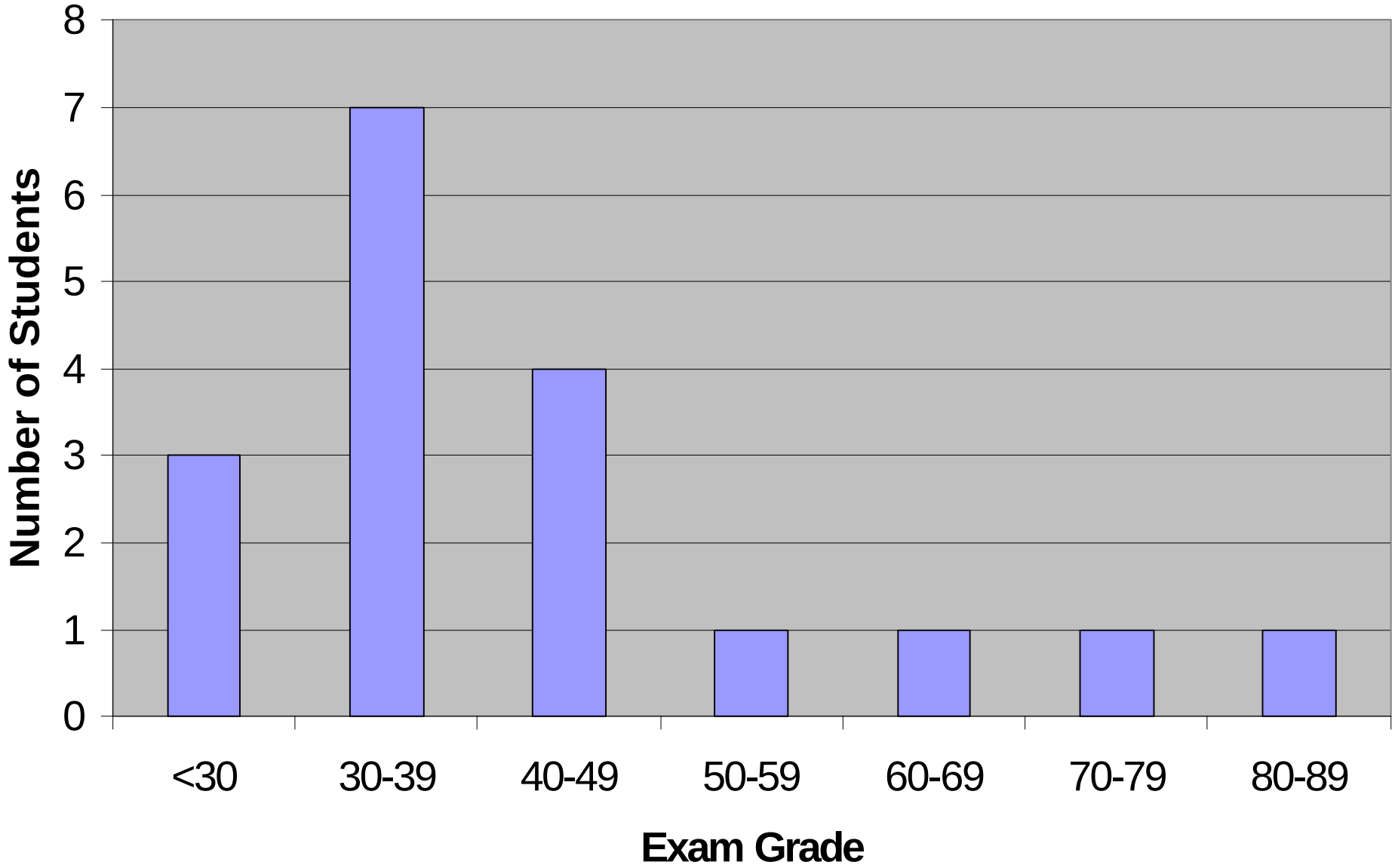
Symphony #1 in D
Last Movement

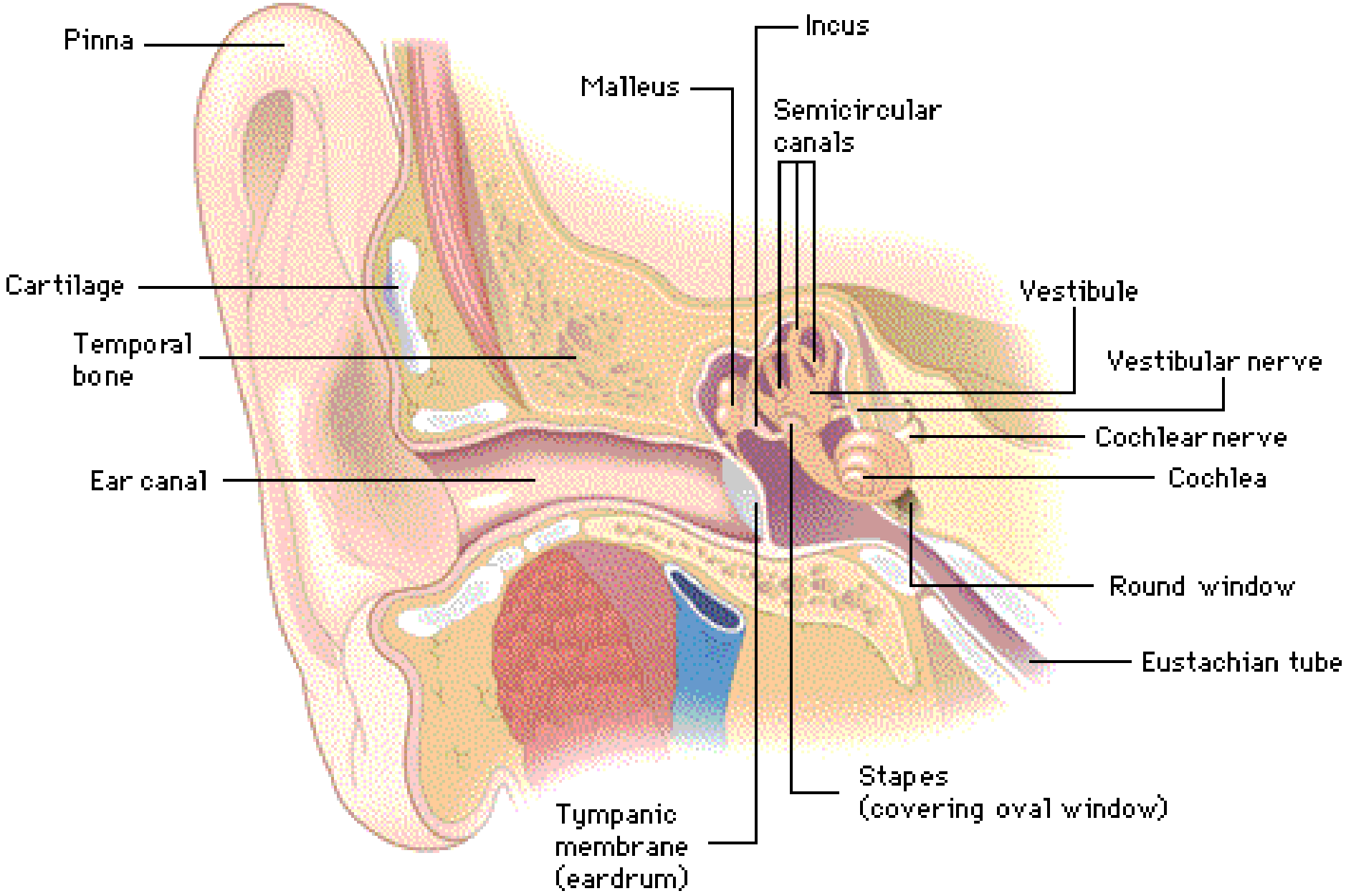
