Human Sensory System

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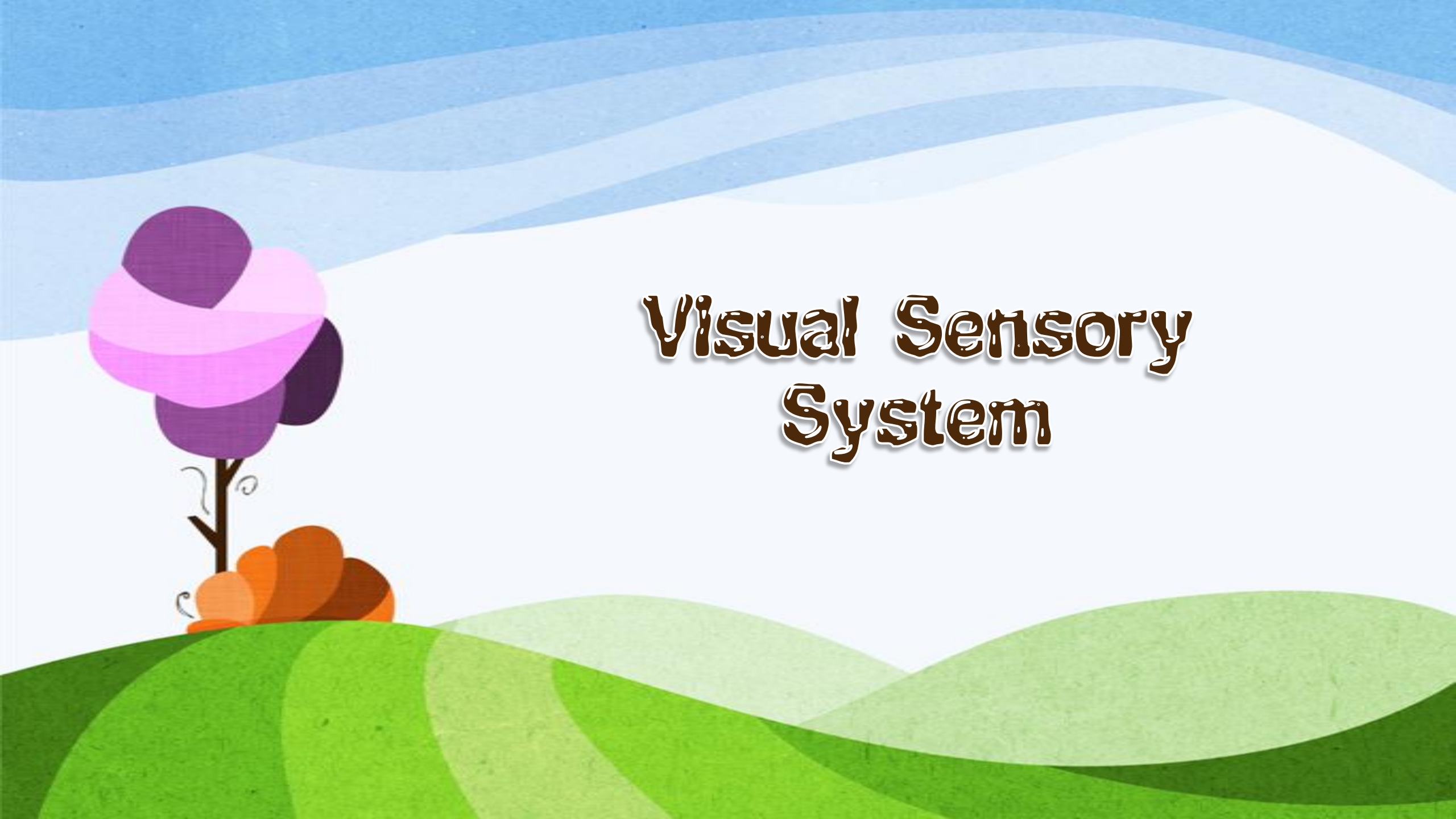
Illustrative Video

New warning signs about cell phone service have been posted on the Adirondack Northway, but drivers say they are hard to read.

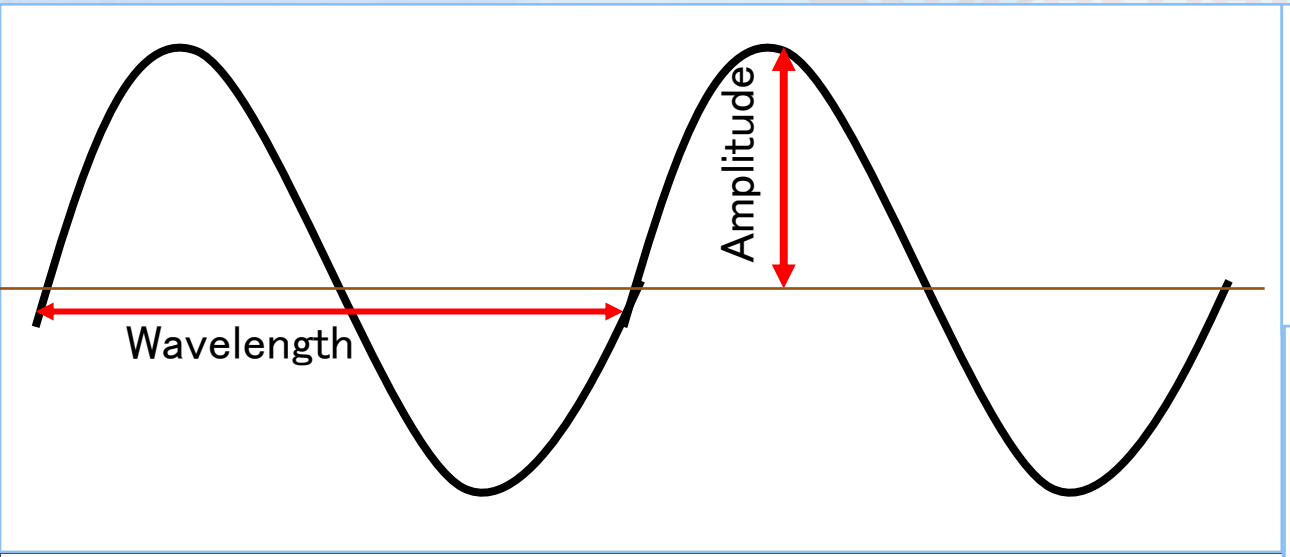
What's your opinion about this condition?

INTRODUCTION

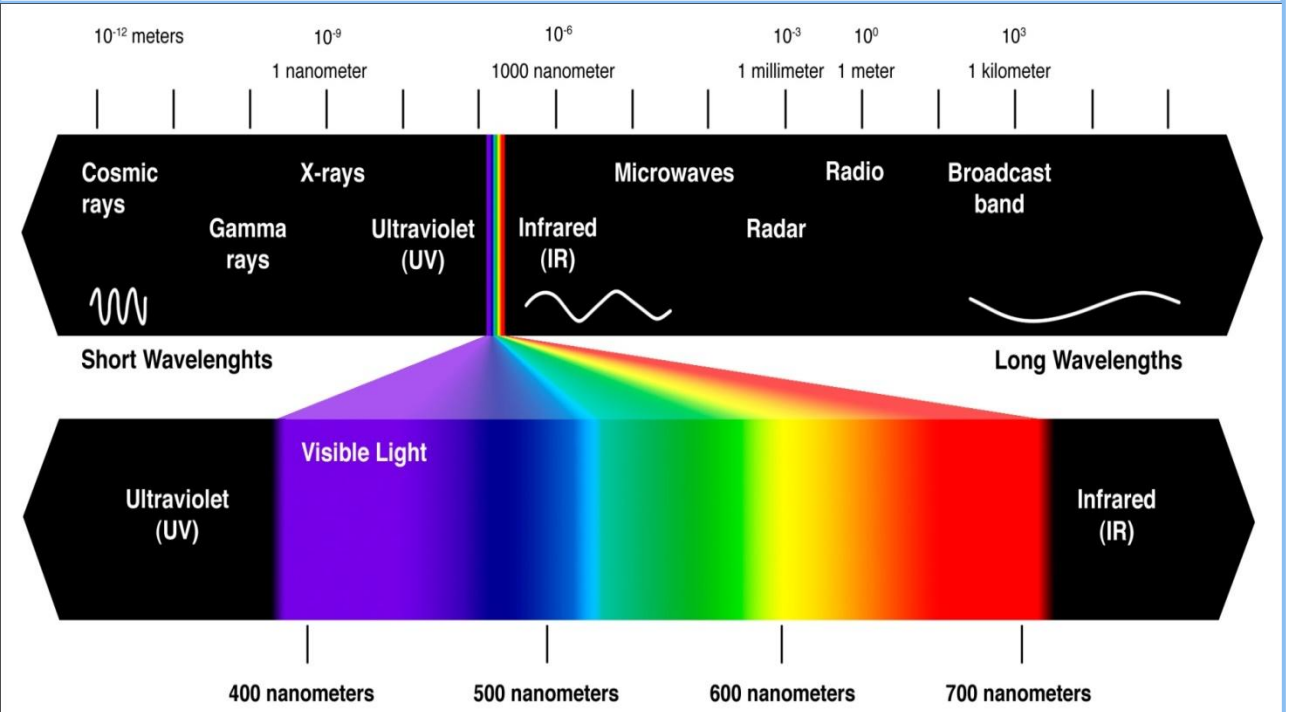
- Human beings receive stimuli from many sources. Some of these can be sensed, some cannot. The stimuli are distant or close sources of energy, such as light, thermal energy, mechanical energy, chemical energy, sound, and so on.
- **Five classic sense (vision, audition, smell, taste, and touch),** known as **EXTEROCEPTORS.** These are so called since they deal with stimuli external to the body.
- **PROPRIOCEPTORS** are stimulated by the actions of the body itself, such as reach or a sudden turn. Proprioceptors are embedded within **the subcutaneous tissue**, such as in the muscles and tendons, around the joints, and the inner ear.


