

# Work Environment Design



## Introduction to Ergonomics

Chapter 9-11

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# Value of Good Environment

- Plants with good working conditions outperform those with poor conditions
- Economic return on investment in better conditions is usually significant
- Good environment enables
  - Improves safety and morale
  - Reduces turn-over
  - Increases profitability
  - Reduces absenteeism
  - Improves convenience
  - Increases efficiency



# Work Environment Design

- Lighting
- Noise
- Temperature
- Work Shifts
- Overtime

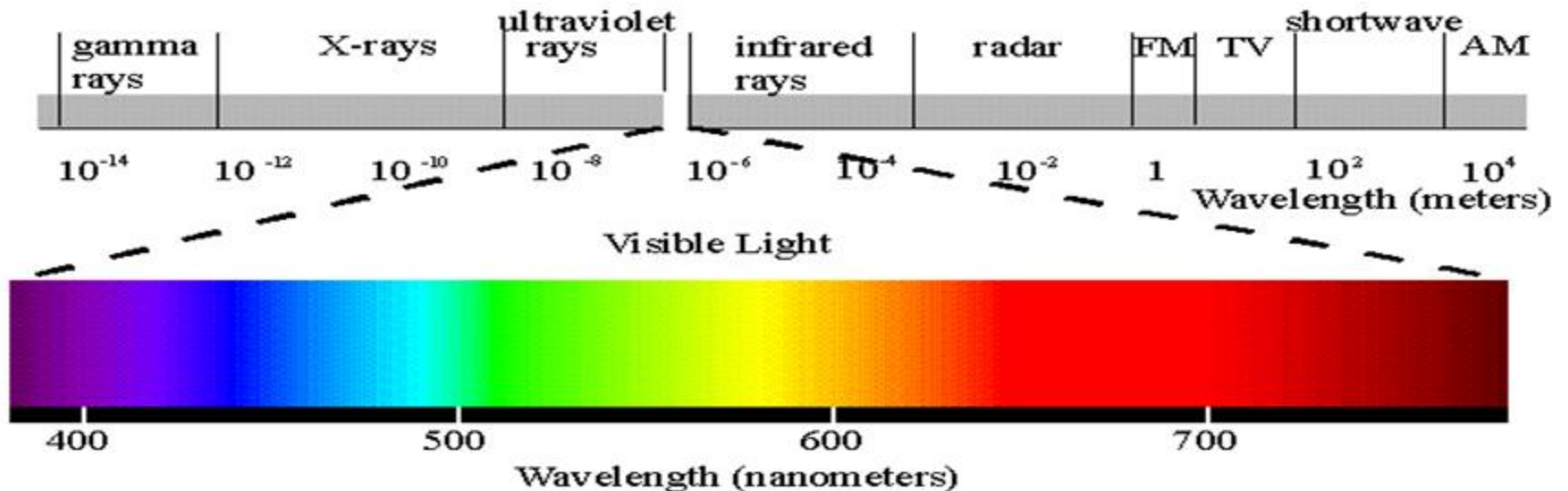


# Lighting

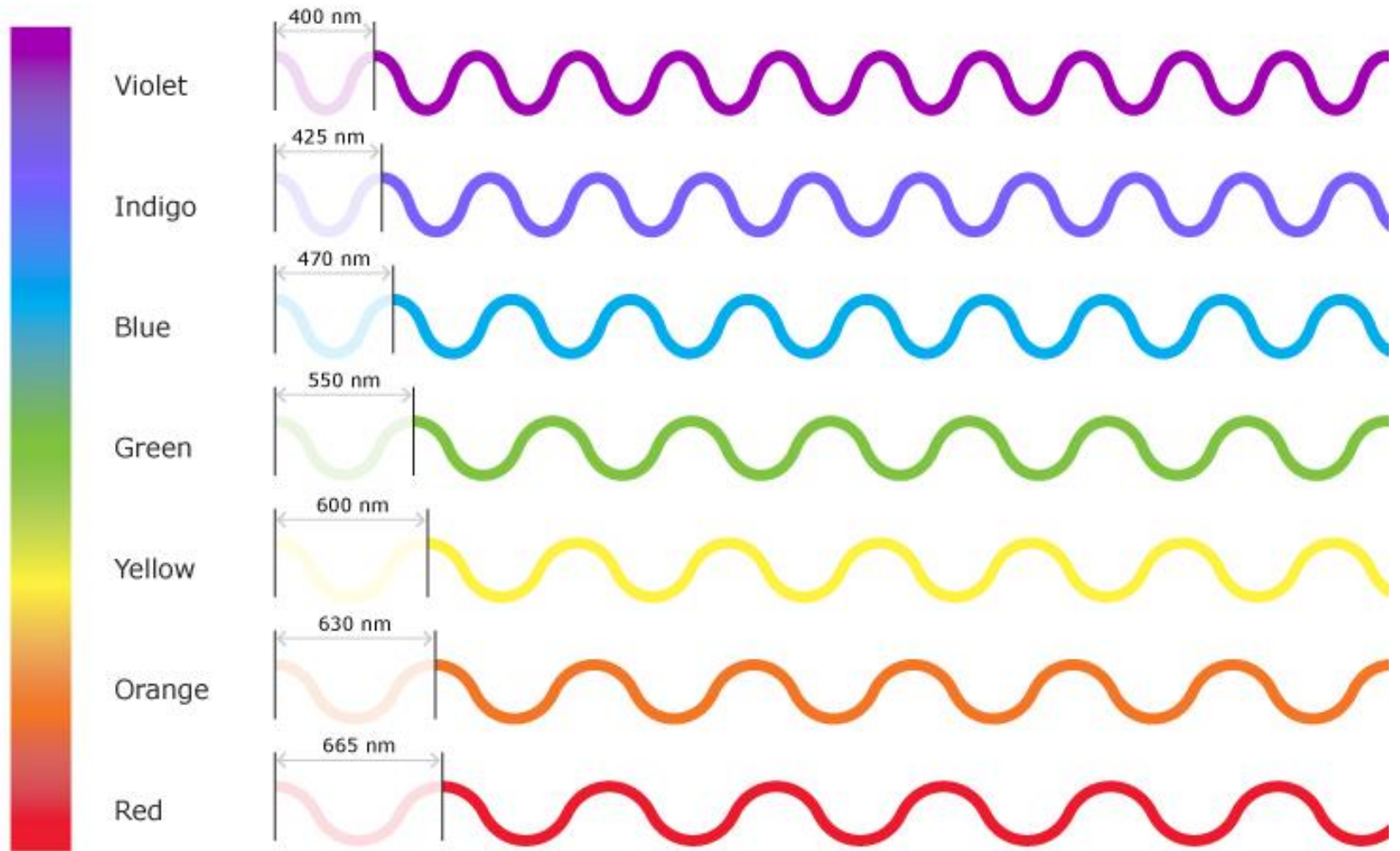


# Light

- Light is electromagnetic radiation that is visible.
- The electromagnetic spectrum is extremely wide but the visible part is extremely narrow.