Exam #1 Grade Distribution



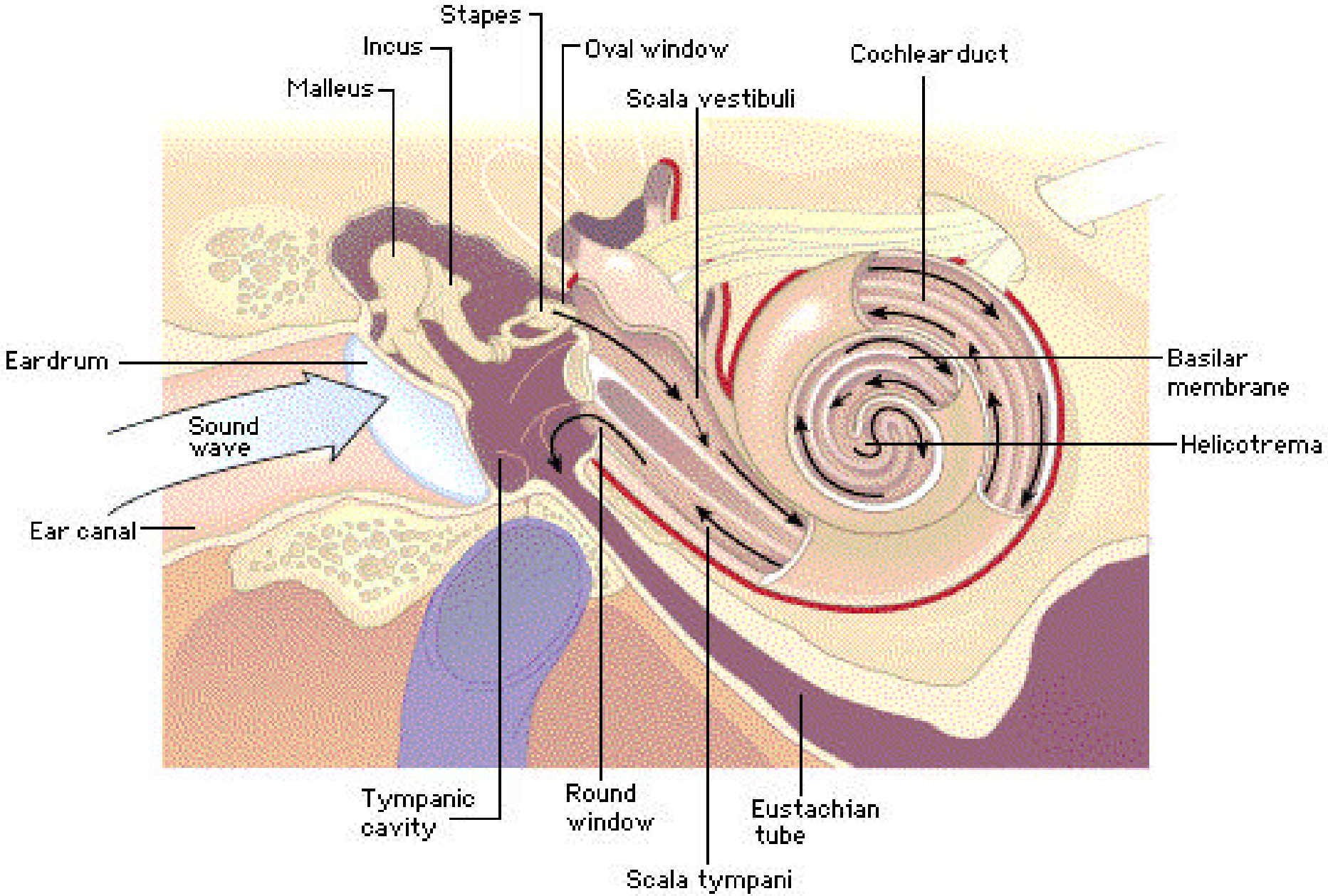
Structure of The Ear

- Outer Ear
- Middle Ear
- Inner Ear

