

# YOUR BRAIN ON MUSIC

JOE VANDERMEER MD

# UBIQUITY AND ANTIQUITY

- No known human culture now or anytime in the recorded past lacked music
- Some of the oldest discovered artifacts are musical instruments
- Until the modern era, producing music was a communal activity
- Before TV and radio, families and friends would sing together for entertainment and worship.





# MUSIC INDUSTRY

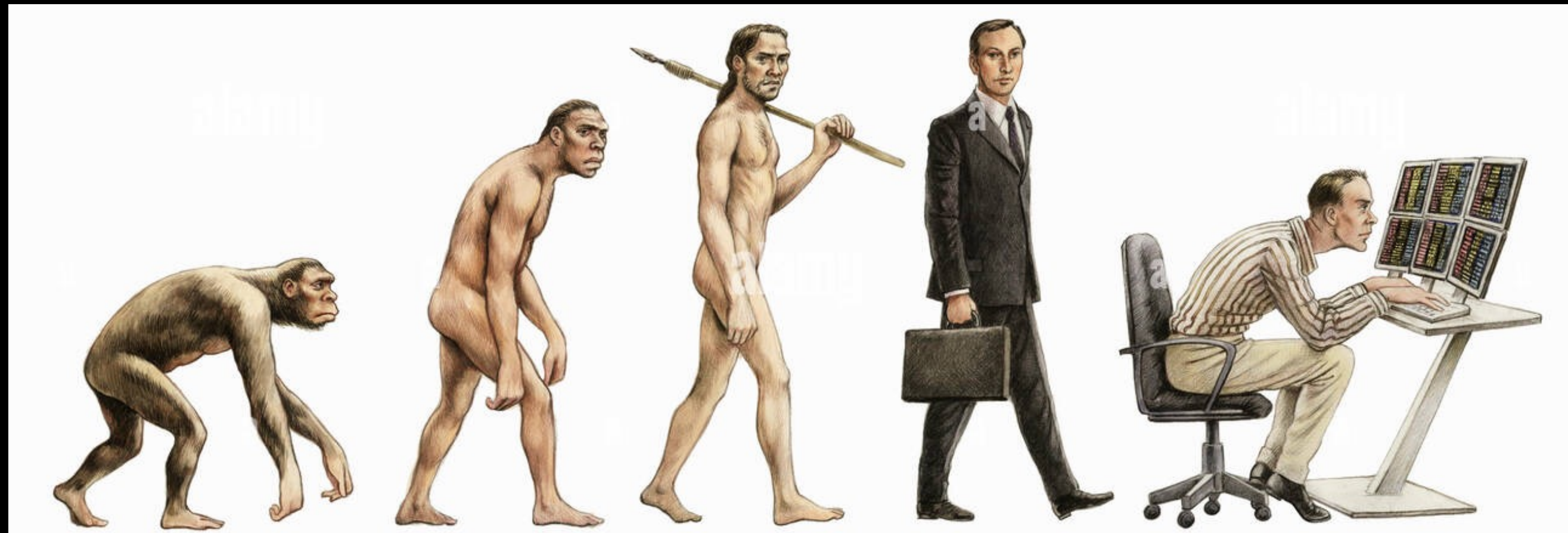
- **Global Music Industry Revenues \$26.2 B**
- Streaming subscription revenue - \$12.7 Billion
- Total streaming revenues (including paid and ad-supported) - \$17.5 Billion
- Performance rights revenues - \$2.5 Billion
- 589 million paid music subscribers





# WHY MUSIC?

- Emotional Communication
- Mating rituals
- Artifact of language development





# IDENTIFICATION OF EMOTION

Music played for both autistic and non-autistic children, comparing those with similar language skills, and asked the kids to match the music to emotions.

- Childrens ability to recognize emotions including happy, sad, triumph, contentment and anger in music did not depend on their diagnosis.
- Music can reliably convey feelings even in people whose ability to pick up emotion-laden social cues independent of language ability

# EMOTIONAL IMPACT OF MUSIC ACROSS CULTURES

- Exposed members of the Mafa ethnic group in Cameroon who had never heard Western music to excerpts of classical piano music.
- The researchers found that the adults who listened to the excerpts consistently identified them as happy, sad or scary just as Western listeners would.

Tom Fritz of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany



# MUSIC IN INFANCY

fMRI to see how the brains of one- to three-day-old newborns responded to classical music and found a pattern that mirrored music processing in adults

Making a section in the middle of the excerpt suddenly jump into another key or playing the entire musical segment in clashing keys preferentially activated the infants' left inferior frontal cortex, an area implicated in musical syntax processing in adults, and the limbic system, the seat of emotional response, just as happens in adults.

Maria Cristina Saccuman and Daniela Perani of Vita-Salute San Raffaele University, *Nature Precedings*, 2008

# SUBJECTIVE JUDGEMENT OF EMOTION

Subjects were asked them to manipulate the song—its tempo, volume and phrasing—to maximize a given emotion by adjusting sliders so that the song best represented a given emotion.

Expert musicians and seven-year-old children all landed on the same tempo for each song to bring out its intended emotion, be it happiness, sadness, fear or tranquility.

Roberto Bresin et al, The Royal Institute of Technology in Stockholm



# CHORDS AND SOCIAL CUES

- fMRI used to pinpoint a brain area that responded to chords but not to words, in a task in which volunteers listened to both.
- The responsive region turned out to be the superior temporal sulcus, a part of the brain's surface near the ears that responds to nonverbal social cues such as nonspeech vocal utterances, eye movements and body movements.
- The activation of this region hints that music may indeed be helping to forge social ties.

Nikolaus Steinbeis of the Max Plank Institute for Human Cognitive and Brain Sciences, Stefan Koelsch of the University of Sussex in England, 2008

# MUSIC AS MEDICINE

39 severely impaired Alzheimer's patients exposed to music **they liked** twice a week for six weeks.

- The favored music reduced the patients' agitation levels during and after the listening period **much more** than did a similar schedule of classical "relaxation" music they heard at a separate time.
- Beloved music also has been found to reduce pain during surgery and child labor. The analgesic effect apparently outlasts the listening: exposure to music during labor or a medical procedure can lessen the soreness experienced afterward, even after the music has stopped.



# THE NATURE OF SOUND

If a tree falls in a forest with no animal or human around to hear it, does it make a sound?

