)

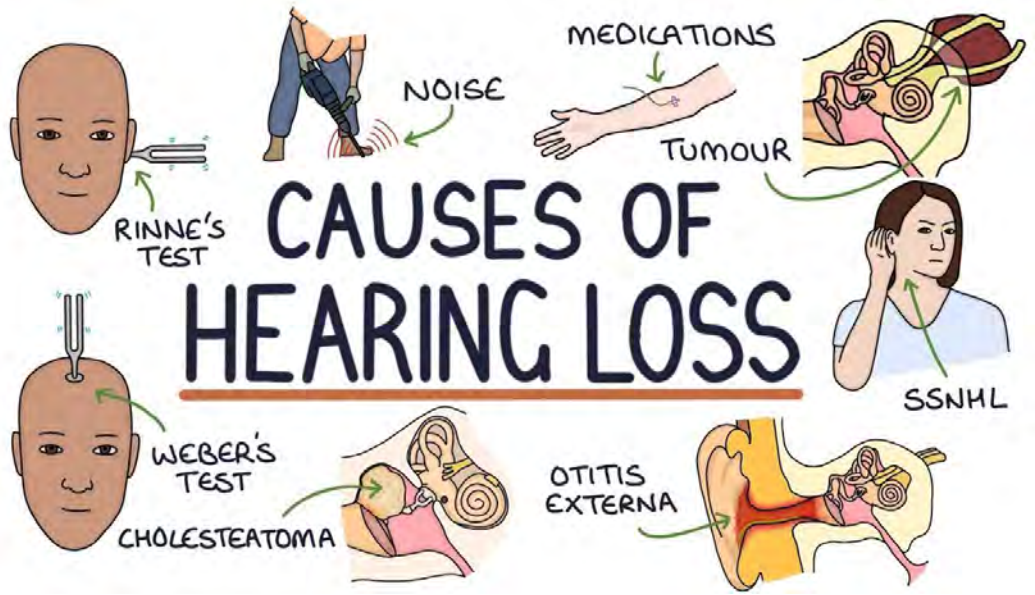
Caused by one loud noise (explosion) or long-time of greater than 85 dB:

Motorcycles (95 dB), sirens (1 min), leafblowers (2 hr), gas-powered lawnmowers, weedwhackers, chainsaws, rock concerts (2 min), loud sporting events (14 min), loud in ear buds, air pods, etc.



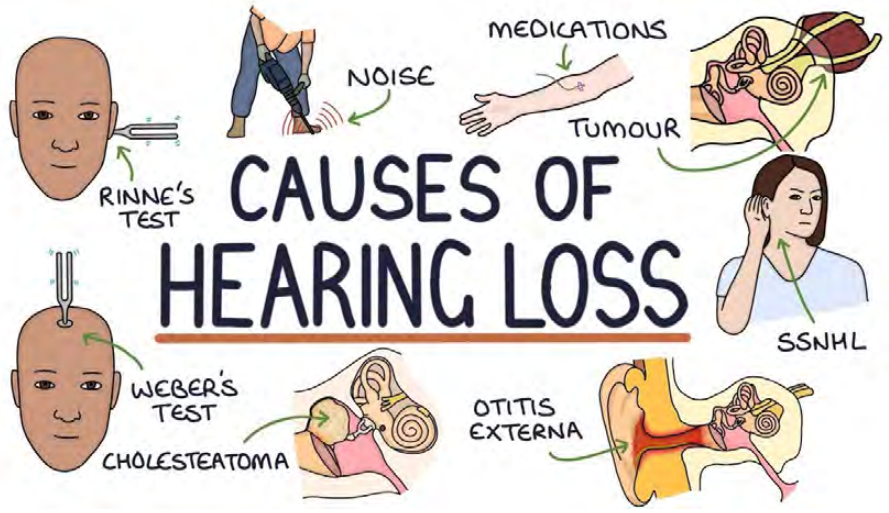
Other causes of hearing loss

- Aging- chronic impacts
- High blood pressure (chronic, untreated)
- Illness/infection (measles, mumps, meningitis)
- Certain prescription drugs (malaria meds, aspirin, NSAIDs), opioids
- Environmental chemicals
- Injury
- Tumor (acoustic neuroma)



Hearing loss linked to neurodegenerative disease

- Account for 8% of new dementia cases: 800,000 each year
- Nearly 1/3 of adults over 65 have hearing loss
- Increased risk of falls, social isolation, depression, cognitive decline
- Increased risk of PD, AD



Li S, Cheng C, Lu L, Ma X, Zhang X, Li A, Chen J, Qian X, Gao X. Hearing Loss in Neurological Disorders. Front Cell Dev Biol. 2021 Aug 11;9:716300. doi: 10.3389/fcell.2021.716300. PMID: 34458270; PMCID: PMC8385440.