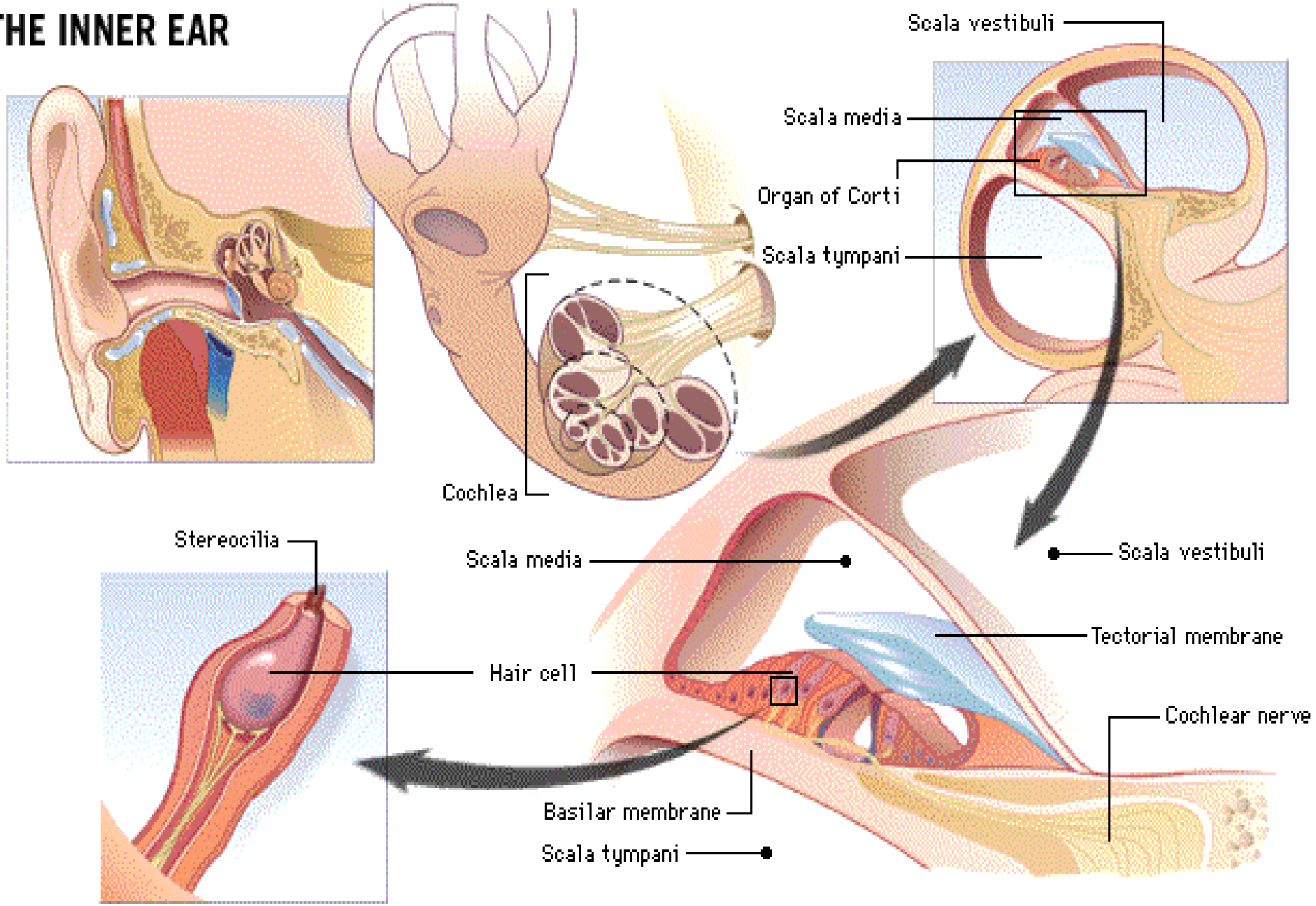
THE HUMAN EAR



THE MIDDLE AND INNER EAR



THE INNER EAR



Hildegard von Bingen (1098-1179)