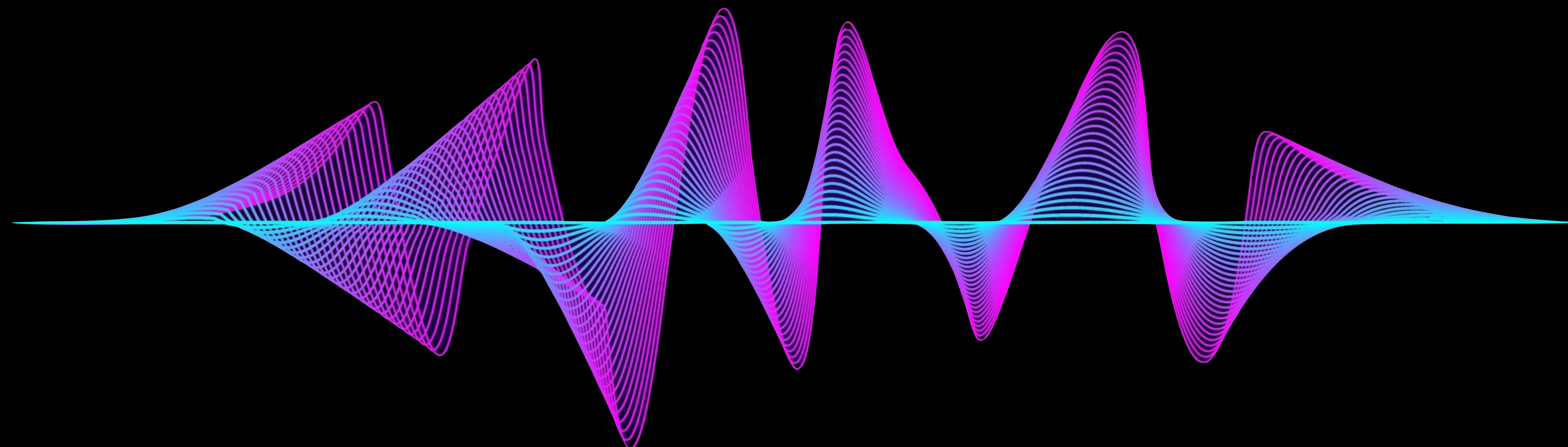
- (not) George Berkeley





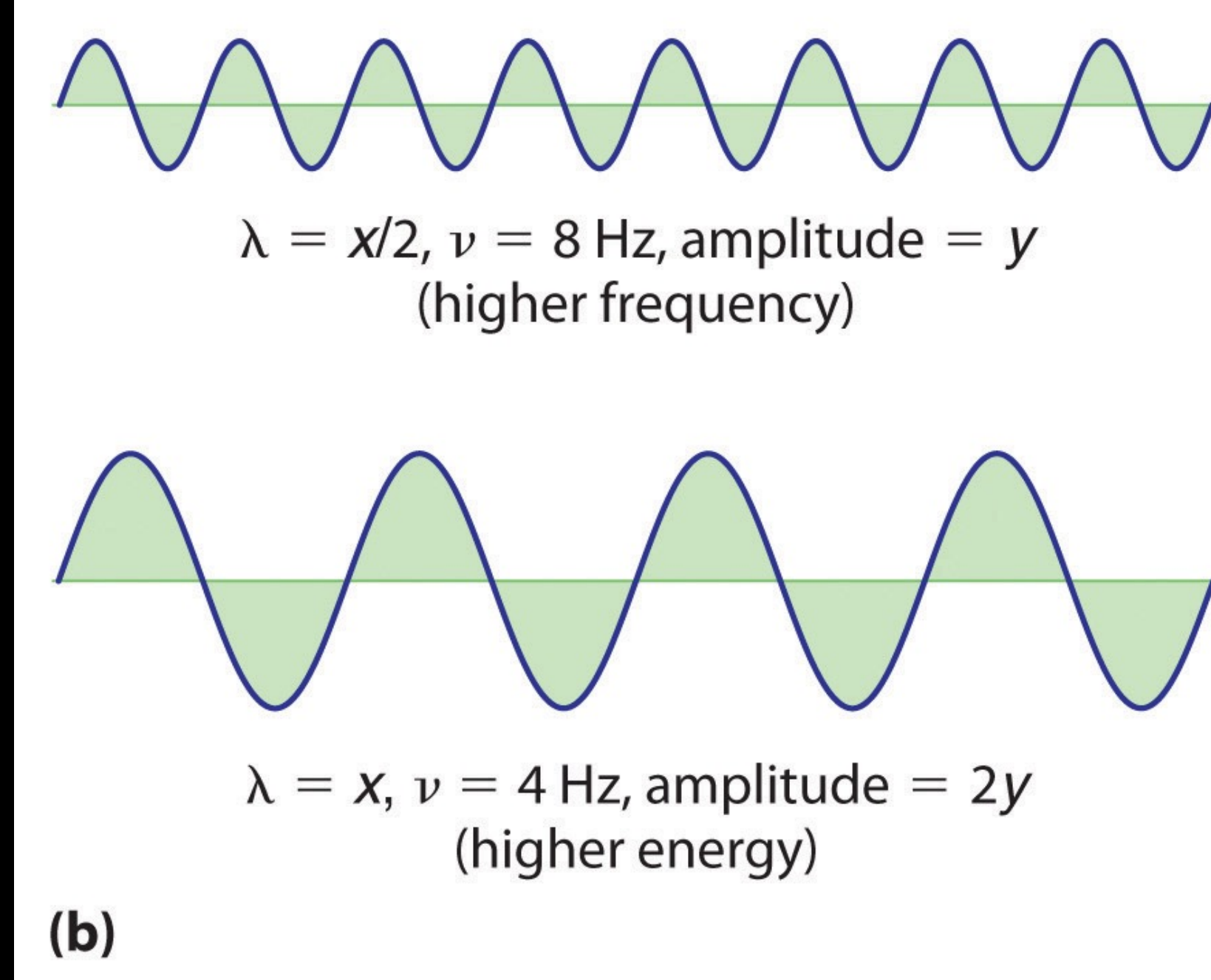
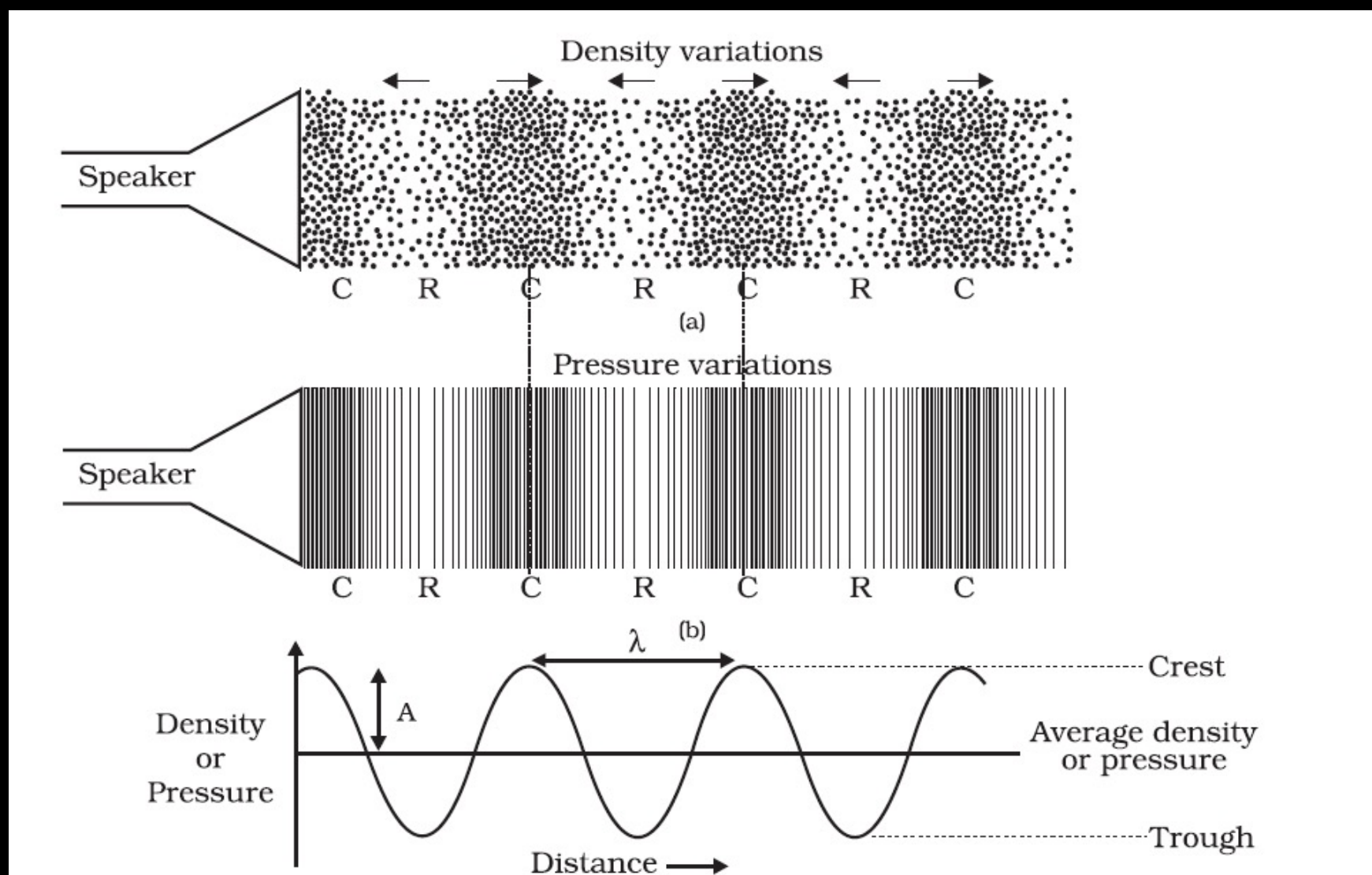