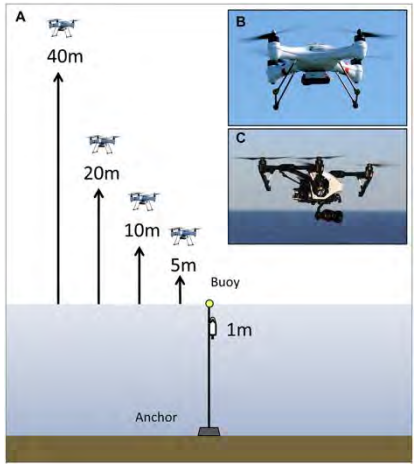
Human Noise is harming many animals

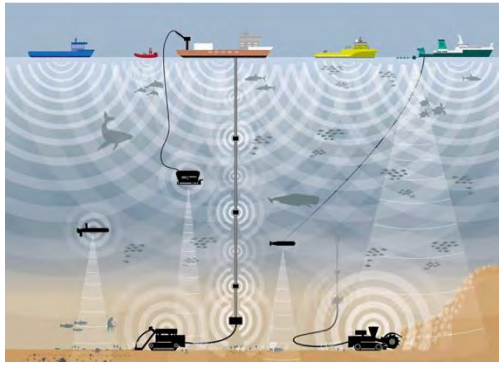
- Traffic noise, chainsaw, lawn mowers affect feeding, threat detection in birds (Great tits, black-capped chicadees)
- Underwater (freshwater streams, lakes) traffic noise dominant sound now
- Honeybee waggle dance disrupted by human noise
- Fish, bird embryos show reduced growth, delayed development
- Pile driving and harbor porpoises



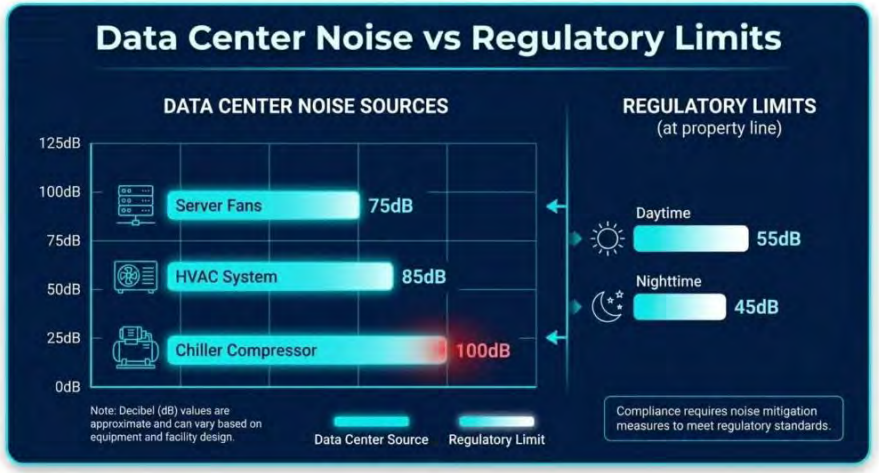
Newer noise concerns

- Drones penetrating areas where humans can’t go
- High speed trains
- HVAC and data centers
- Deep sea mining





- Noise was considered a national hazard, the 1972 Noise Control Act, OSHA/EPA, largely ignored now



What can we do?

- Be mindful of when and how long you use equipment like leaf blowers- respect others around you (maybe use a rake? Electric equipment?)
- Consider being active in your community on noise ordinances
- Trees, landscaping to reduce noise spread
- Don’t suffer in silence
- Use an app with warnings of loud noise