# Light



# Light

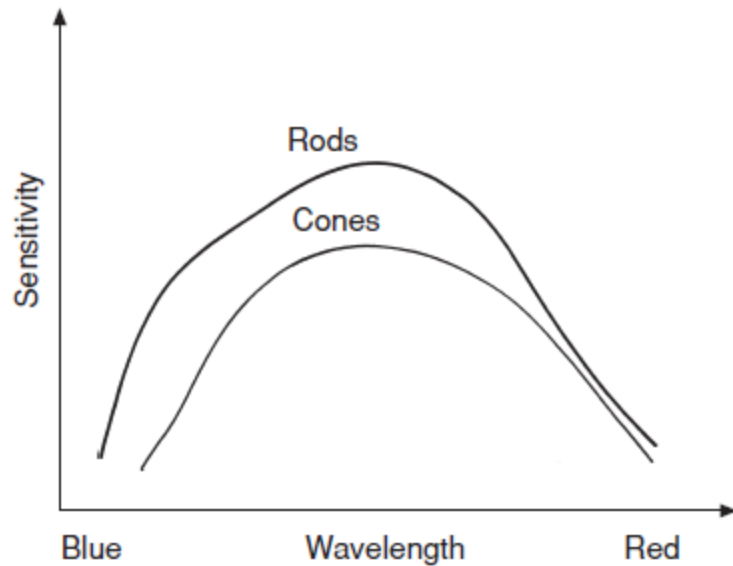
FREQUENCY

› *determines hue*

AMPLITUDE

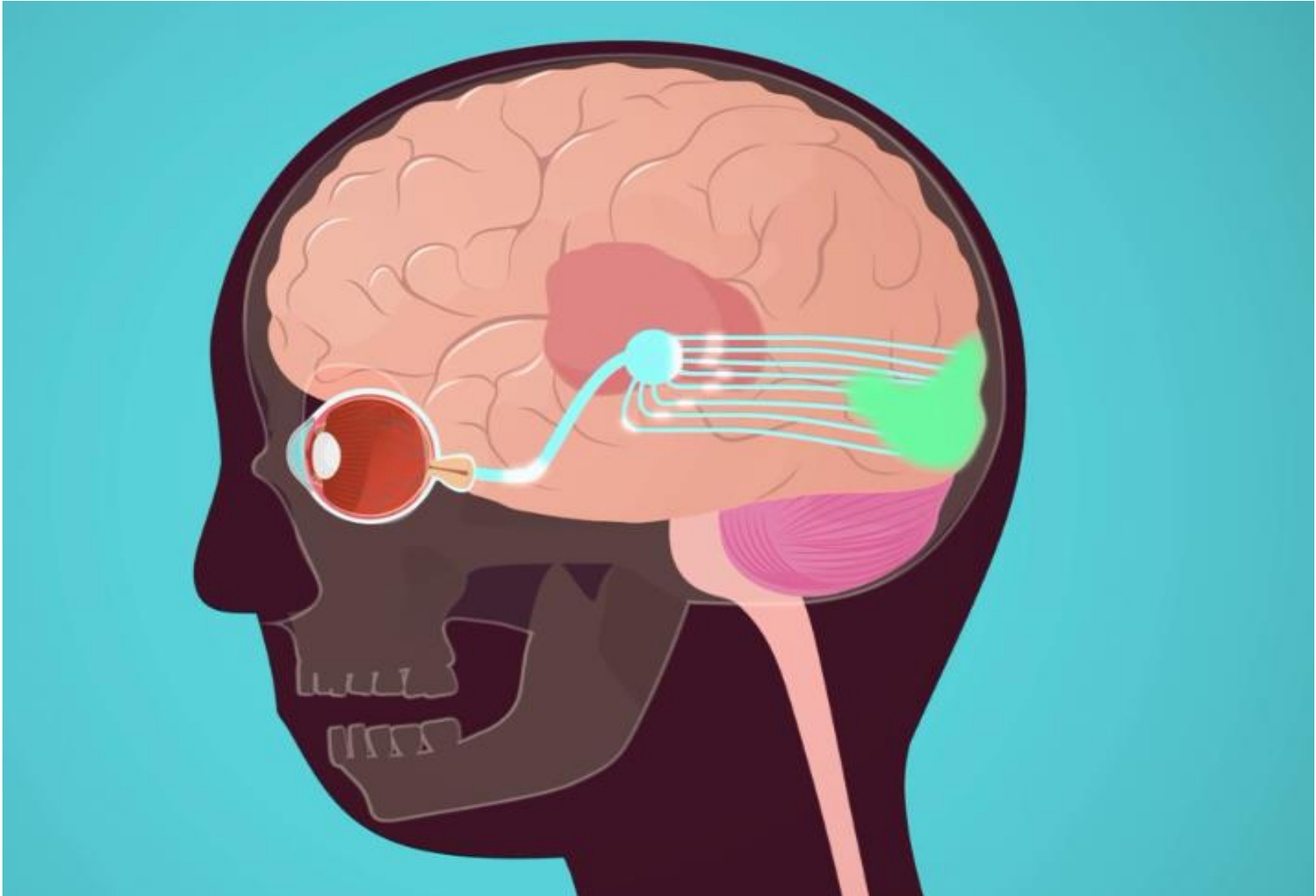
› *relates to its brightness*

# Vision and The EYE



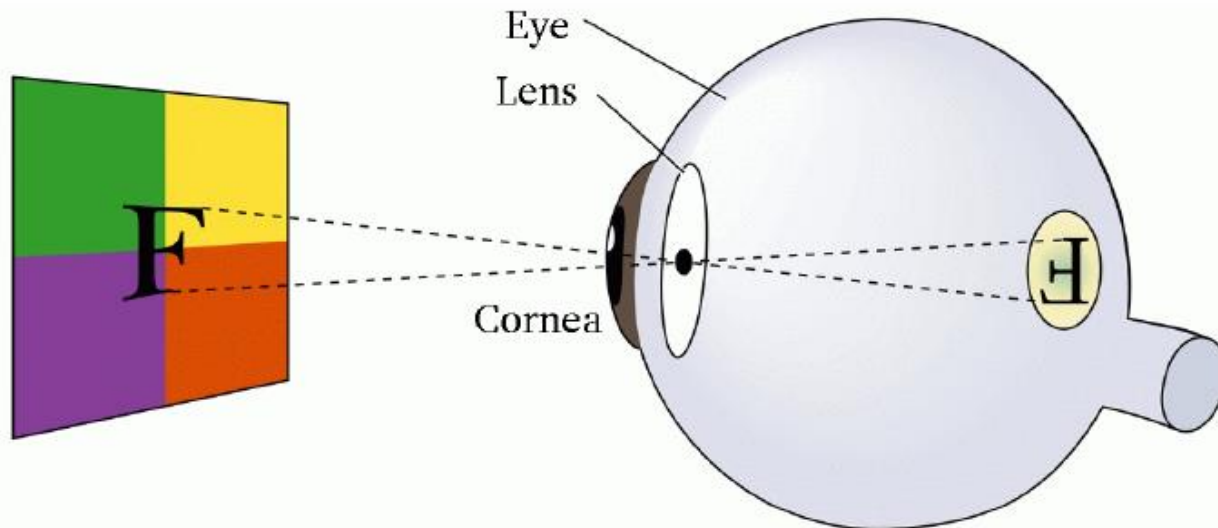
Both are maximally sensitive to light in the middle of the spectrum (which is perceived as blue-green, green and yellow). Violet and red are less readily sensed