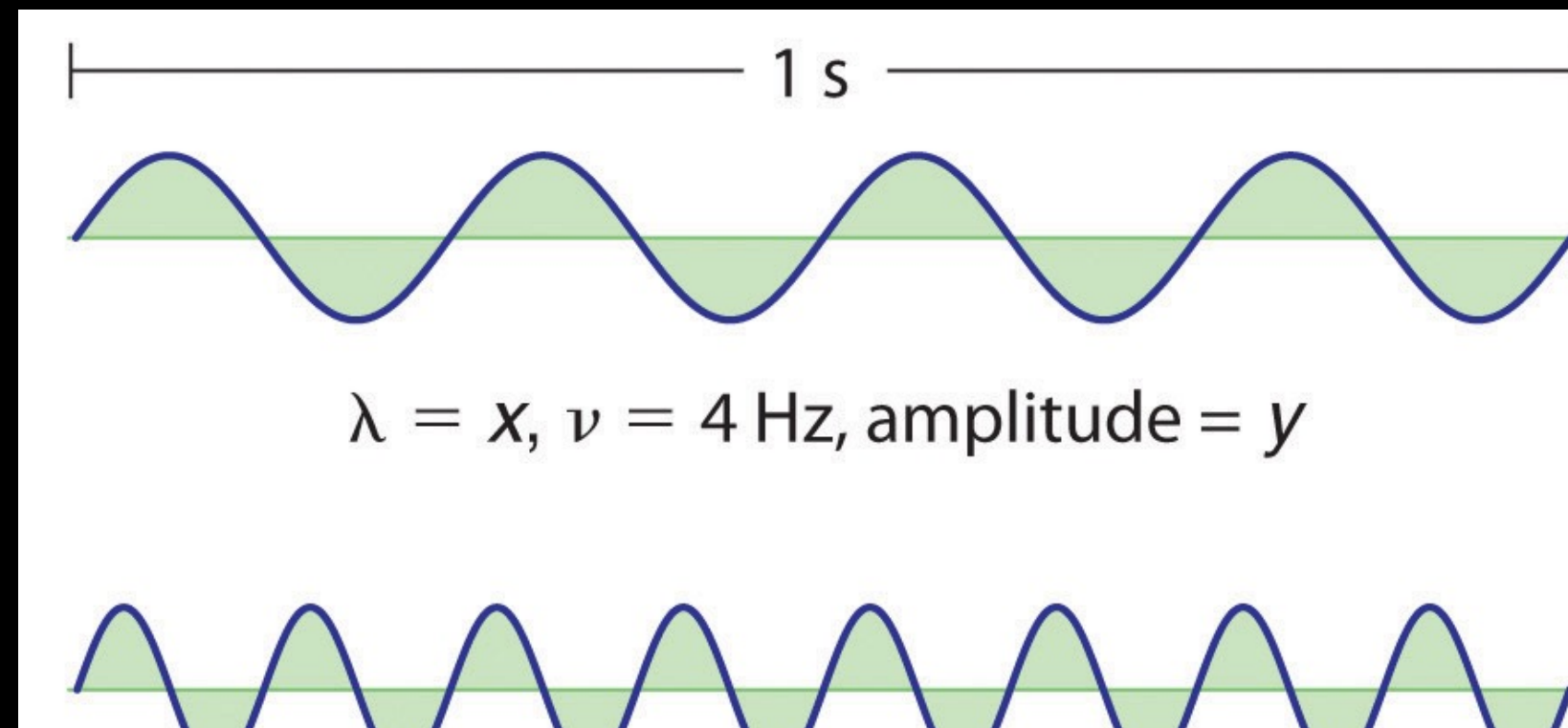
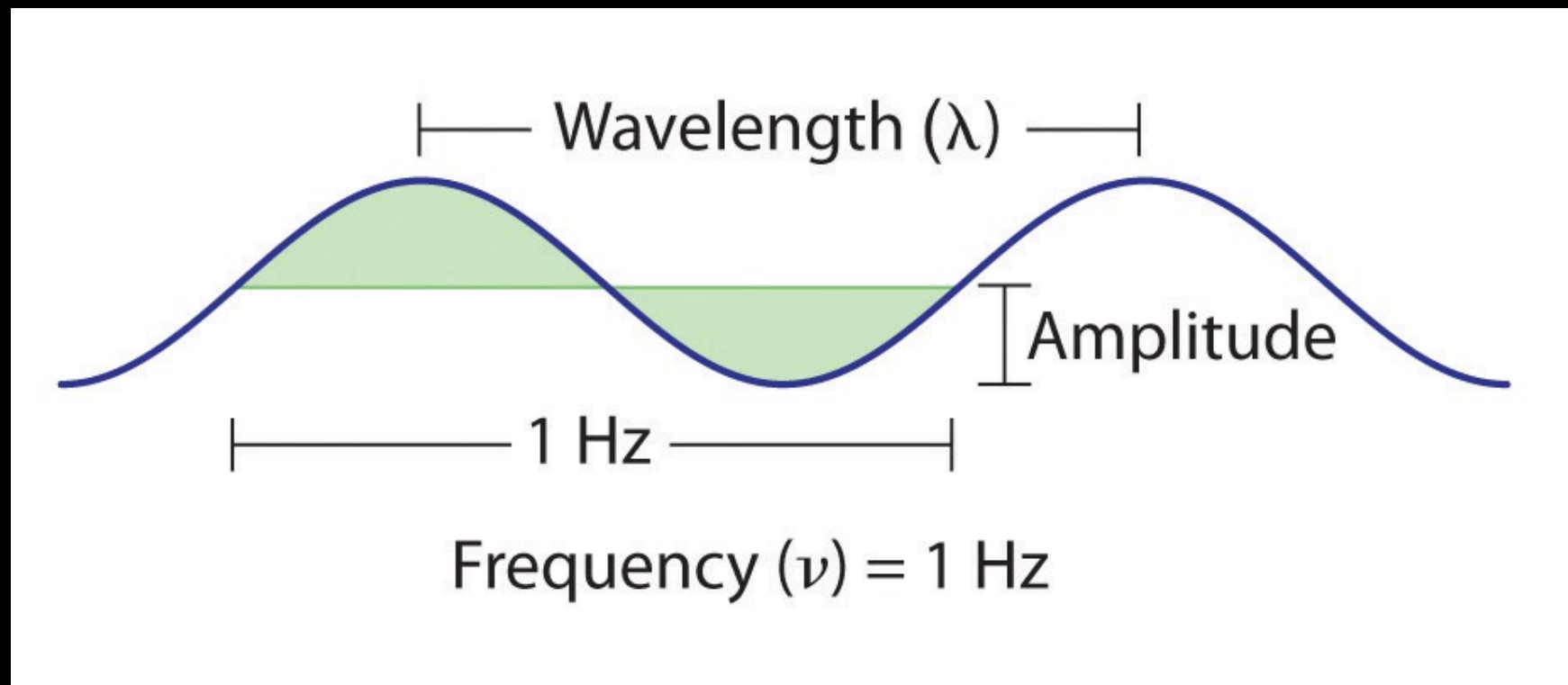
# THE MENTAL REPRESENTATION OF SOUND