Music from

Symphonia Harmonia Caelestium Revelationum

Discrimination Between Sounds

Just Noticeable Difference

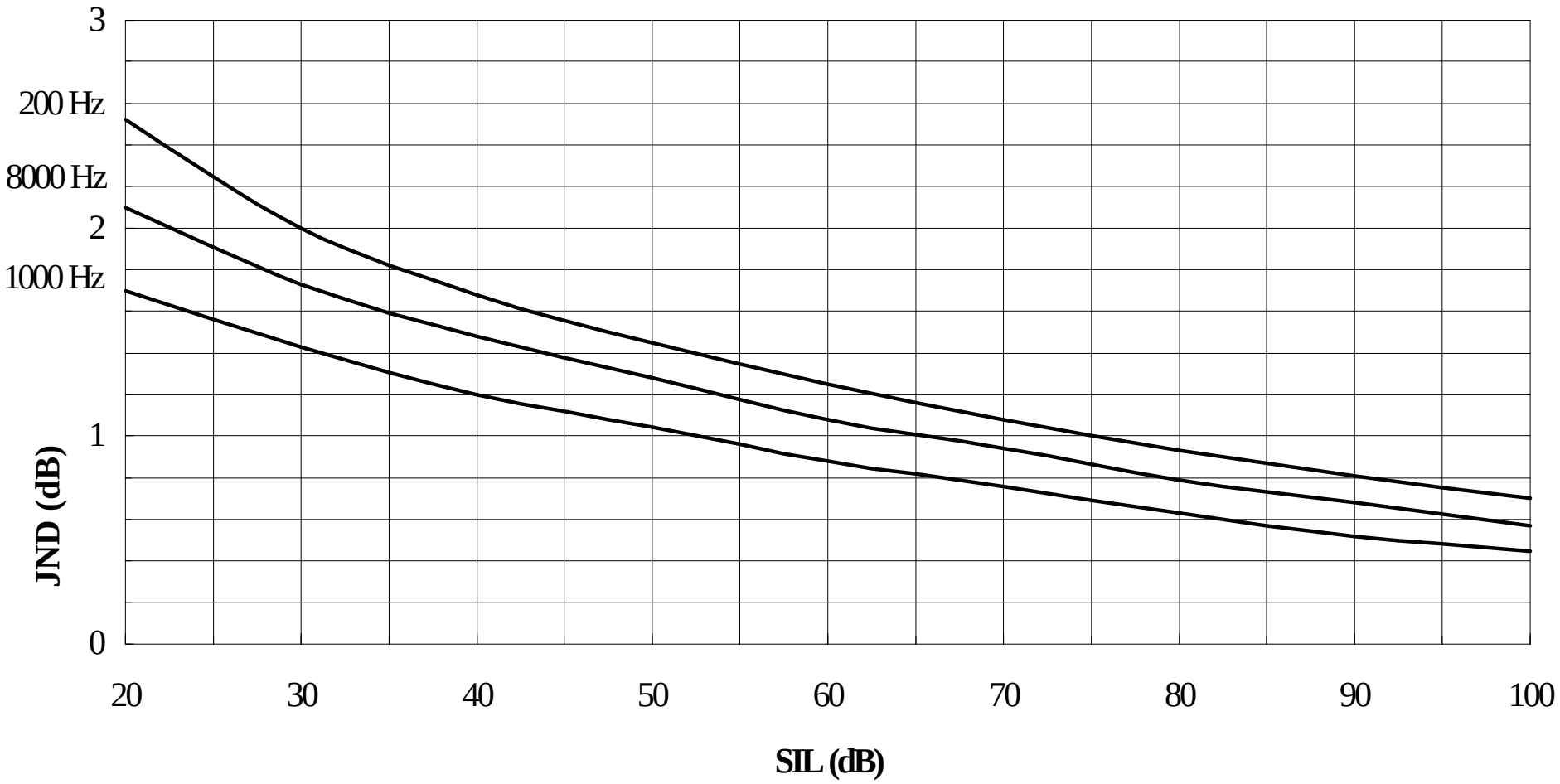
or

JND

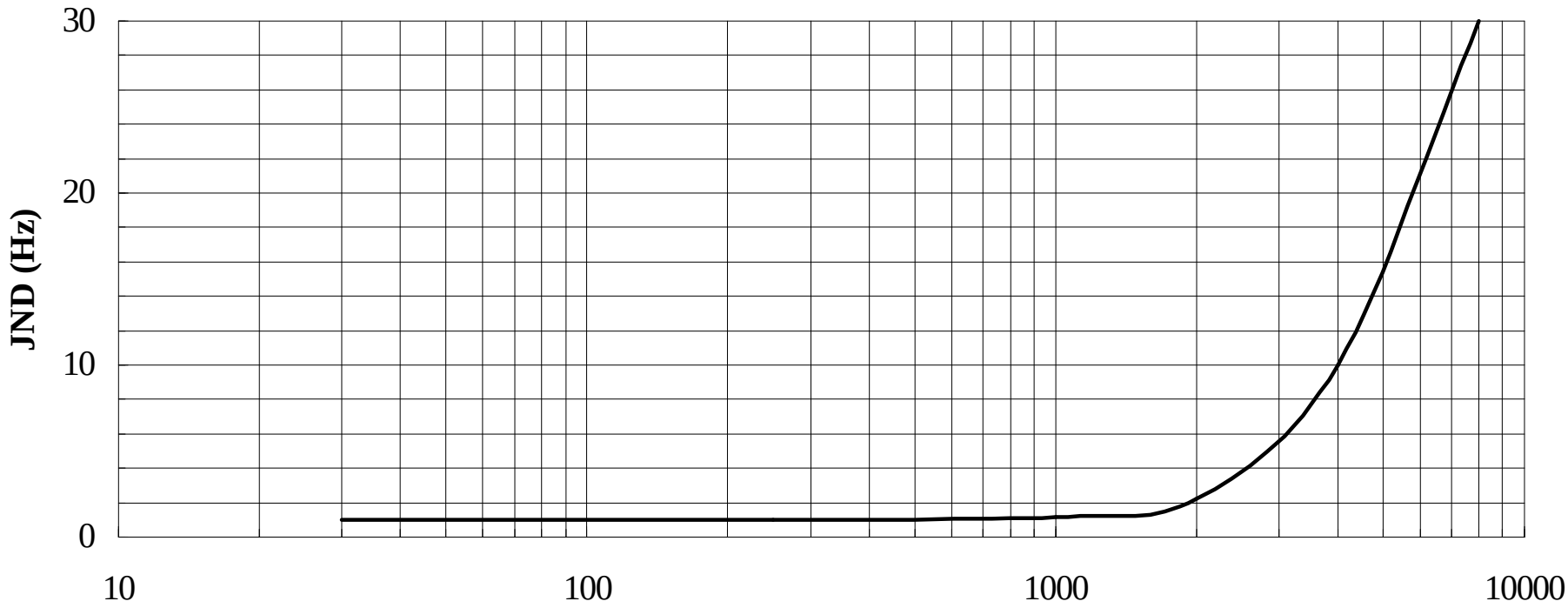
2AFC Testing

- 100 % correct ⇒ Certainty
- 50% Correct ⇒ Guess
- Cutoff is defined for 75%

JND for SIL


3
200 Hz
8000 Hz
2
1000 Hz
1
0
JND (dB)
20
30
40
50
60
70
80
90
100
SIL (dB)

JND for Frequency



Physical Characteristics

- Intensity = I (W/m^2)
- Sound Intensity Level = SIL (dB)

Psychological Characteristic

Loudness

Psychological Characteristic

For two sounds,

A and B,

if $I_A/I_B = 2$,

what to we hear?