Visual Sensory System

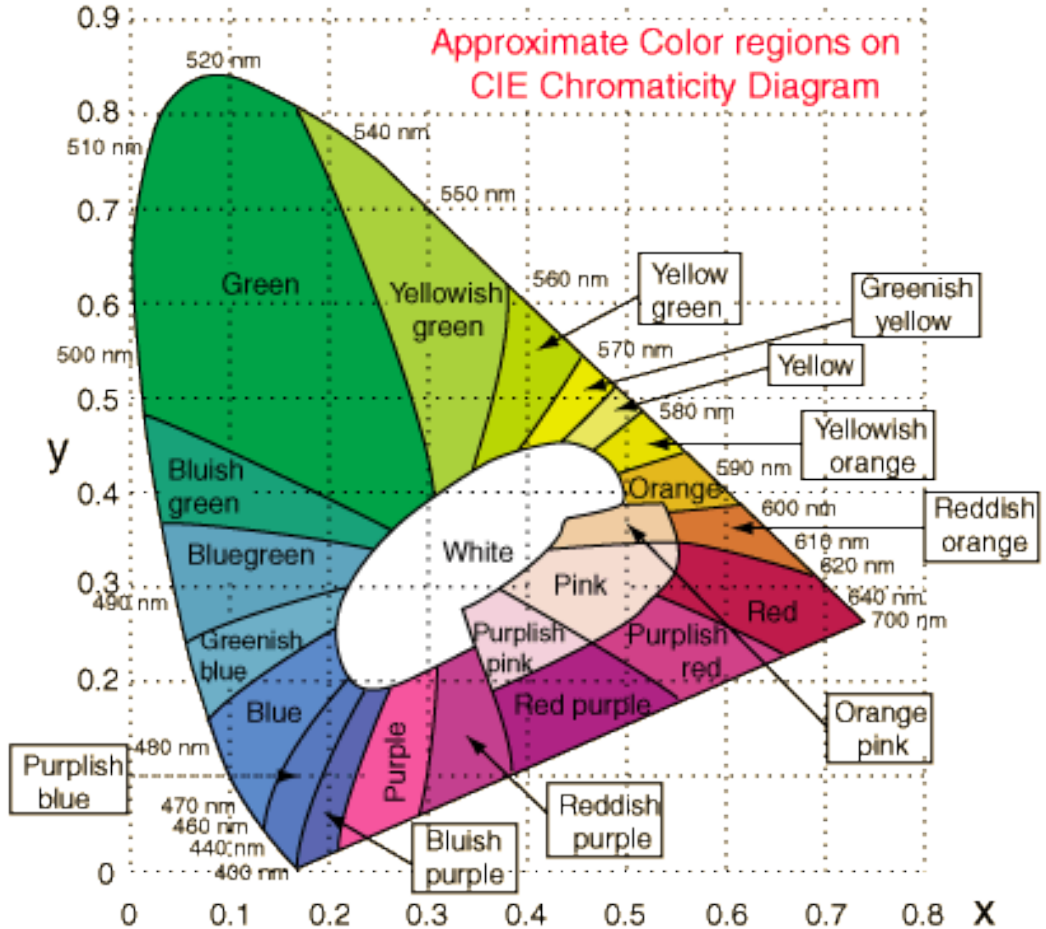
Properties Of Light



- Light is a wave of electromagnetic energy
- Amplitude perceived as brightness
- Wavelength (nm) perceived as hue (warna)
- Eye is sensitive to the light



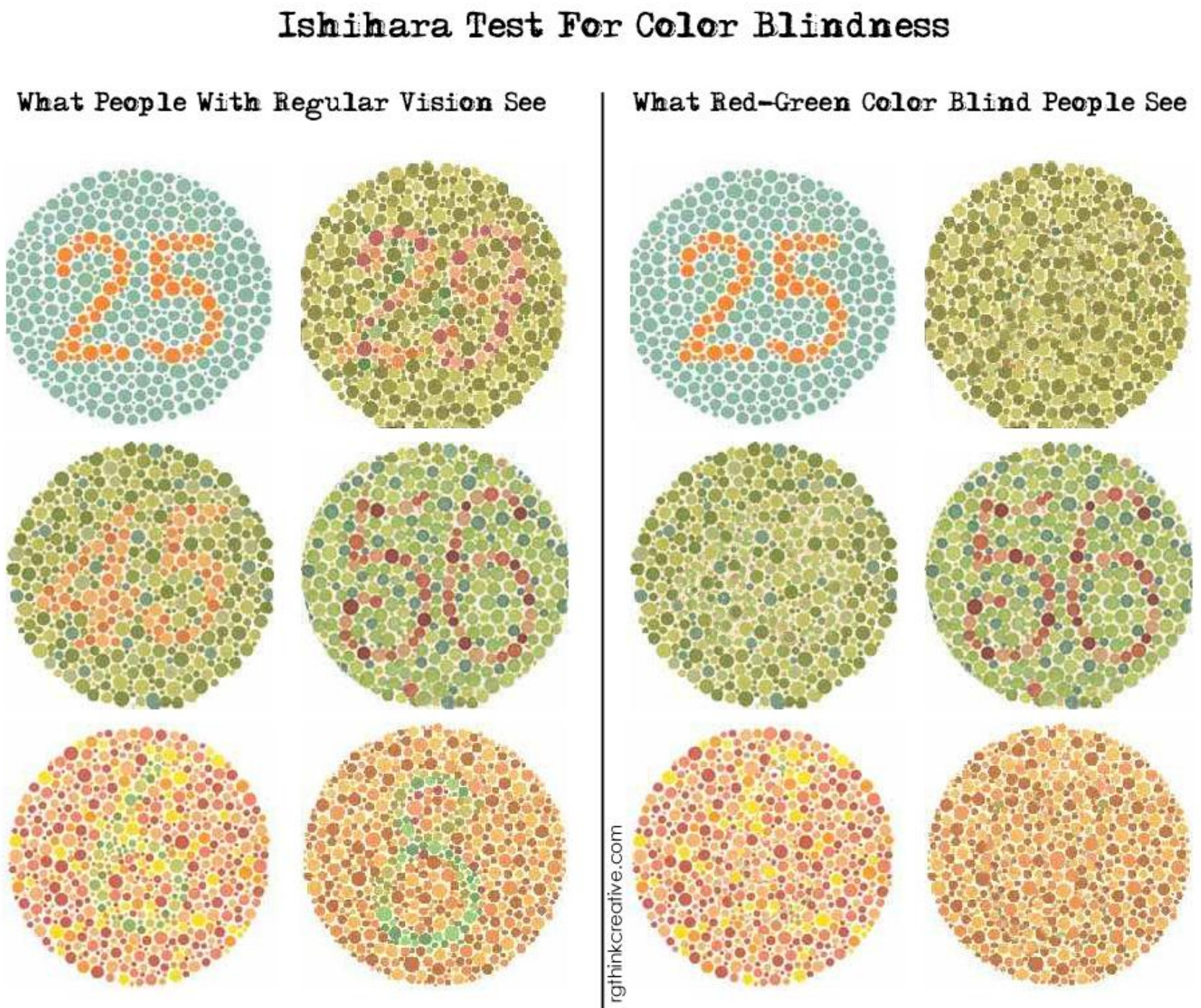
(The visible spectrum of electromagnetic energy / light)