- Sound is waves propagating through the molecules within a space, impacting the ear drum, moving the ossicles, deflecting the hair cells in the cochlea, creating an action potential in the auditory nerve, stimulating the auditory cortex.





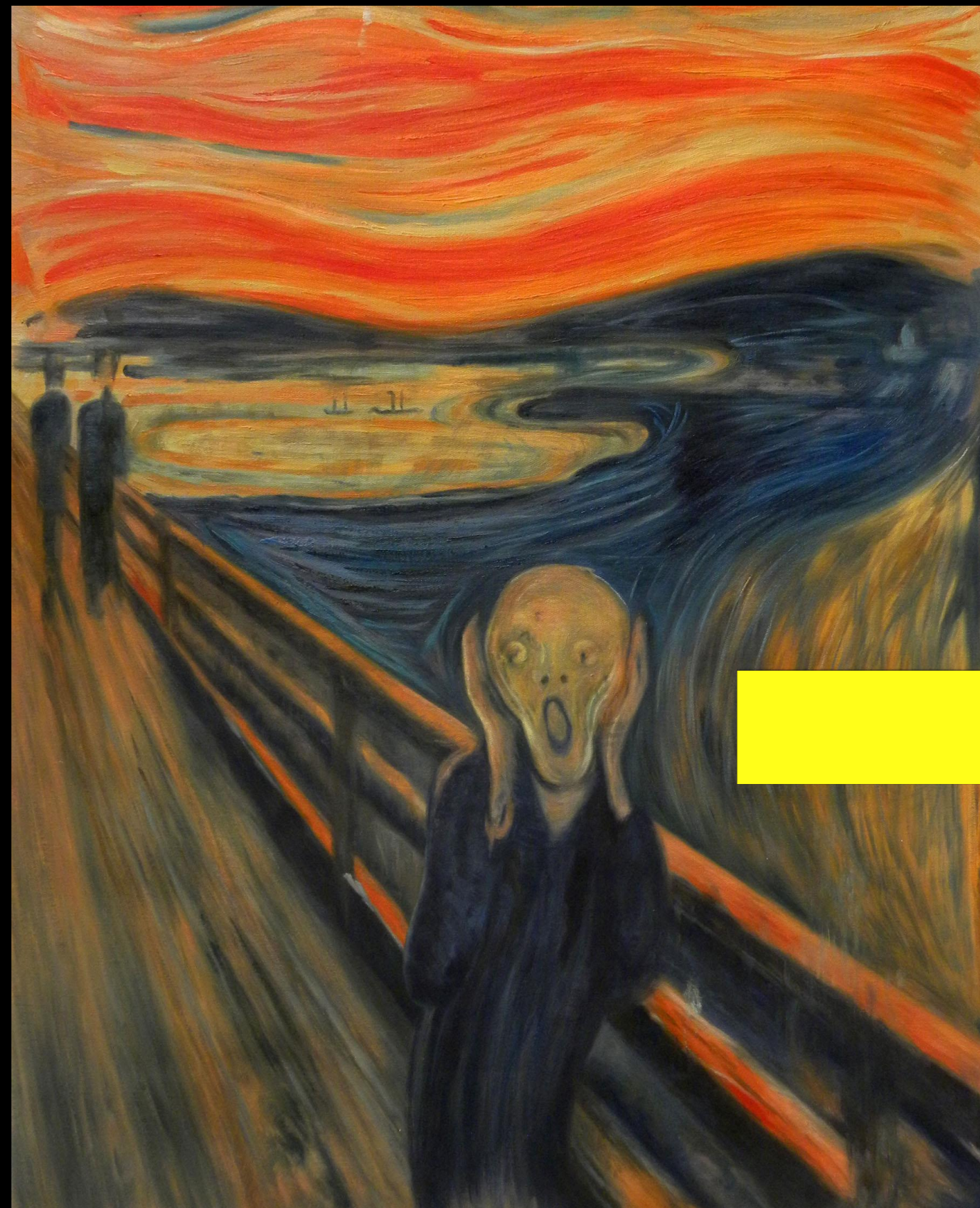
# PHYSICS INTERLUDE





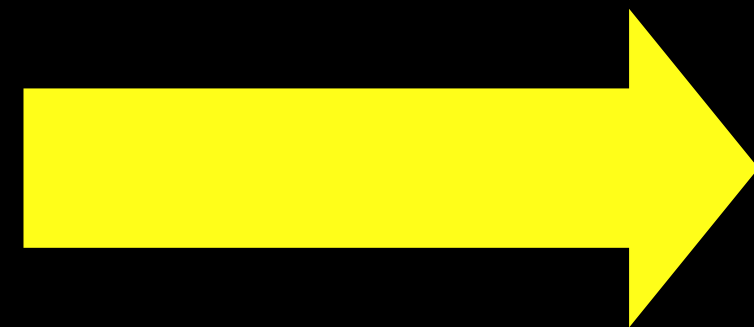


# SOUND WAVES TO FLUID WAVES



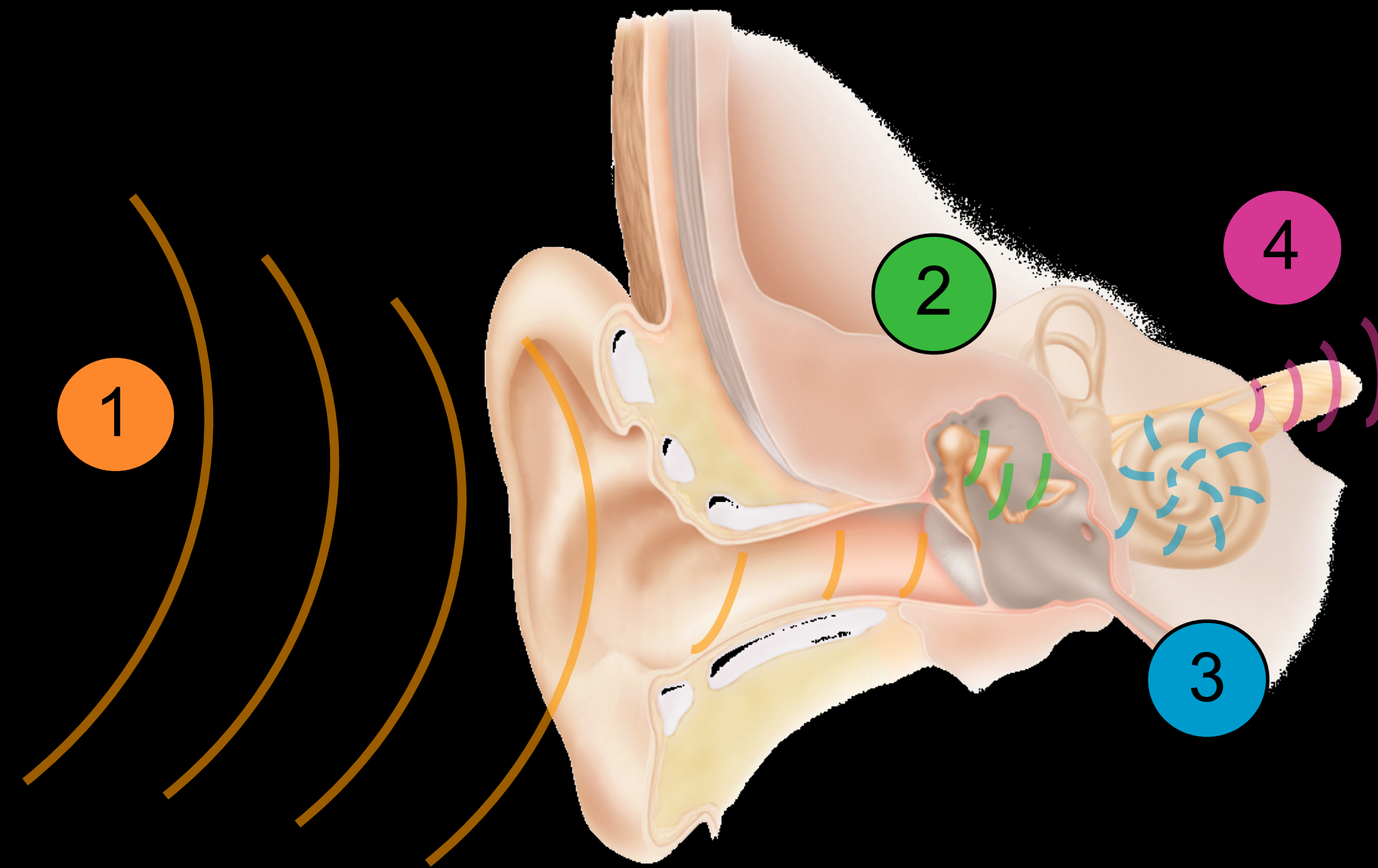


# FLUID WAVE TO ELECTRICAL IMPULSE



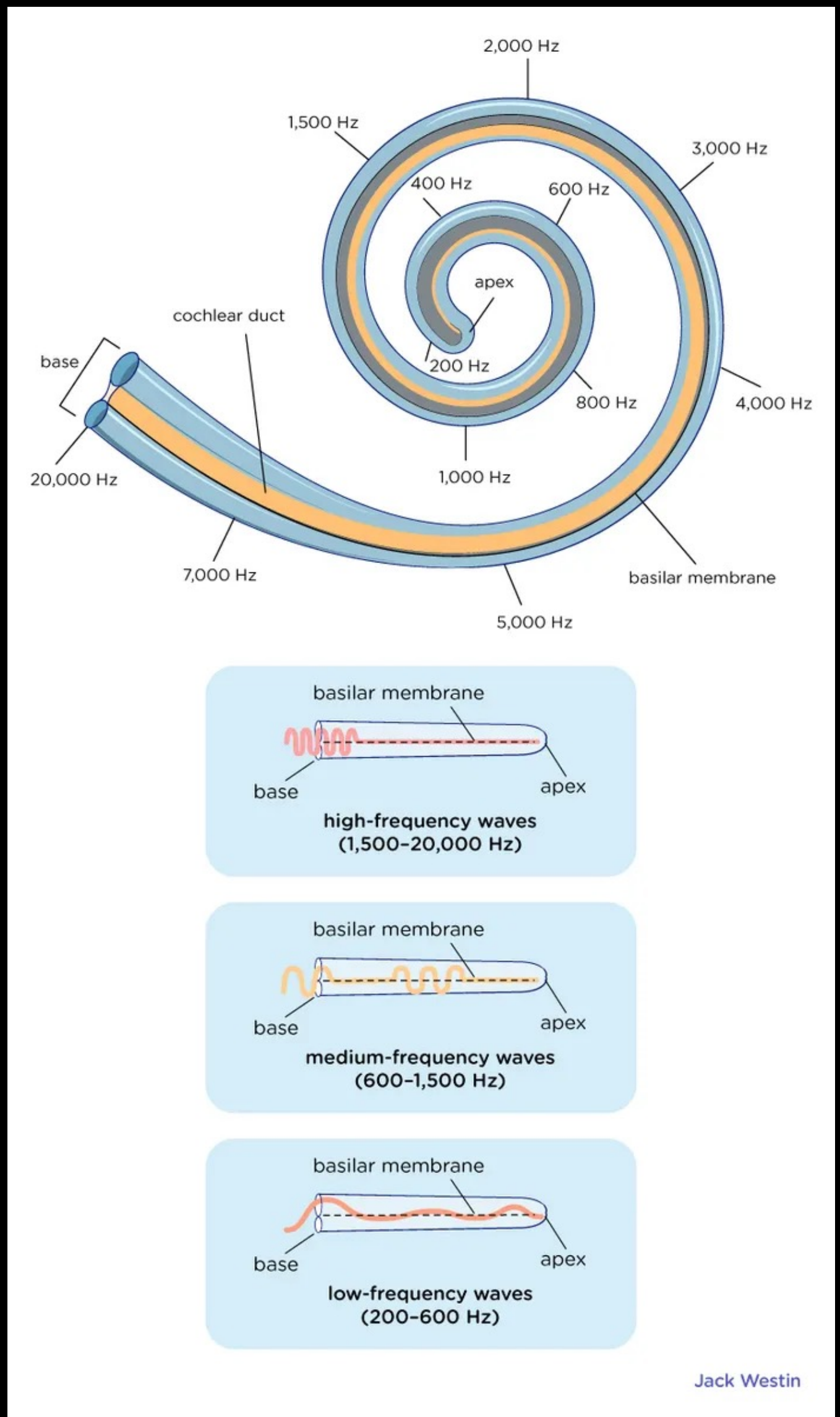
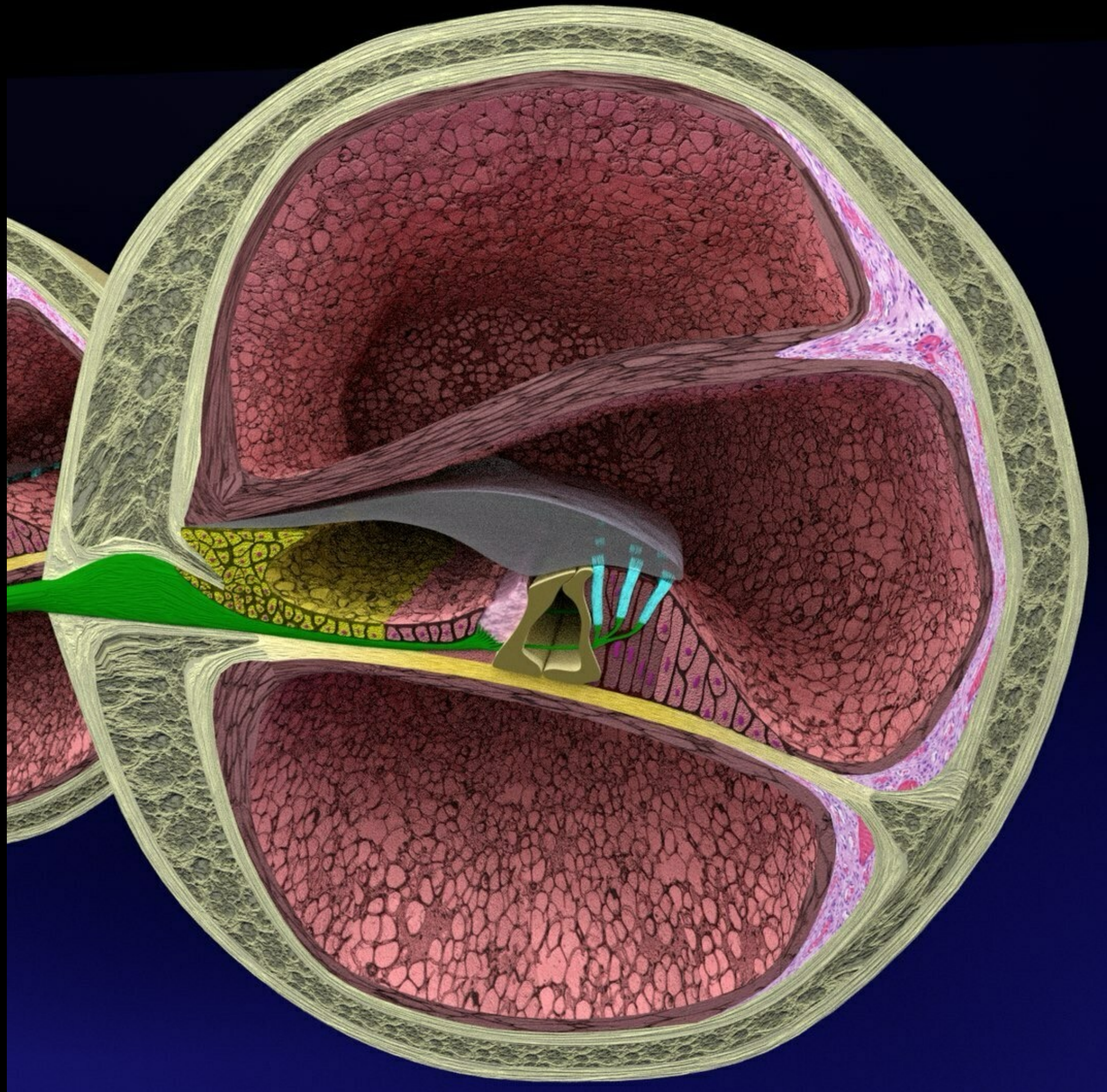