Psychological Characteristic

For two sounds,

A and B,

if $SIL_A/SIL_B = 2$,

what to we hear?

Phon

The phon is the unit of

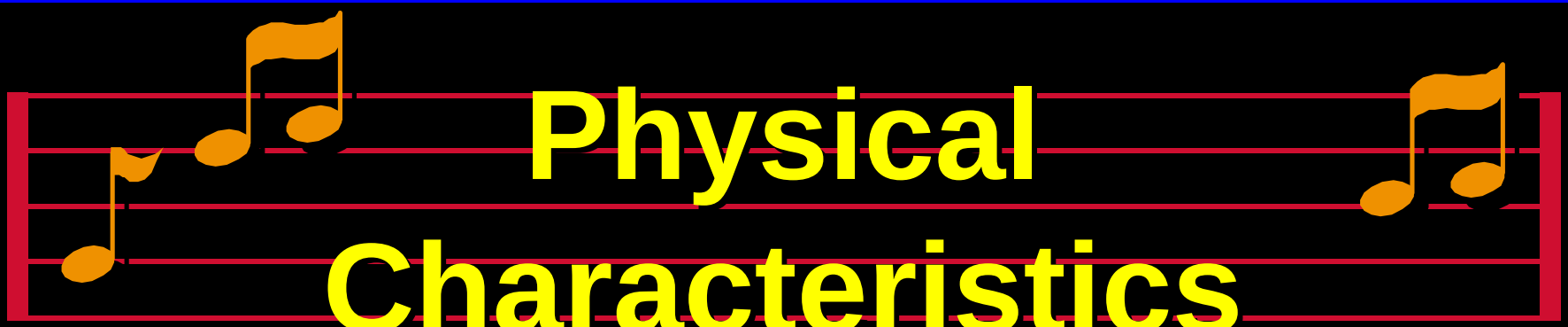
Loudness

Level

(LL)

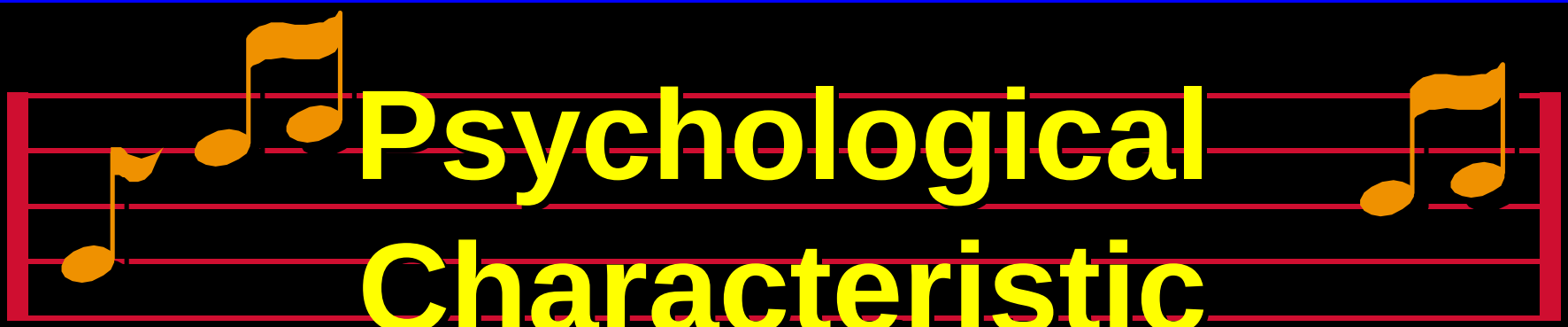
Phon

The LL (in phons) of a sound is defined to be numerically equal to the SIL (in dB) of a 1000 Hz tone that sounds equally loud ***to the listener***.