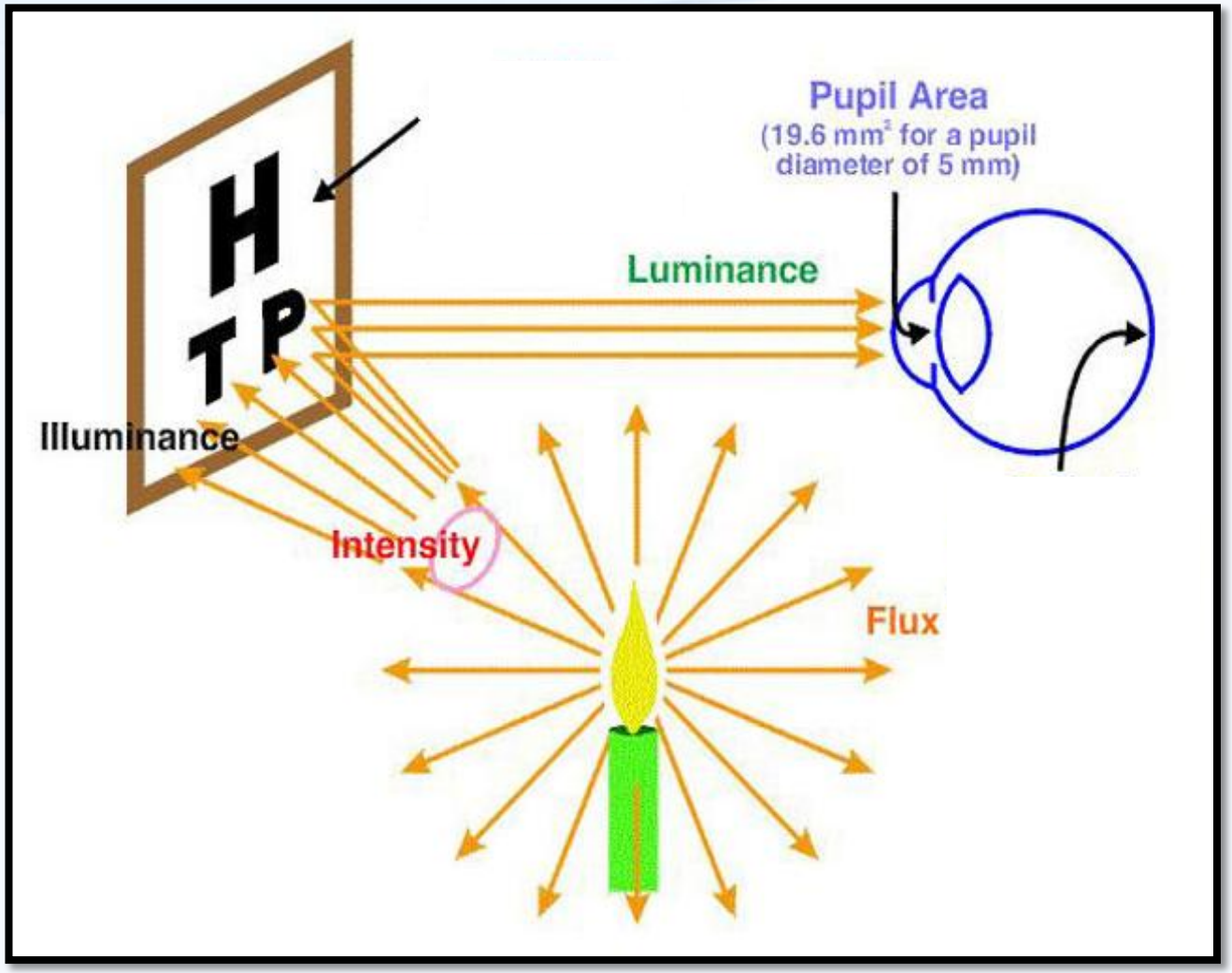
Color Vision

Types of color deficiencies and color blindness :

- **Protanomaly** (1% of males) – low sensitivity to red
- **Deuteranomaly** (6% of males) – low sensitivity to green
- **Protanopia** (<1% of males) – the brightness of red, orange, and yellow is much reduced compared to normal. This dimming can be so pronounced that reds may be confused with black or dark gray.
- **Deuteranopia** (<1% of males) –suffers the same hue discrimination problems as the protanopia, but without the abnormal dimming. The names red, orange, yellow, and green really mean very little to him aside from being different names that every one else around him seems to be able to agree on.
- **Tritanomaly/Tritanopia** (very rare in both sexes) – blue–yellow deficiency/blindness
- **Monochromacy** (extremely rare) – inability to distinguish any colors



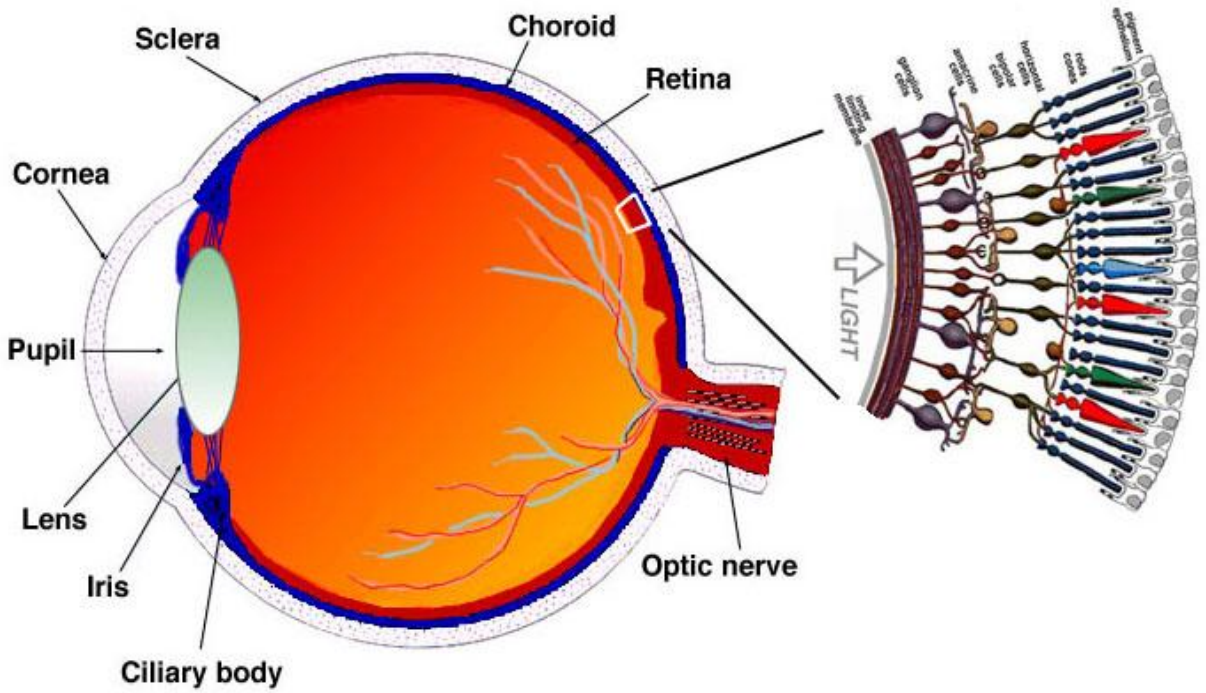
Concept Behind The Perception Of Visual Brightness



- Source of light : candle
- **Luminous intensity / flux** : the actual light energy of the source (measured in units of **candela or 12.57 lumins**)
- **Illuminance** : the amount of light that actually strikes the surface of an object to be seen (measured in units of **10.76 lux or foot candles**)
- **Luminance** : the amount of light reflected off of objects to be detected, discriminated, and recognized by the observer when the objects are not themselves the source of light (measured in units of **foot lamberts or candela/m^2**).
- **Luminance is different from illuminance** because of differences in the amount of light that surfaces either reflect or absorb. Which one is reflect between black surface and white surface?

$$\text{Reflectance}(\%) = \frac{\text{luminance(FL)}}{\text{illuminance(FC)}}$$

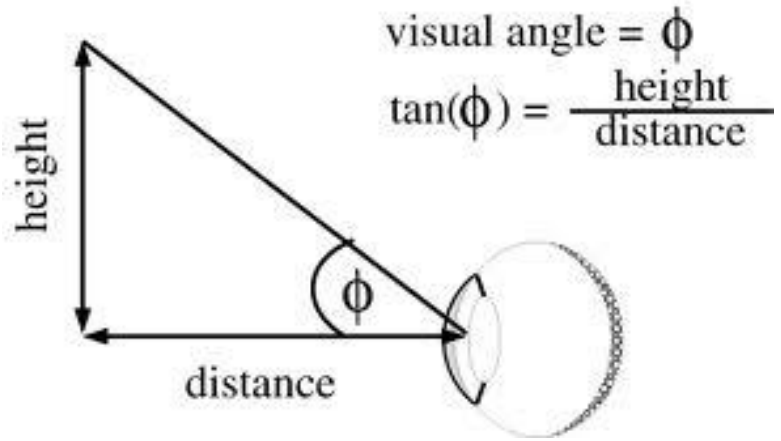
Anatomy Of The Eyeball



- **Cornea** – protective surface that absorbs some of the light energy
- **Pupil** – opens or dilates (in darkness) and closes or constricts (in brightness) to admit adaptively more light when illumination is low and less when illumination is high.
- **Lens** – adjusting its shape or accommodating, to bring the image to a precise focus on the back surface of eyeball.
- **Retina** – area in back of eye containing photoreceptor
  - **Rods** – sensitive to dim light (night vision) – found mostly in periphery – function under low illumination levels (scotopic) – seeing shades of black and white.
  - **Cones** – sensitive to color (daylight vision) – concentrated in fovea – provides fine detail – function under high illumination levels (photopic)
- **Accommodation** – changing the shape of the lens to focus images on the retina caused by contracting/relaxing ciliary muscles. Lens flattens (muscles relax) when focusing on distant objects and becomes rounder for focusing on close objects (muscles contract causing fatigue).
- **Myopia** – nearsightedness caused by inability to flatten the lens enough to focus image on retina (may be due to elongated eye)
- **Presbyopia** – farsightedness that occurs naturally with age as the lens becomes less flexible.