# HOW HEARING WORKS



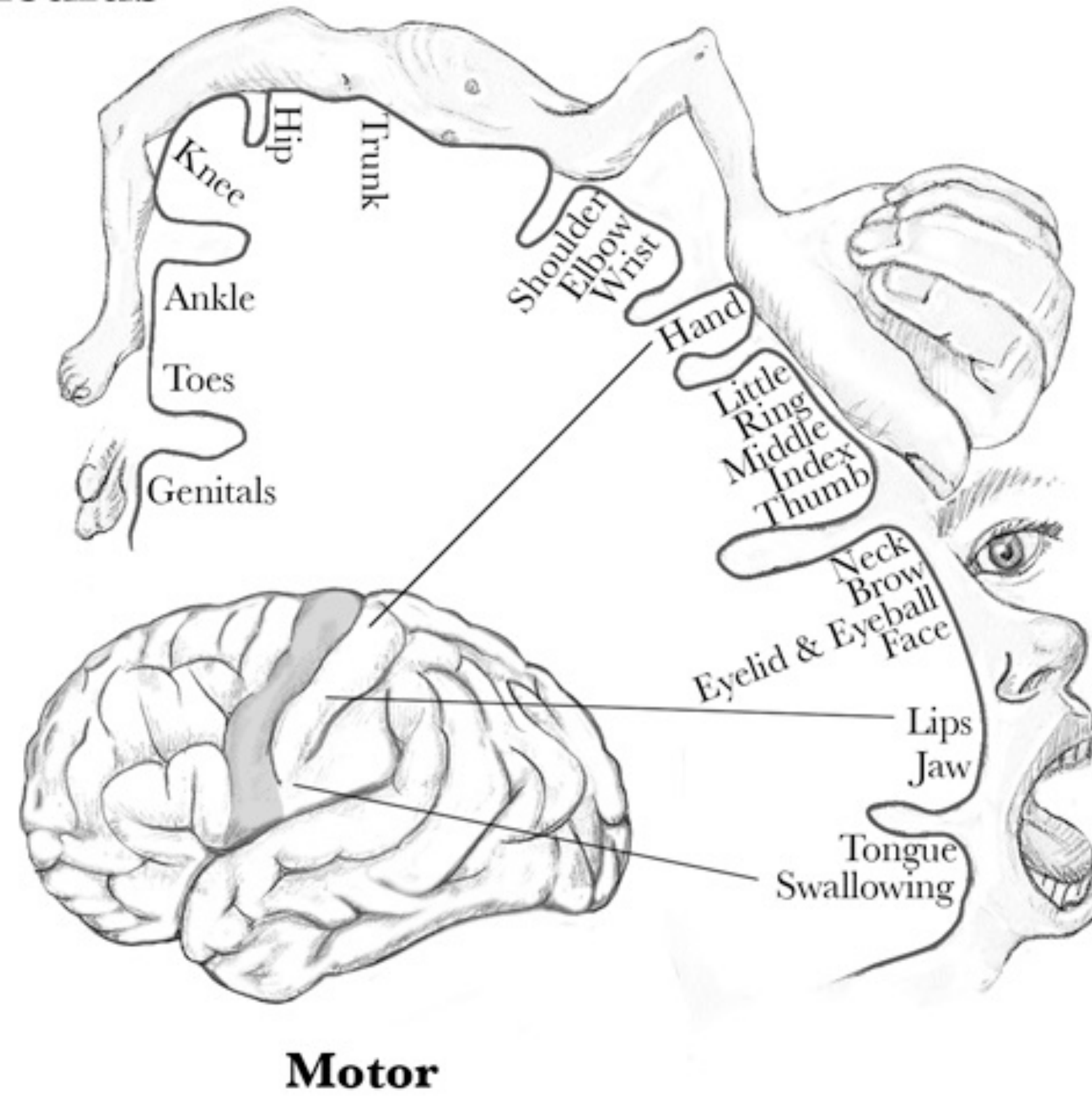
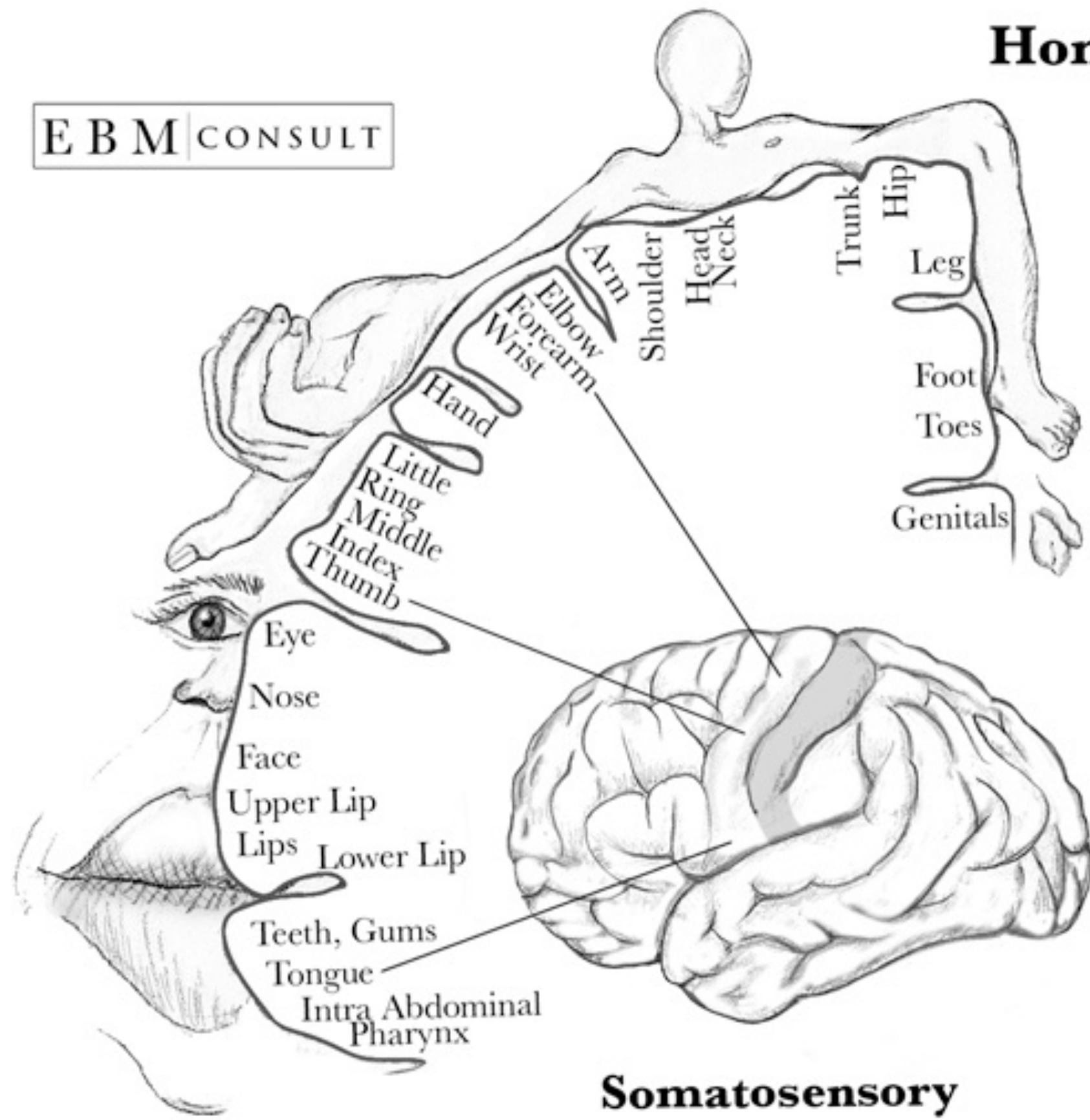