# Vision and The EYE



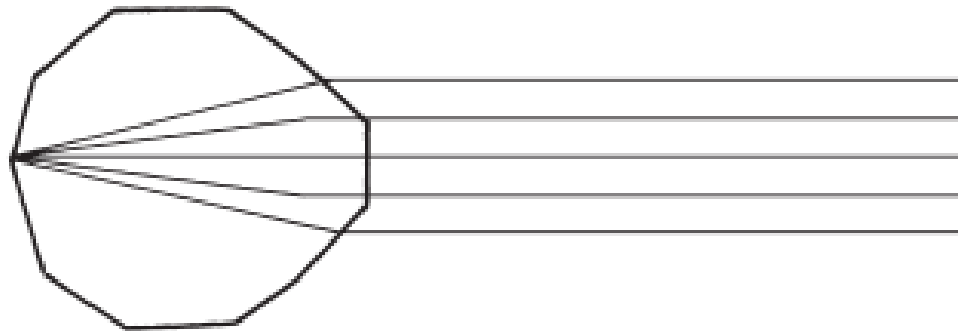
# Vision and The EYE

- *Good lighting increases the depth of field* of the eye. When the pupil is very small, the eye acts like a pinhole camera – all objects are focused on the retina irrespective of viewing distance.
- Increased depth of field reduces the need for optical adjustment by the lens. It is in this sense that it can be said that good lighting reduces the load on the visual system.