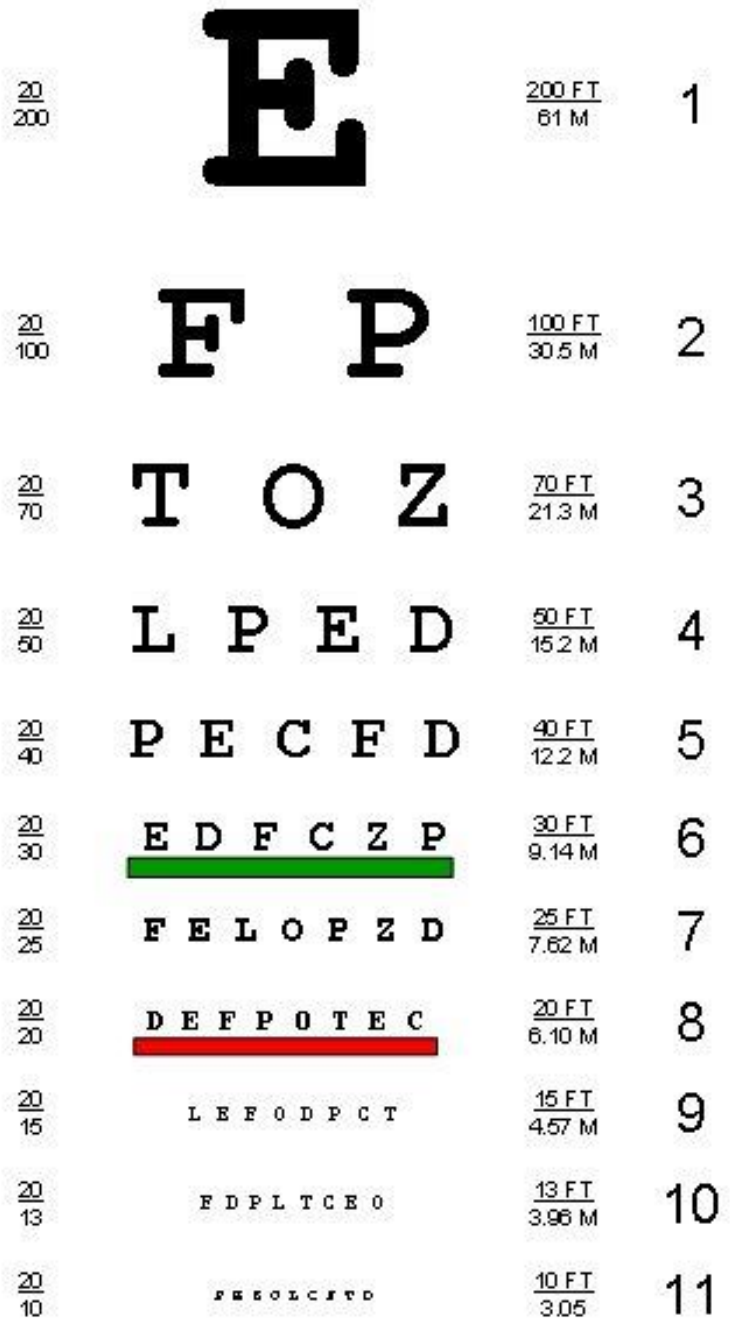
For visual angles less than around 10°,
the angles may be expressed in minutes of arc
rather than degrees (60 minutes = 1 degree),
and approximated by the formula :

$$VA = 5.7 \times 60 \times (H/D)$$



VISUAL ACUITY

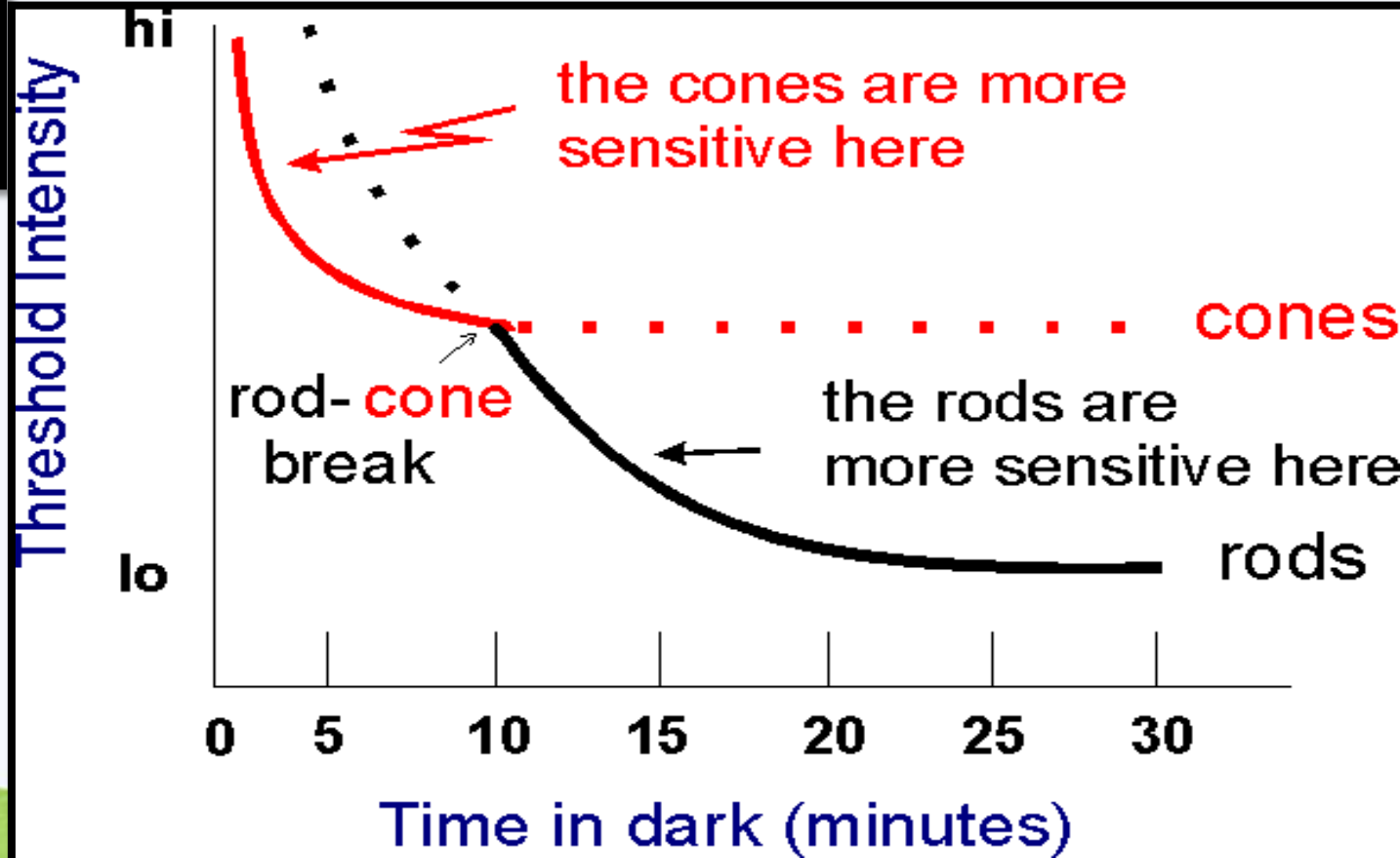
- It is the ability to see fine detail / sharply.
- The test can be done using Snellen Eye Chart.
- 20/40 Vision – a person can see from 20 feet what a person with “normal” vision can see from 40 feet
- 20/20 Vision – a person can see from 20 feet what a person with “normal” vision can see from 20 feet