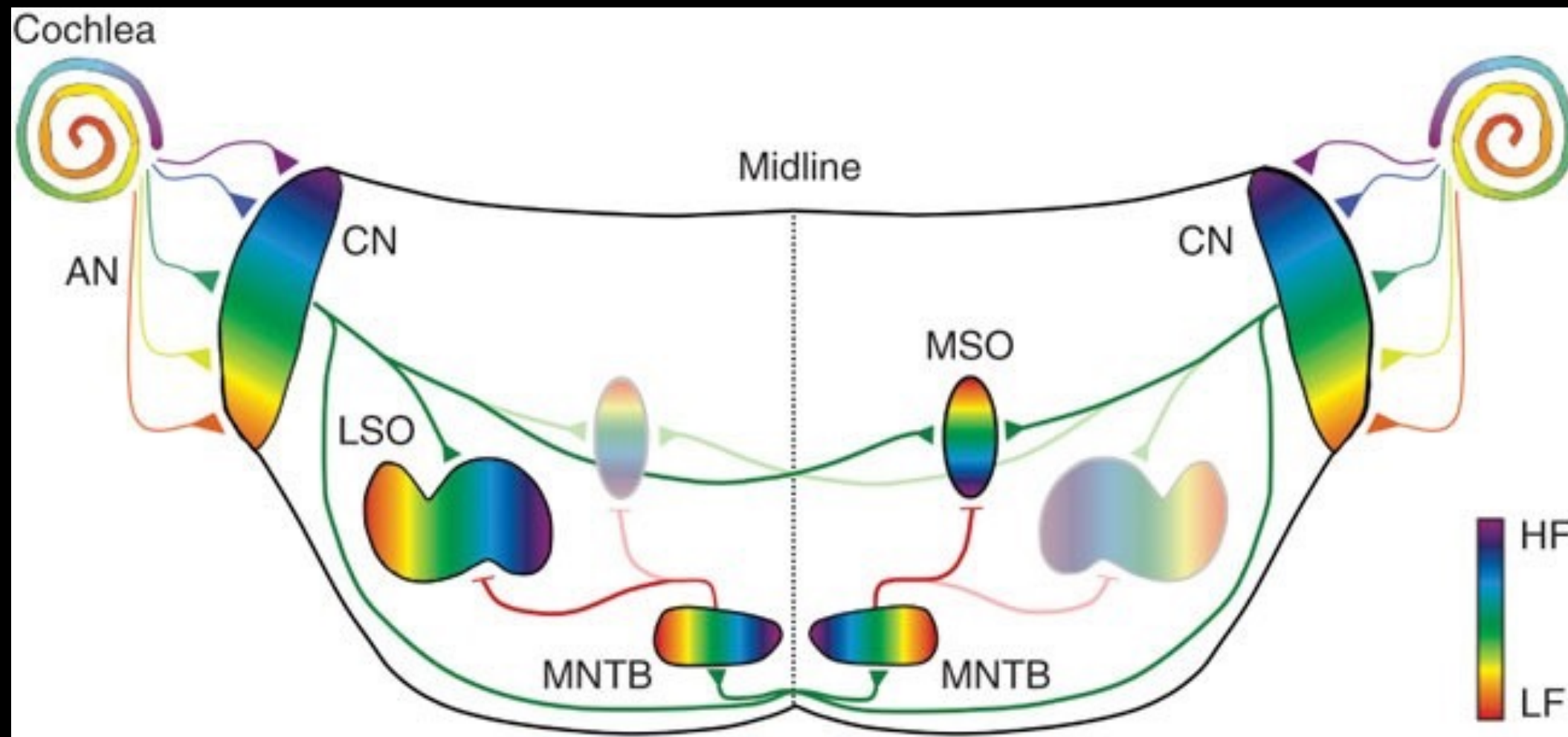
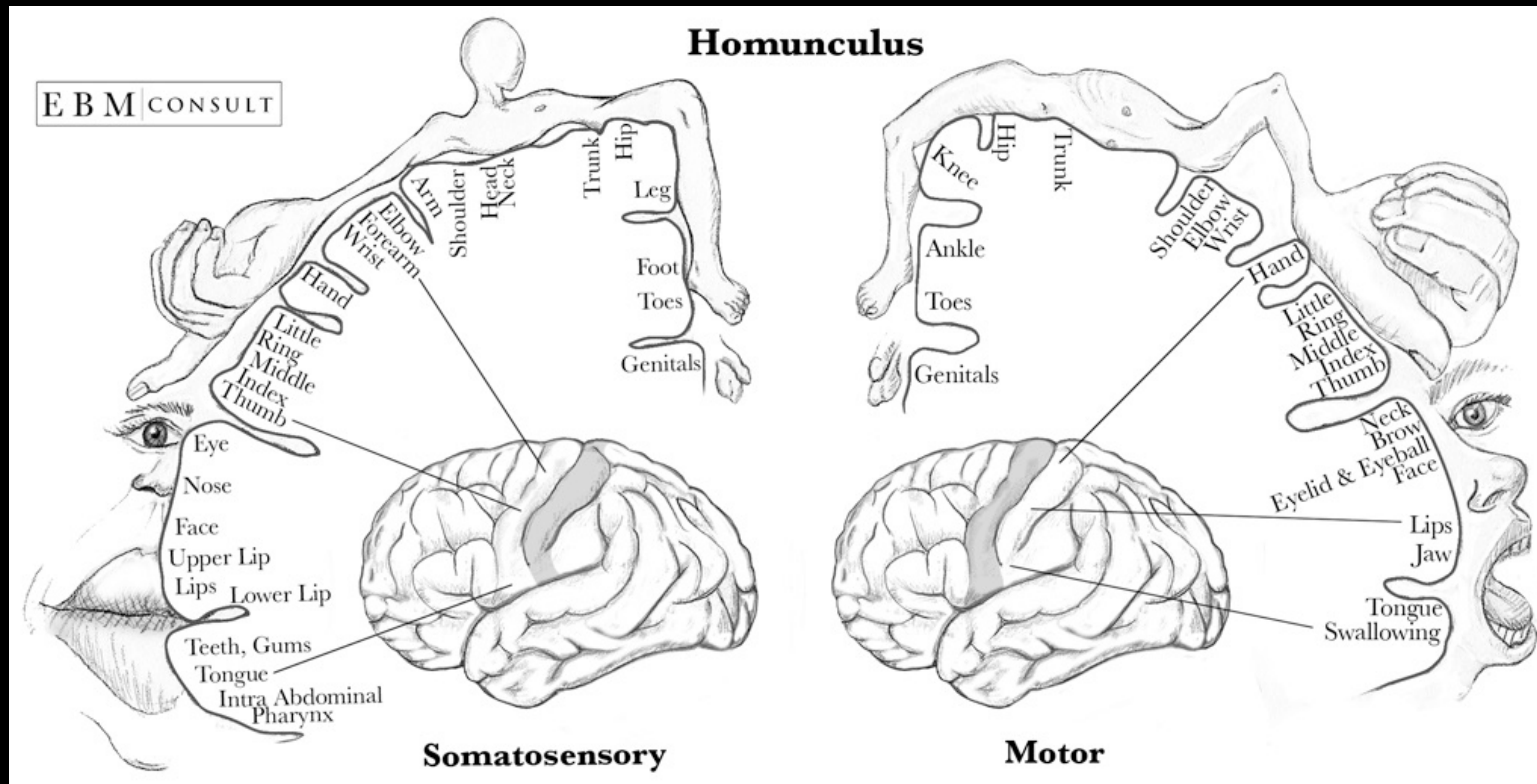
# TONOTOPIC ORGANIZATION