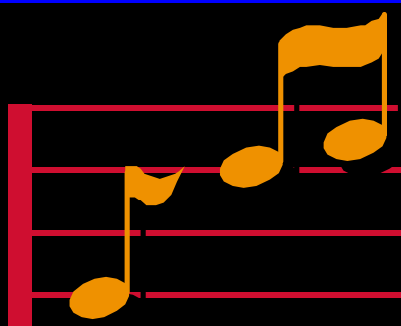
Physical Characteristics

Frequency



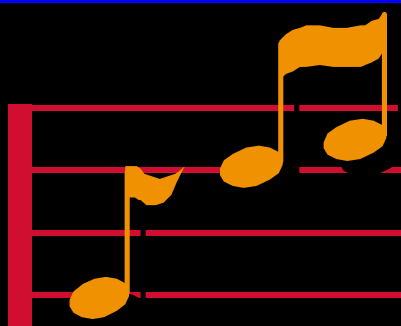
Psychological Characteristic

Pitch



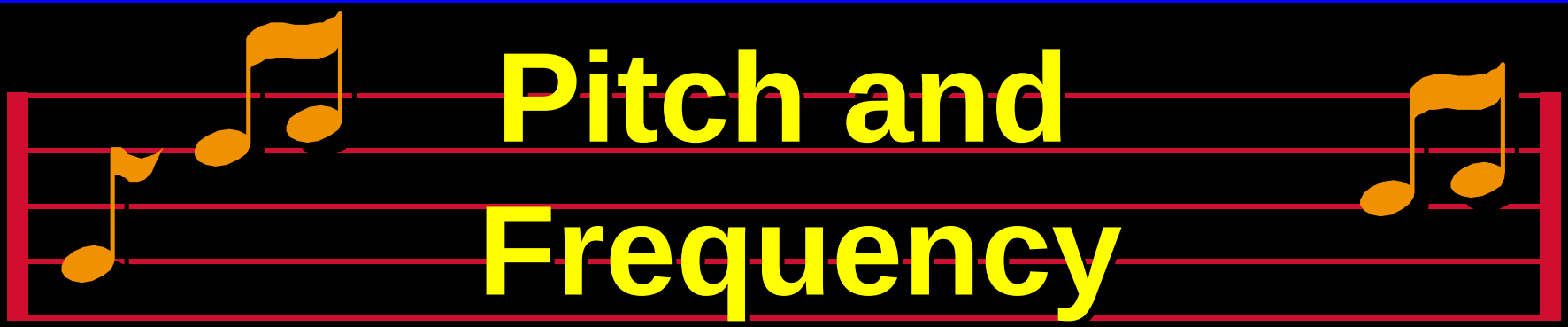
Pitch and Frequency

If note A ***sounds*** twice as high in pitch as note B, it is found that the ***frequency*** of A is twice that of B.



Pitch and Frequency

- Natural unit of pitch is the **Octave**.
- Simple relationship between pitch and frequency.



Pitch and Frequency

Demo with keyboard.

Loudness and Frequency

The loudness of a sound depends on the frequency of the sound.