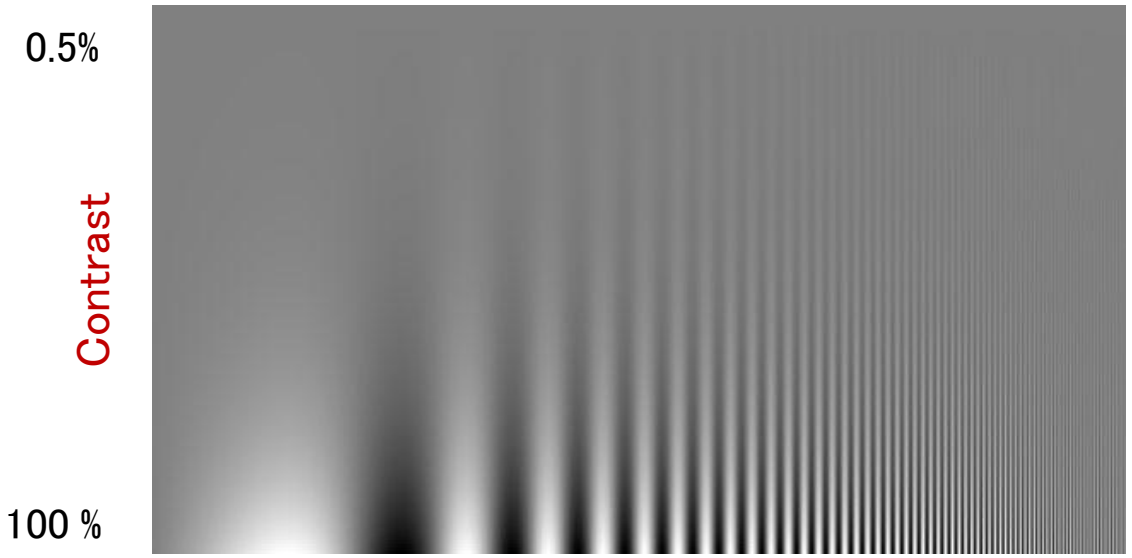
DARK ADAPTATION

- When moving from dark to light room, the human eye adapts in a few seconds.
- But it takes up to 40 minutes to adapt from light to dark room.

- In industrial tasks, where light conditions change from light to dark, sufficient time must be allowed for dark adaptation.
- Human Factors Application : why are red lights used in cockpits and darkrooms?
- Because rods are insensitive to the longest wavelengths (red). It didn't degrade dark adaptation.



SPATIAL FREQUENCY



Spatial frequency is expressed as
the number of cycles per degree of visual angle.

Contrast, Spatial Frequency (Font Size) and Font Style must be considered in the display of text for optimum legibility
(Human Factors Application : While the green background provides good contrast and the font size is highly legible, the font style does not allow for visual separation of letters.)

CONTRAST AND VISIBILITY

Variable	Effect	Example
↓ Contrast	↓ Visibility	Black print on gray
↓ Illumination	↓ Contrast Sensitivity (CS)	Reading map in poor light
Polarity	Black on white better than white on black	Designing viewgraphs
Spatial Frequency	Optimum CS at 3 C/D	Ideal size of text font given viewing distance
Visual Accommodation	CS	Map reading during night driving
Motion	↓ CS	Reading a road sign while moving

TOP-DOWN VS BOTTOM-UP PROCESSING

EXPERIENCE

Top – Down Processing

- Knowledge
- Expectations
- Desires

Perception

- The 5 senses

STIMULUS WORLD

Bottom – Up Processing

DEPTH PERCEPTION is the visual ability to perceive the world in three dimensions (3D) and the distance of an object.

MONOCULAR CUES can be represented in just two dimensions and observed with just one eye

Relative Size : If two objects are roughly the same size, the object that looks the largest will be judged as being the closest to the observer.

Linear Perspective : Parallel lines appear to meet as they travel into the distance.

Interposition : When one object overlaps another, the object that is partially obscured is perceived as being farther away.

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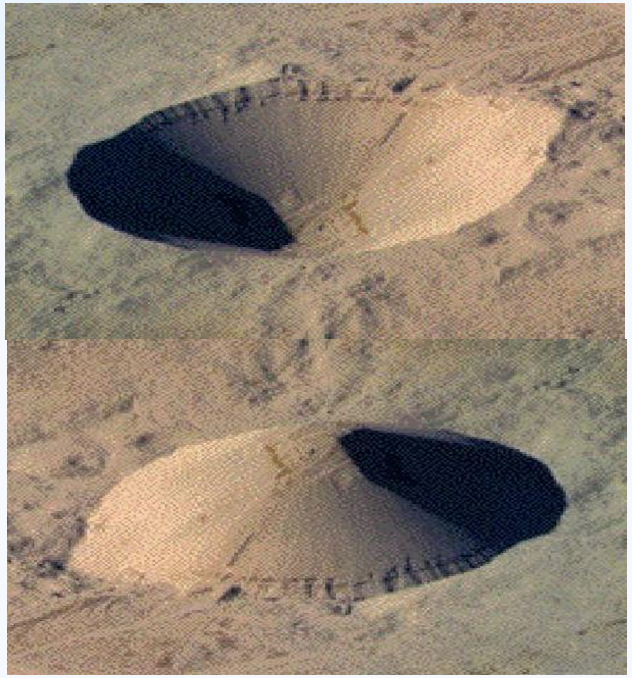
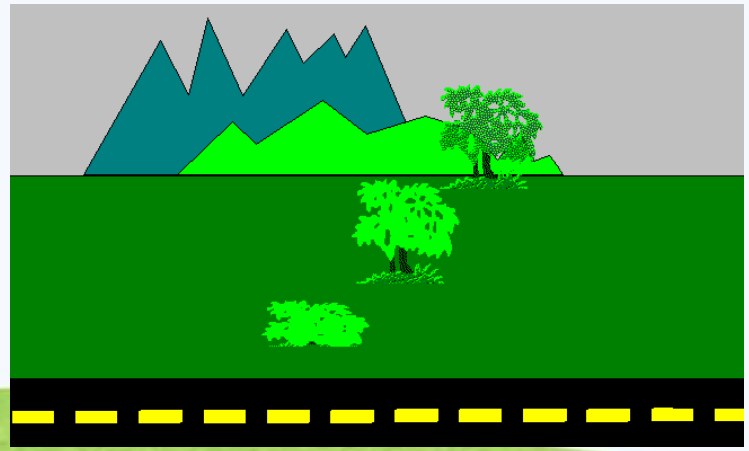


Light & Shading – 3D objects cast shadows and shade on opposite side of illumination source, and reflections on same side

Textual Gradients – Texture appears more fine with increasing distance

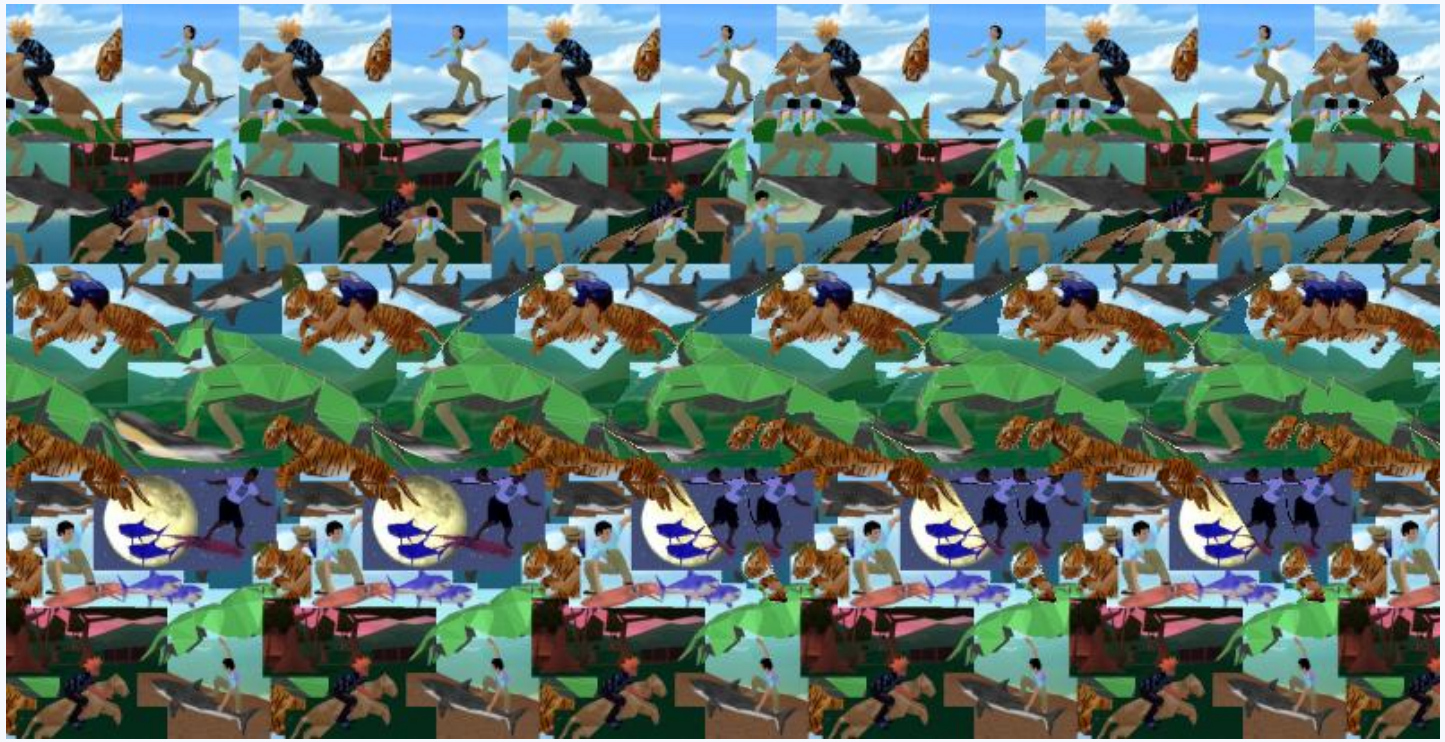
Aerial Perspective – Objects in the distance appear hazy or bluish



Motion Parallax – As perceiver moves, objects in foreground appear to move by faster than objects in background

DEPTH PERCEPTION is the visual ability to perceive the world in three dimensions (3D) and the distance of an object.