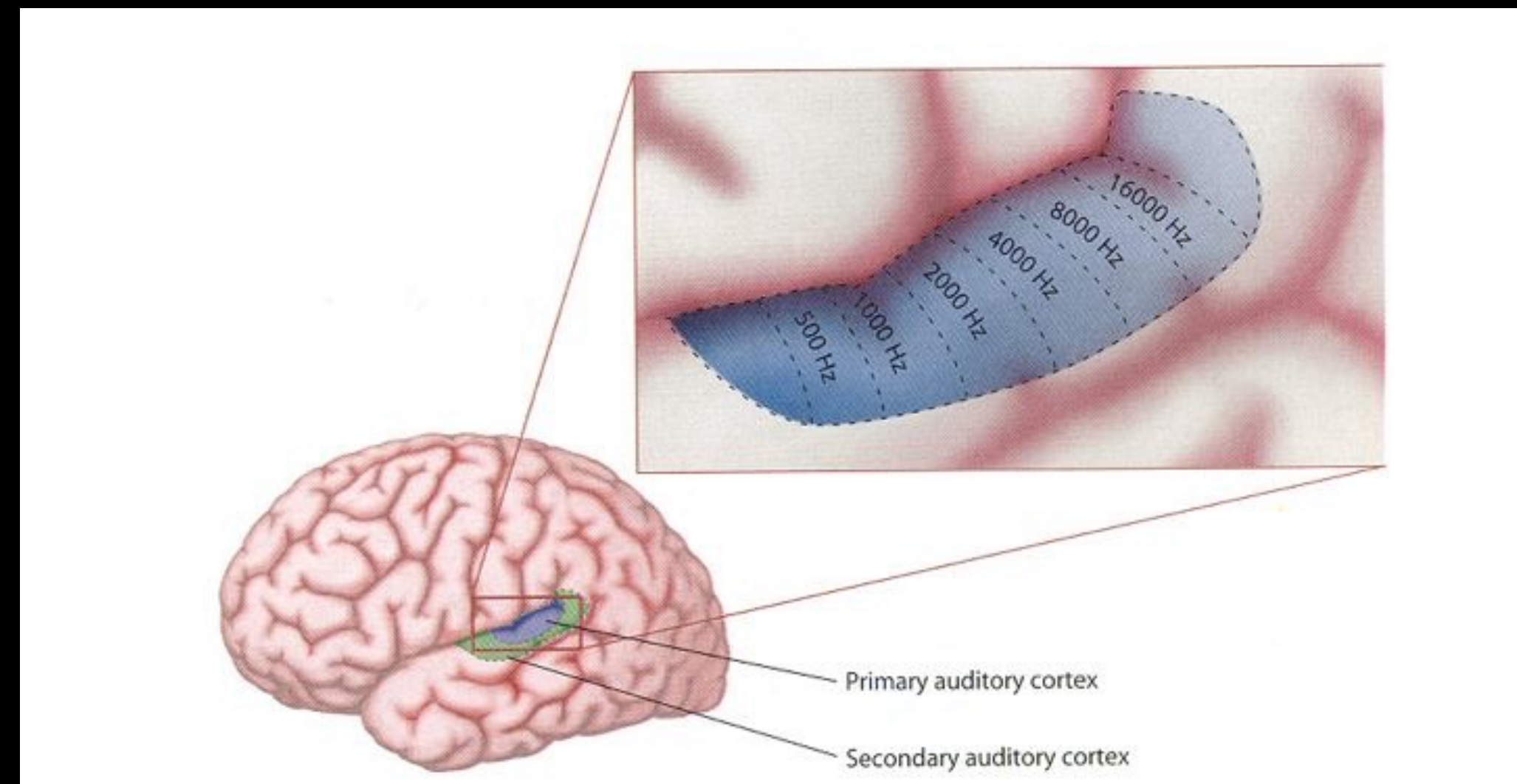
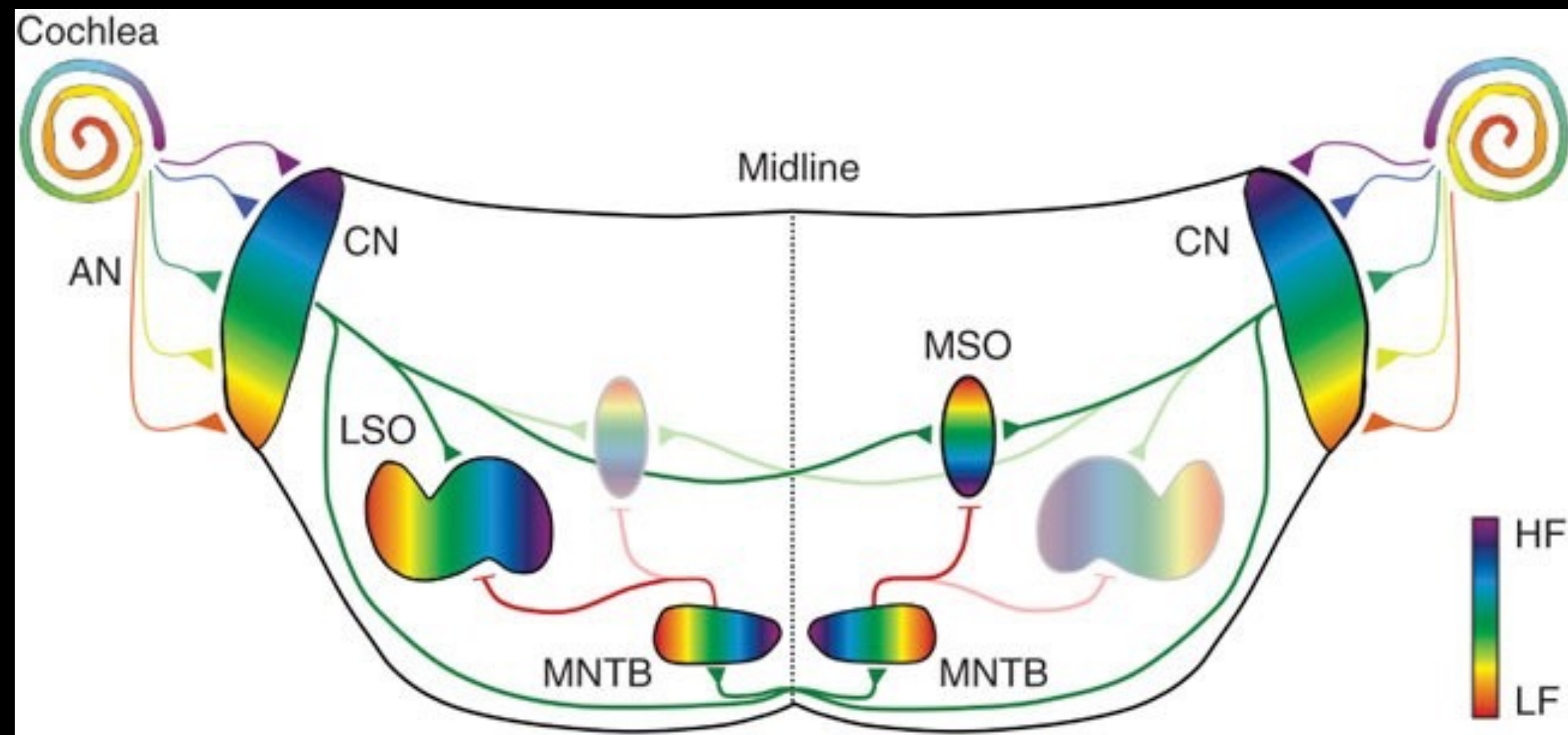
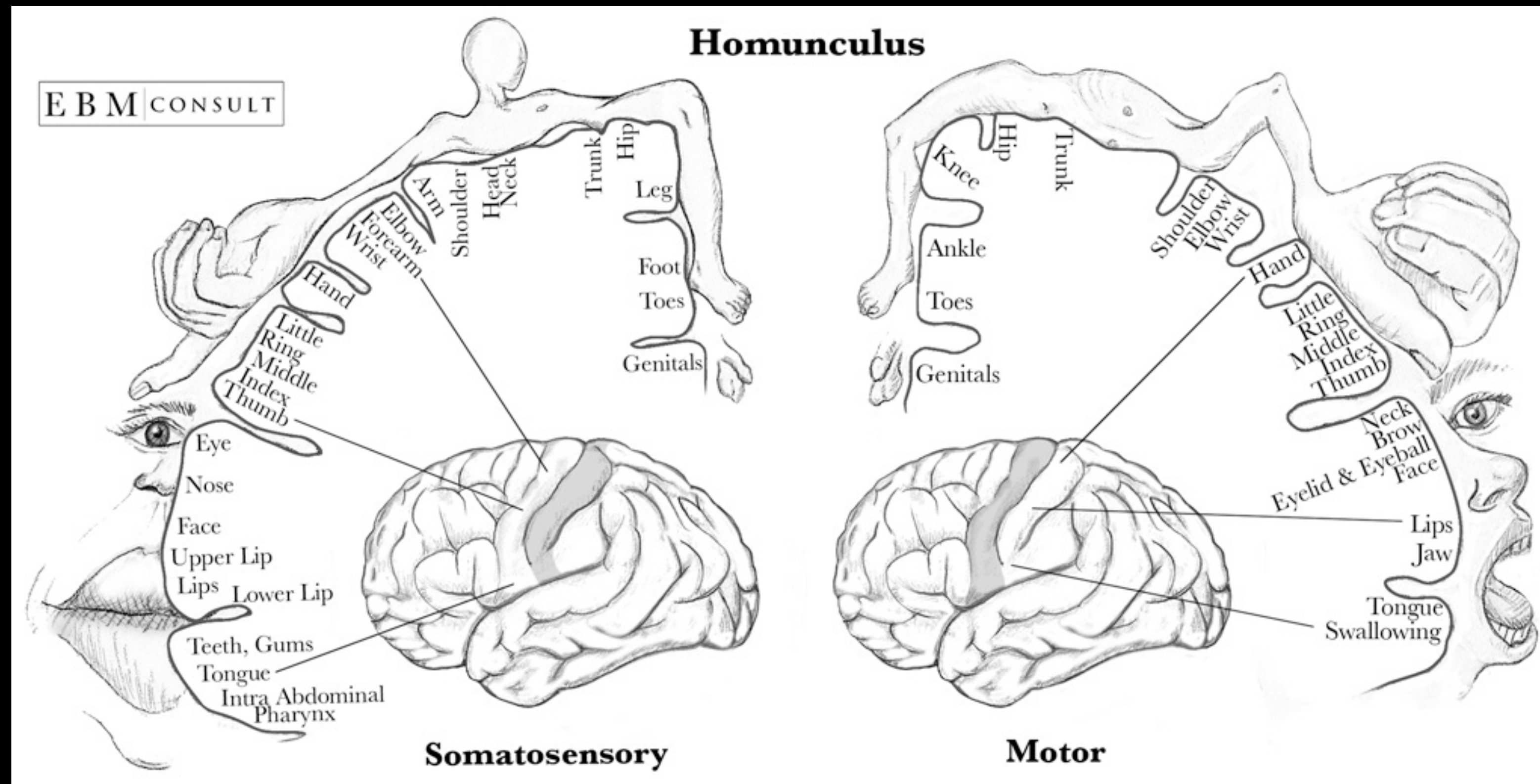


# Homunculus









# FUNDAMENTAL SOUND CONSTRUCTION

- **Pitch** - Tone (frequency) or Note (musical notation)
- **Rhythm** - Duration of a series of notes
- **Tempo** - Overall speed or pace of a piece of music
- **Contour** - "Shape" of a melody
- **Timbre** - Tonal Color by overtones and vibrations
- **Loudness** - How much energy and instrument creates
- **Reverberation** - distance to the source and echo within a space



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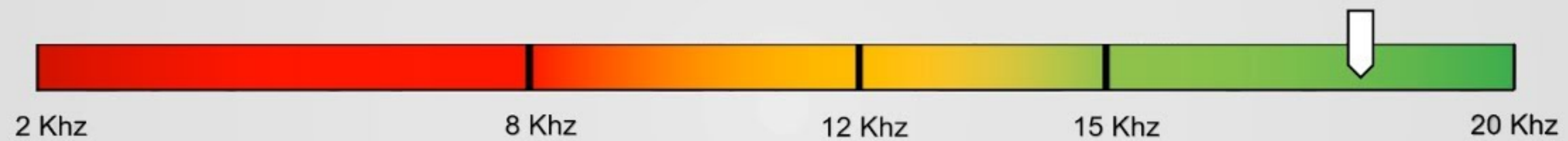


# PITCH

- Psychological phenomenon, a mental construct of the frequency of vibrations of molecules in the air.
- Sugar is only sweet because we agree on that term
- Humans have the physiologic machinery capable of producing a neural stimulus in response to frequencies from 20-20,000 Hz

# PITCH

## Too Old To Hear That?



Your hearing age is:

**18039 HZ**

**19**



# PITCH

- We have least pitch discrimination at the extremes of our physiologic capabilities.
- Most cultures use a semitone (half step) as the smallest interval in musical tradition
- The human ear can detect a pitch change of about 1/10 of a semitone
- Each tone represents a 6% increase in the frequency. Thus although there is a perception of equal intervals, the actual change in frequency between specific tones varies slightly.