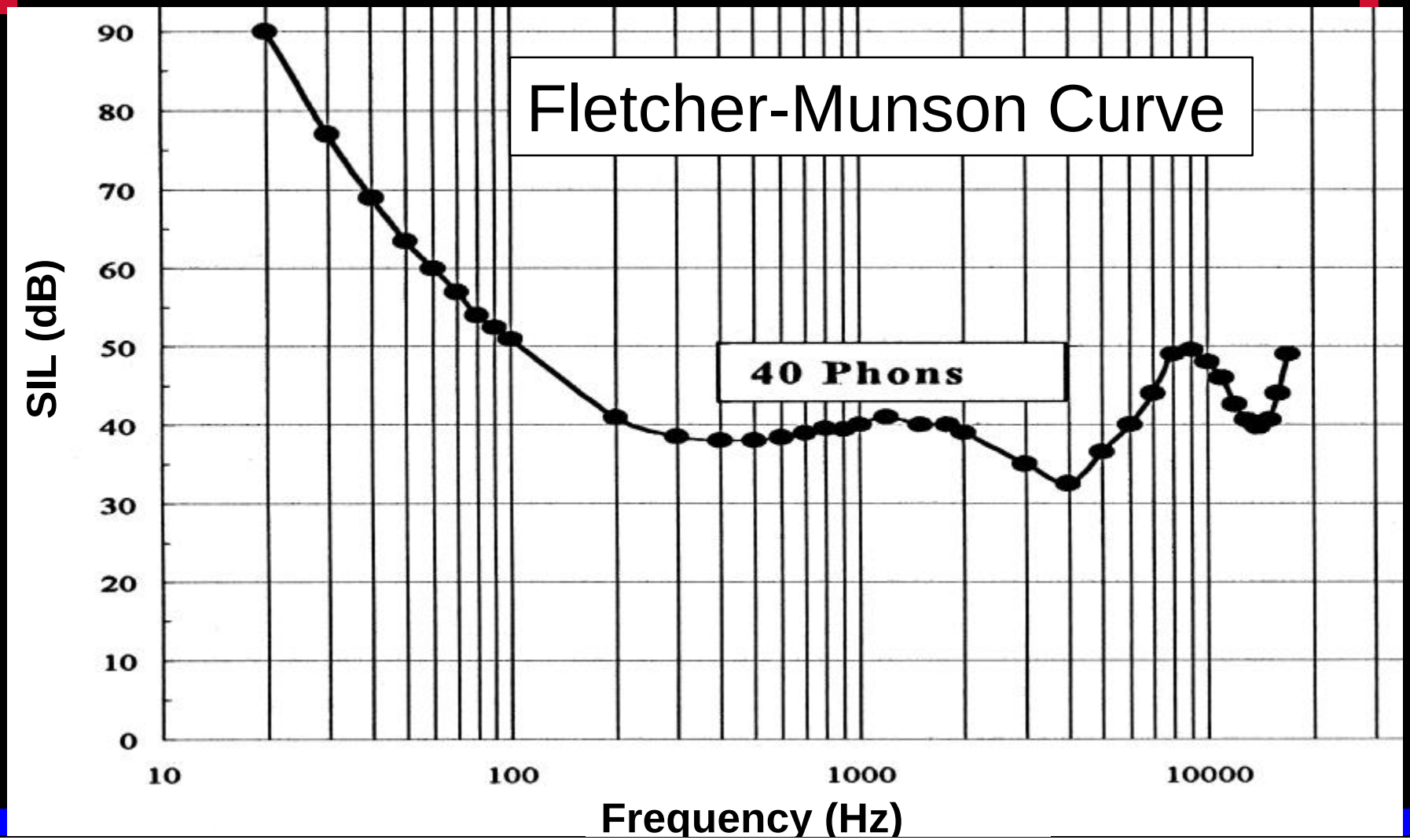
Experiment

1. Play 1000 Hz at SIL=40 dB.
2. Play 100 Hz. Ask listener to adjust for the same loudness.
3. Repeat for many frequencies

Experiment

f(Hz)	SIL (dB)		f(Hz)	SIL (dB)
20	90		2000	39
50	64		4000	32
100	51		6000	36
500	38		8000	49
1000	40	defined	10000	48
1500	40		15000	41

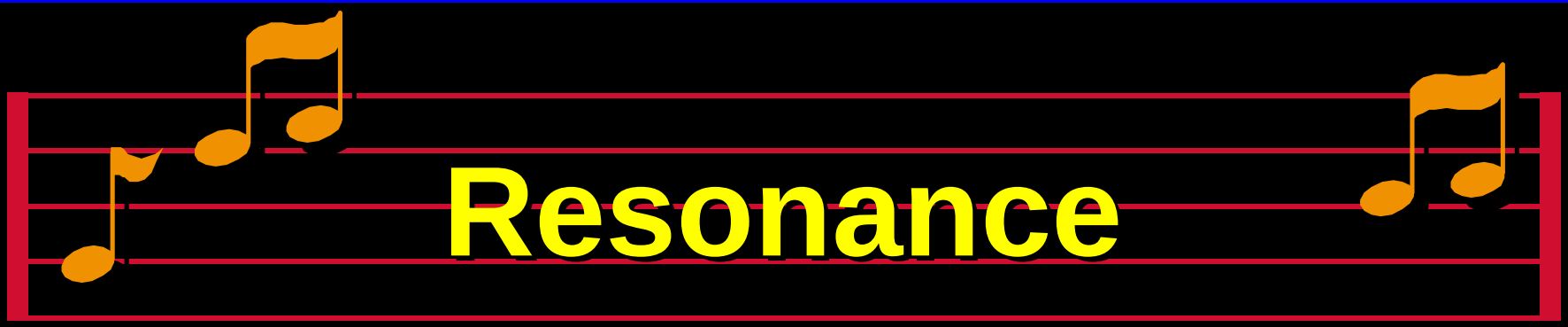
Equal Loudness Contour



Loudness changes with Frequency

Auditory Demo CD

Tracks 17 and 18



Resonance

Hearing is most sensitive in the range 2,500 – 5,000 Hz. Why?

Ear canal is a tube closed at one end

$\lambda = 4L = 4(2.5\text{ cm}) = 10\text{ cm}$

$f = v/\lambda = 344\text{m/s} / 0.1\text{m} = 3{,}440\text{ Hz}!$

Repeat for all SIL's