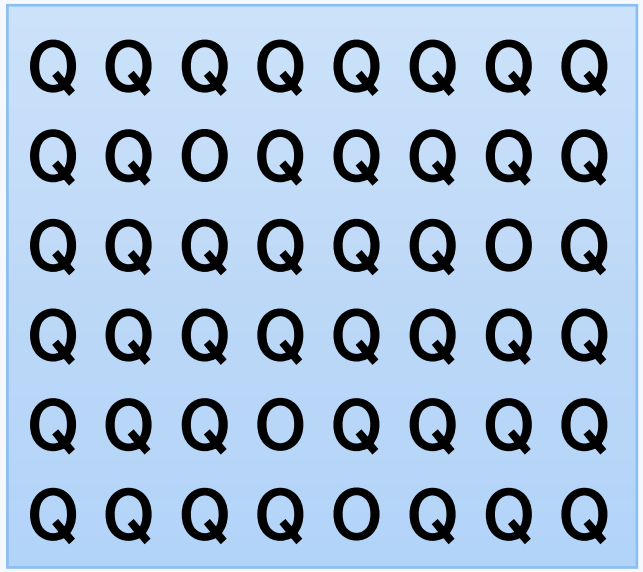
BINOCULAR CUES that are based on the receipt of sensory information in three dimensions from both eyes



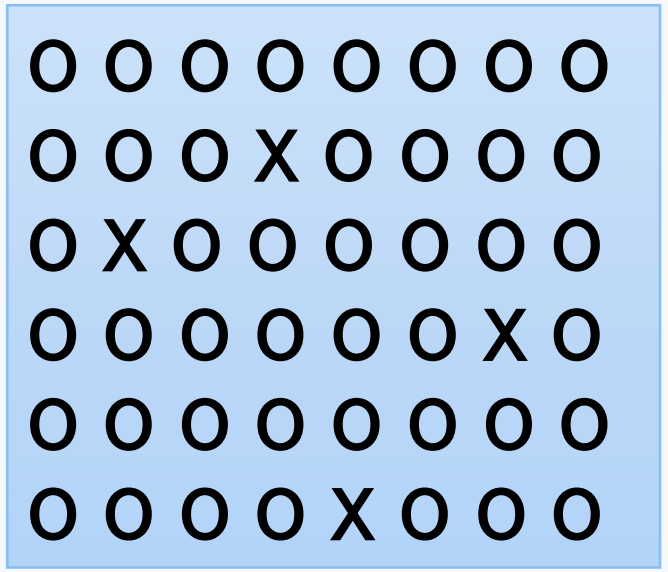
Stereogram

3D movie

VISUAL SEARCH



Serial Search



Parallel Search

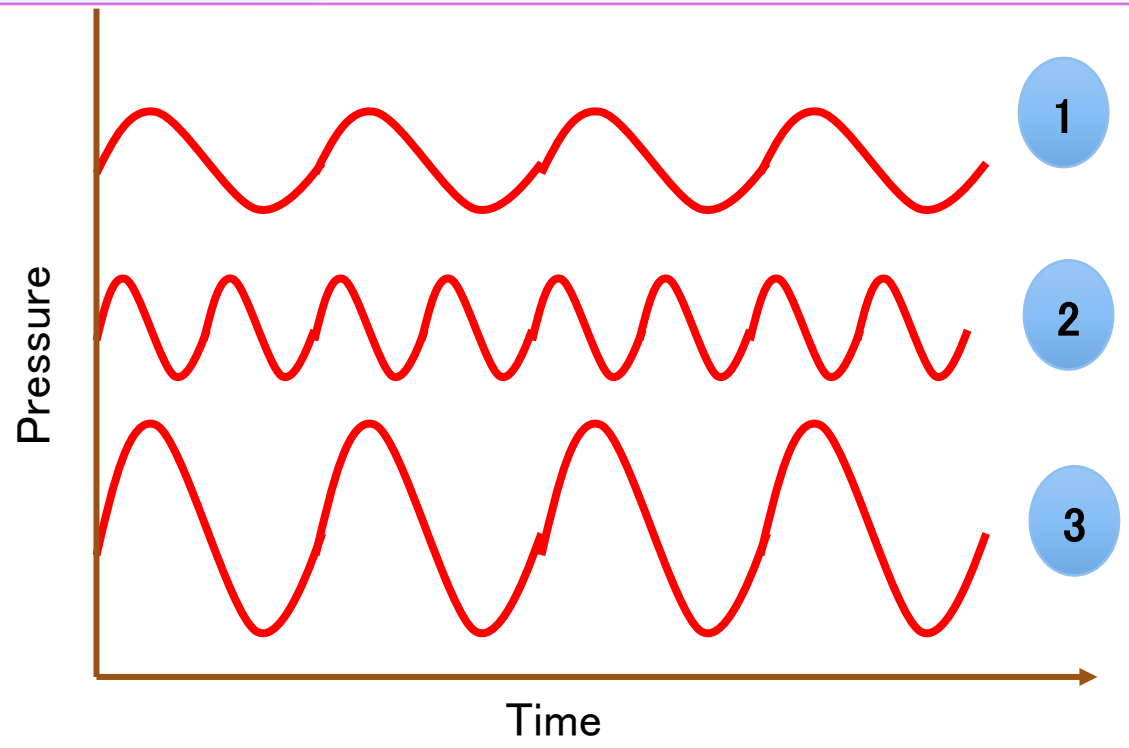
Search time : $T = (N \times I) / 2$

I = inspection time per object

N = total number of objects


Auditory Sensory System

Properties Of Sound



- **Sound** is the vibration of air molecules
- **Amplitude** – sound pressure perceived as loudness, measured in decibels (dB)
- **Frequency** – cycles per second (Hertz) perceived as pitch