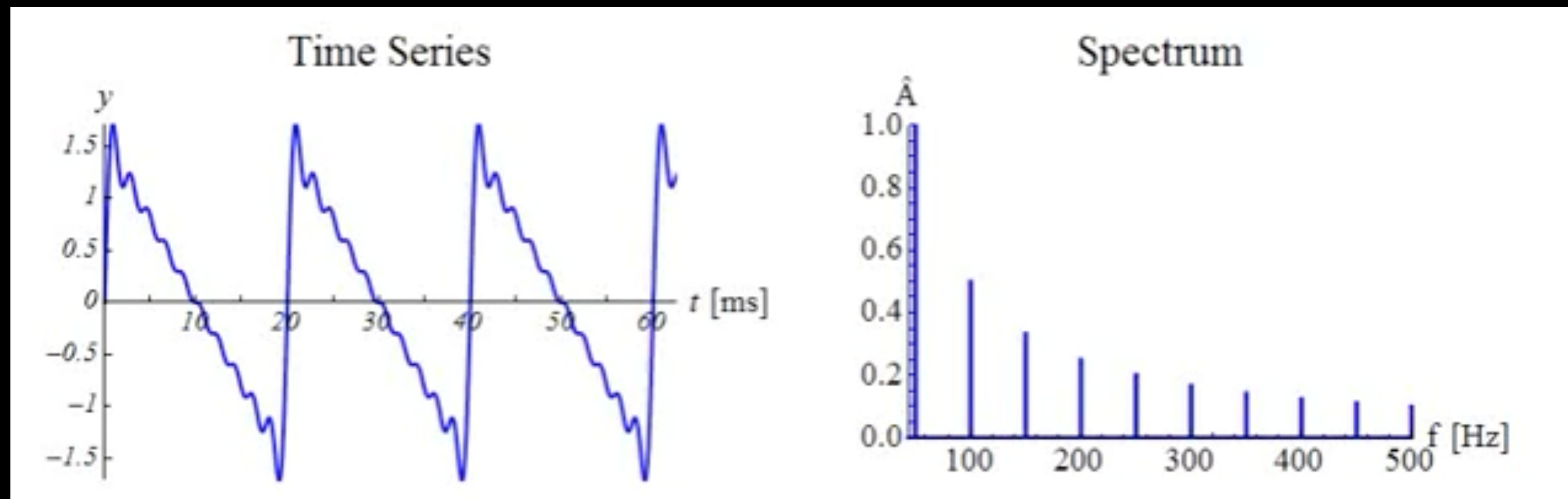
# TIMBRE

- All matter vibrates in more than one mode
- The fundamental frequency is the Lowest frequency that a substance vibrates
- Overtones are additional waves emanating from a vibrating object at multiples of the fundamental frequency
- When the multiple is an integer of the fundamental frequency, the overtones are said to be harmonic.



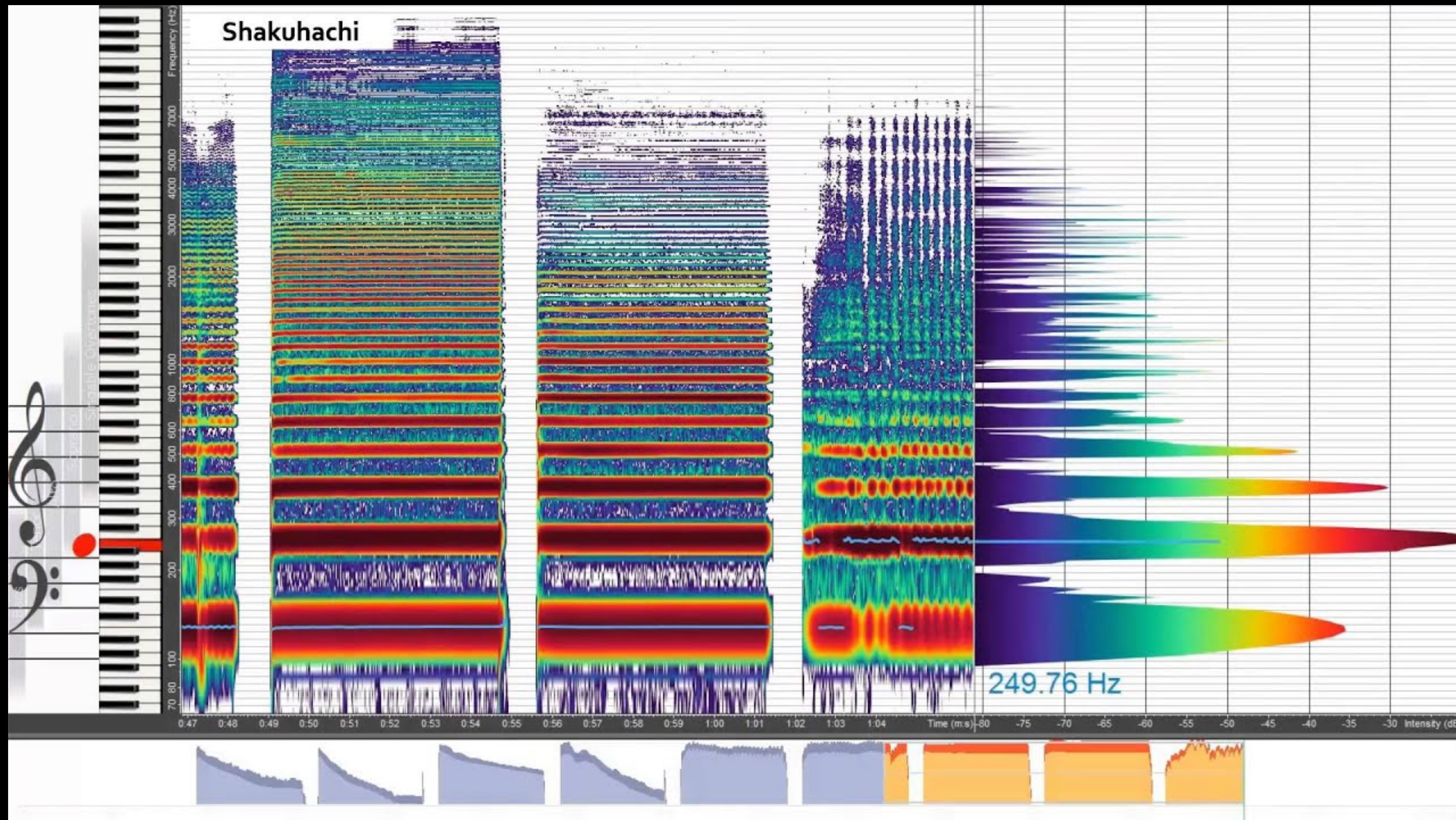
# SYNCHRONOUS NEURAL FIRING

- Vibrations of the fundamental frequency and the various overtones produce Synchronous Neural Firing in the auditory cortex
- Instrumental in identifying overtones as emanating from the same object
- *Restoration of the missing Fundamental*





# TIMBRE OF VARIOUS INSTRUMENTS





# INTERVAL

- An interval is the difference in frequency between two tones, or the distance within the octave between two notes
- The smallest distance in musical notation is the semitone or half-step
- There are 12 semitones in an octave
- The octave is a feature in all musical traditions and styles

<i>Distance in semitones</i>	<i>Interval name</i>
0	unison
1	minor second
2	major second
3	minor third
4	major third
5	perfect fourth
6	augmented fourth, diminished fifth, or tritone
7	perfect fifth
8	minor sixth
9	major sixth
10	minor seventh
11	major seventh
12	octave



# THE OCTAVE

- Tones with a frequency ratio of 1:2 are described as an octave (i.e. the bottom key on a piano is 27.5 Hz, the next A is 55 Hz, the next...110 Hz and so on up the keyboard)
- Mens voices are approximately 1 octave below women's and Childrens voices an octave higher again





# RHYTHM

- People on average can detect about 4% variation in tempo (bpm)
- Detecting tempo/rhythm/meter is directed by the cerebellum and possibly the thalamus



# PITCH AND TEMPO MATCHING





# FUNDAMENTAL MUSIC CONSTRUCTION

- The complex interaction between the sounds within music
  - **Meter** - grouping of tones across time using rhythm, pitch and loudness
  - **Key** - Hierarchy of tones in a musical piece
  - **Melody** - Main theme of a musical piece made of a succession of tones that are most salient in your mind
  - **Harmony** - the relationship between pitches of different tones and the progression of chords



# THE SOUND OF MUSIC

- Music is the neural integration of a collection of sounds into a mental construct

♩ = 76

1

3 2

6 3 2 0 1 4 2 0 3

8 3 2 4 0 2 1

10 4 0 2 1

12 0 4 0 4

15 0 3 2 0

18 1 2 2 4 4 1 4

21

23 4 4



# GREAT EXPECTATIONS

- Much of music composition is playing to...or at times defying the expectations of
  - Rhythm
  - Pitch
  - Interval
  - Tuning

# NEURAL FUNCTION IN MUSIC

- "Music listening, composition and performance engage nearly every area of the brain that we have so far identified"