Sound intensity (dB) = 20 log (P1/P2);
where P2 is the threshold of hearing

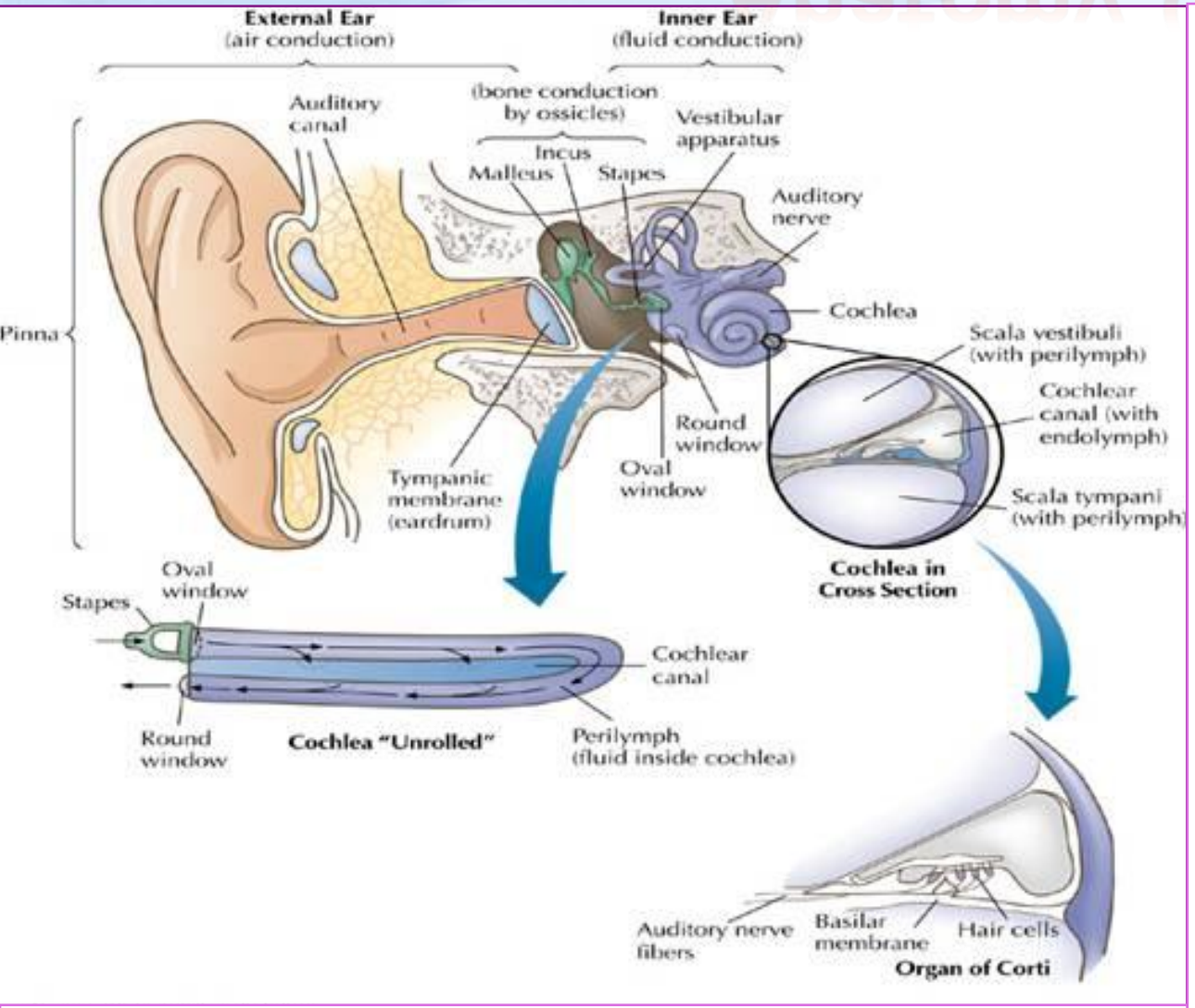
- Noise and vibration are both fluctuations in the pressure of air (or other media) which affect the human body.
- Vibrations that are detected by the human ear are classified as sound.
- We use the term **'noise'** to indicate **unwanted sound.**
- *Noise and vibration can harm workers when they occur at high levels, or continue for a long time.*

•Try NOISE METER !

PERMISIBLE NOISE EXPOSURE	
Duration	**Intensity**
8 hrs	90 dB
6 hrs	92 dB
4 hrs	95 dB
3 hrs	97 dB
2 hrs	100 dB
1.5 hrs	102 dB
1 hr	105 dB
0.5 hr	110 dB
< 0.25 hr	115 dB

THE DECIBEL SCALE	
Source	**Intensity**
Jet at take-off; ear damage possible	140 dB
Painful sound	130 dB
Propeller plane at take-off	120 dB
Loud thunder	110 dB
Subway train	100 dB
Truck or bus	90 dB
	80 dB
Average auto, loud radio	70 dB
Normal conversation	60 dB
Quiet restaurant	50 dB
Quiet office, household sounds	40 dB
Whisper	20 dB
Normal breathing	10 dB
Threshold of hearing	0 dB

Anatomy Of The Ear



Outer ear converts sound energy to mechanical energy (middle ear) to electrical nerve energy (inner ear), then sends signal to the brain.

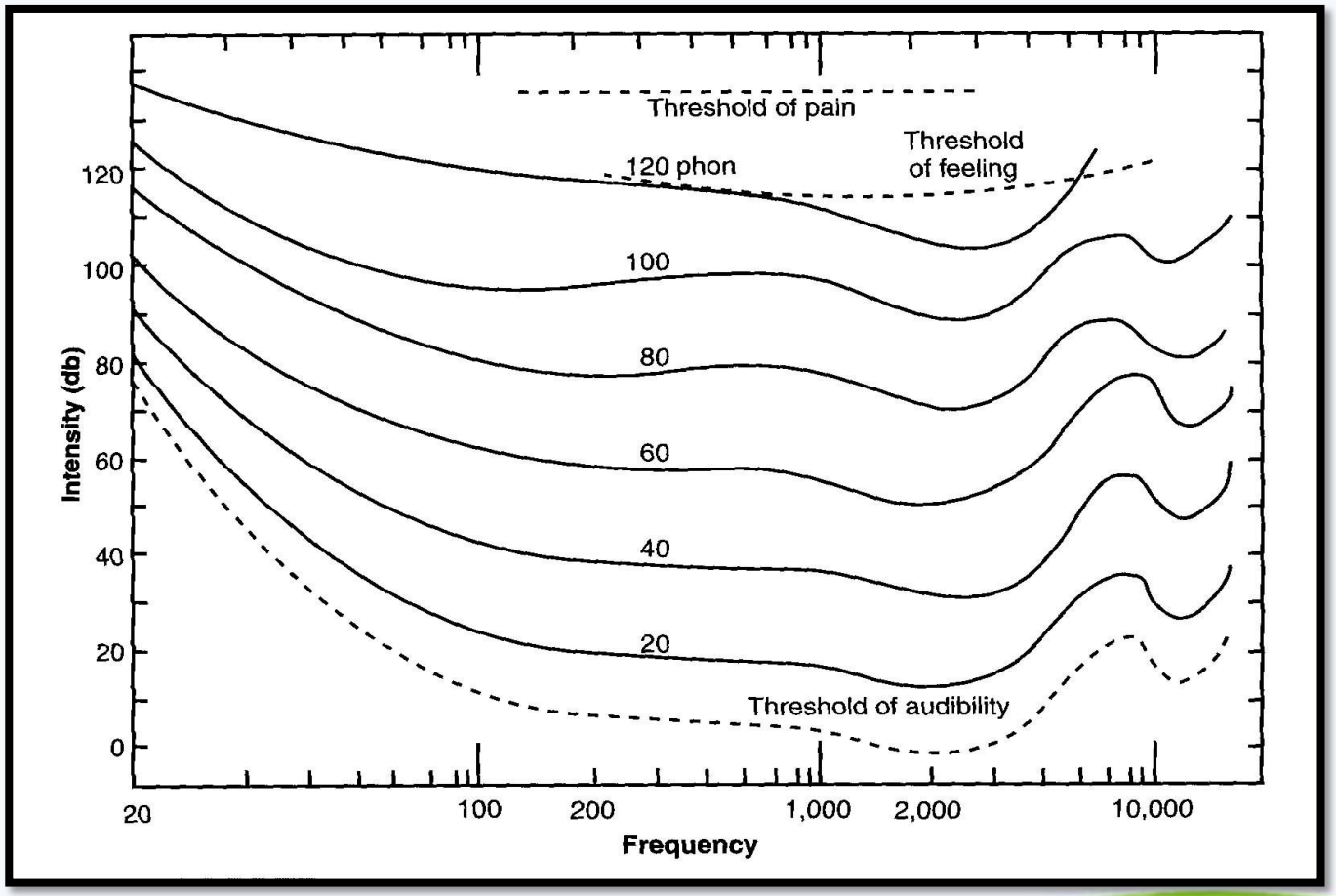
- **Pinna** – collects sound, helps localization (holds up glasses)
- **Tympanic Membrane** (ear drum) – at end of ear canal, vibrates to sound pressure (like a drum head)
- **Ossicles** – bones of middle ear that convert sound to mechanical energy.
  - **Malleus** (hammer) is the largest bone and receives vibration from ear drum, which then strikes the **Incus** (anvil), which is hinged to the smallest bone, the Stapes (stirrups), which presses on the Oval Window of the cochlea.
- **Cochlea** – "snail-like organ" where mechanical energy is transduced to electrical nerve energy, by way Hair Cells along the waving Basilar Membrane that "fire" when they are bent against the rigid Tectorial Membrane of the Organ of Corti, which sends a signal along the Auditory Nerve to the brain.

PSYCHOPHYSICAL SCALING

- Equal increases in sound intensity (on the decible scale) do not create equal increases in loudness; for example, an 80 dB sound doesn't sound twice as loud as a 40 dB sound.
- 1 sone = 40 dB tone of 1,000 Hz;
- Loudness doubles with each 10 dB increase

EQUAL LOUDNESS CURVES

- Loudness is affected by sound frequency.
- Humans are sensitive to sounds between 20 Hz and 20,000 Hz, but most sensitive to 1,000 – 4,000 Hz range.
- All tones along a contour are equally loud.
- 1 phon = perceived loudness of a 1 dB, 1000 Hz tone



ALARMS

Criteria for good alarms:

1. Must be heard above background noise (approx 30 dB above)
2. Avoid excessive intensity
   - Should not be above the danger level for hearing (85–90 dB)
   - Using a very different frequency may help (especially if conflicts with criteria point 1)
3. Should not be too startling
4. Should not disrupt processing of other signals
   - Do not want alarm to mask speech or other important signals
5. Should be informative, not confusing
   - Should communicate the appropriate actions

Sample Alarms

Place mouse over each, do not click

Is each sound discernible?
What does each mean?

ALARM DESIGN

1. Conduct environment/task analysis – must understand what sounds/noises (and their qualities) are associated with the job
2. Make sure alarms are within human's capability of discrimination by varying on different dimensions:
   - Pitch (low to high), Envelope (rising/falling pitch), Timbre (quality), and Rhythm (synchronous vs. asynchronous)
3. Design specific qualities of sound
   - For example : Use pulses to create unique sound and to give perception of an approaching, then receding sound to create sense of urgency
4. Establish repeating sequence
   - After initial alert, may be less intense

FALSE ALARMS

- **Cry Wolf Syndrome** – Human operator fails to respond to alarm due to the large number of false alarms in the past.
- To avoid "Cry Wolf Syndrome":
  - Set the alarm criterion to be sensitive enough to minimize misses, without increasing false alarms.
  - May use more complex algorithms to determine true threshold.
    - may use more than one signal measure
  - Train operators on the tradeoffs of false alarms/misses
    - understand actual false alarm rates
  - Use multiple alert levels (denote different urgency states)

SPEECH PERCEPTION

McGurk Effect – is a perceptual phenomenon that demonstrates an interaction between hearing and vision in speech perception. The illusion occurs when the auditory component of one sound is paired with the visual component of another sound, leading to the perception of a third sound The visual information a person gets from seeing a person speak changes the way they hear the sound.

Speech communication measures:

- **Articulation Index** (bottom up) – signal to noise ratio
  - (speech dB – background noise dB)
  - Higher frequencies are more vulnerable to being masked by noise
- **Speech Intelligibility Index** (top down) – percentage of items correctly heard

OCCUPATIONAL NOISE

Dangers of excessive noise:

- **Hearing loss** – caused by exposure to loud noises. Some hearing loss is expected with age (higher freq.)
  - **Loss of sensitivity** while noise is present
  - **Temporary Threshold Shift (TTS)** – Loss of hearing that lingers after noise is terminated (post–rock concert)
    - – *Tinnitus* or ringing in the ears
    - – 100 dB for 100 min causes a 60 dB TTS
  - **Permanent Threshold Shift (PTS)** – *Occupational Deafness* caused by long term exposure (especially high frequency).

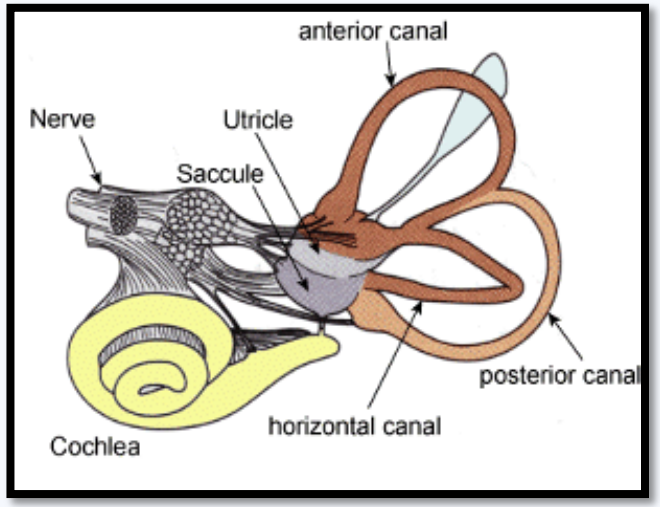
NOISE REMEDIATION

- **Signal Enhancement** – increase the signal to noise ratio (make signal louder relative to background)
- **Noise Exposure Regulations** – OSHA standards based on Time Weighted Average (calculated with dosemeter)
  - if TWA > 85 dB (action level) employer must provide hearing protection
  - if TWA > 90 dB (permissible exposure level) employer must take noise reduction measures
- **The Source** – Select equipment and tools that have built in sound dampening
- **The Environment** – Use sound attenuating or sound absorbing materials to reduce transmission and reverberation
  - **White Noise** – Humming noise used to mask distracting sounds
- **The Listener** – Ear protection such as earplugs (internal) or earmuffs (external)

Tactile and Vestibular Sensory System

Vestibular System

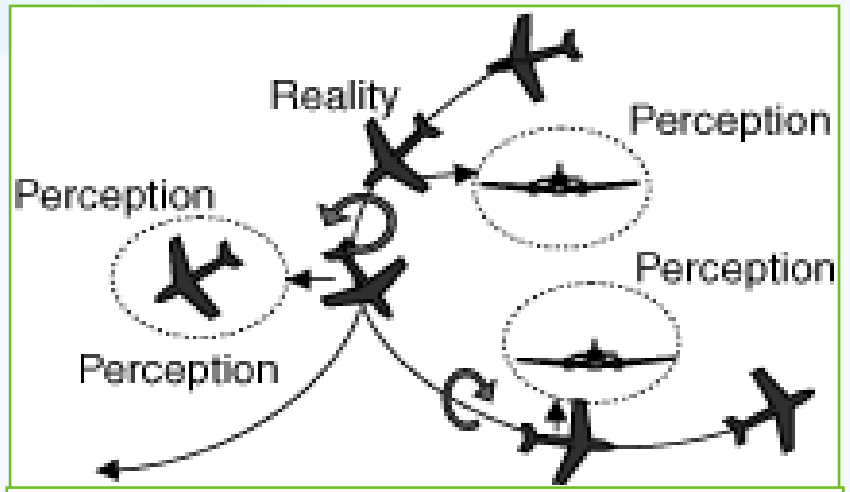
- **Vestibular System** – which contributes to balance in most mammals and to the sense of spatial orientation, is the sensory system that provides the leading contribution about movement and sense of balance.



- **Semicircular Canals** – detect angular acceleration (rotation) in 3 axes
  - a **crista** embedded in a jelly-like material (cupola) is supported by hair cells that bend and fire when the crista moves in response to head rotation.

- **Vestibular Sacs (Utricle & Saccule)** – detect linear acceleration
  - hair cells embedded in jelly-like substance lag behind when the head moves. When motion becomes steady, **otoliths** catch up and hairs no longer bent.

Motion Disturbances



Spatial Disorientation – the inability to correctly interpret aircraft attitude, altitude or airspeed, in relation to the Earth or point of reference, especially after a reference point (e.g., the horizon) has been lost.

Vection – When a large part of the visual field moves, a viewer feels they have moved and that the world is stationary.

For example, when one is in a train at a station, and another neighbouring train moves, one can have the illusion that one's own train has moved in the opposite direction.

Motion Disturbances

- **Motion Sickness** – nausea, disorientation and fatigue attributed to disturbance of vestibular system caused when vision and inner ear send conflicting (decoupled) signals
- **Treatments** :
  - **Medications** – Antihistamines (Dramamine), Dopamine blockers or anti-psychotics (Thorazine), anti-nausea (serotonin) and Scopolamine (anticholinergic)
  - **Behavioral strategies** – sit facing front with front window view, eat bland foods such as bread, bananas, rice. If on a boat, stay in middle (less rocking) and look forward at the horizon, not at the waves.

Sopite Syndrome

- **Sopite Syndrome** – a neurological disorder that relates symptoms of fatigue, drowsiness, and mood changes to prolonged periods of motion.
  - Subset of motion sickness symptoms, but sometimes the sole manifestation
  - Dangerous because victims often not aware of its onset or the likelihood of onset
  - Found to affect passengers and operators of cars, trucks, ships, helicopters, planes, and simulators
  - No known prevention techniques (many motion sickness medications increase drowsiness)
  - May be a major cause of accidents and military pilot training washout

Sense Of Touch : Tactile And Haptic

- **Tactile** – Cutaneous or somatosensory sense provided by receptors just under the skin.
- **Types of Receptors**:
  - Thermoreceptors – detect heat/cold
  - Mechanoreceptors – detect pressure
  - Nociceptors – detect noxious stimuli (caustic substances)

- **Haptic** – Shape information provided through manipulation of fingers

Haptic Responding Experiment

- **Haptic technology**, or haptics, is a tactile feedback technology which takes advantage of the sense of touch by applying forces, vibrations, or motions to the user.
  - This mechanical stimulation can be used to assist in the creation of virtual objects in a computer simulation, to control such virtual objects, and to enhance the remote control of machines and devices (telerobotics).
  - It has been described as ″doing for the sense of touch what computer graphics does for vision″.
  - Haptic devices may incorporate tactile sensors that measure forces exerted by the user on the interface.
- **Tactile haptic feedback** is becoming common in cellular devices. Handset manufacturers like Nokia, LG and Motorola are including different types of haptic technologies in their devices; in most cases, this takes the form of vibration response to touch.

WHAT INSPIRES YOU ?


KEEP
CALM
AND
STUDY
HARD