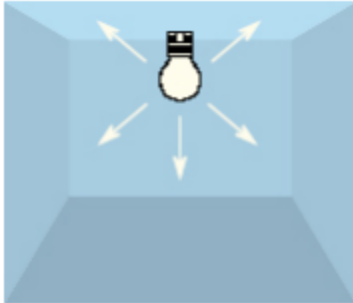


# Visual Defects

- In a normal or *emmetropic* eye, there is a correct relationship between the axial dimensions of the eye and the power of its refractive system. Parallel light rays are focused sharply on the retina.

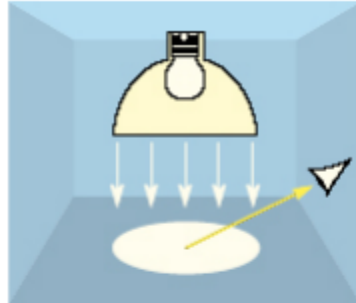


# Photometry



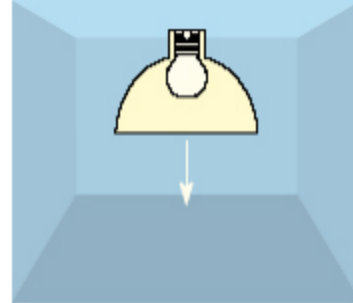
## Luminous intensity (I)

Luminous intensity is the amount of light, luminous flux, radiating in a particular direction. A point source of light of luminous intensity of 1 candela (**cd**) in all directions emits 12.57(4) lumens. The distribution curve for a luminaire indicates the luminous intensity in a particular plane. The plane at right angles to a fluorescent lamp is known as the transverse plane ( $0^\circ$ ) and that is normally provided in manufacturers technical data.



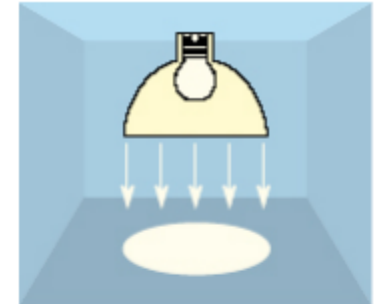
## Luminance (L)

Luminance is the brightness of a light source, an illuminated or luminous surface. It is measured in intensity per unit area, that is candelas per sq.metre, **cd/m<sup>2</sup>**. Luminance is the measured brightness of an object. What the eye actually perceives is not luminance but as apparent brightness or luminosity, and that cannot be measured.



## Luminous flux (LM)

Luminous flux is the rate of light emitted by a light source. It is measured in **lumens**. The lumen output of a 100W tungsten lamp is 1300 lumens and that of a multi-phosphor 1200mm T8 36W fluorescent lamp 3350 lumens.



## Illuminance (E)

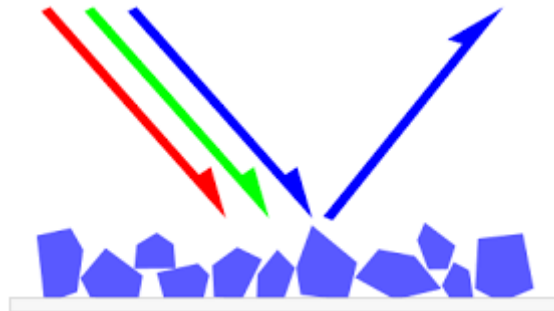
Illuminance is the amount of light, **luminous flux**, falling on a surface. It is measured in lumens per unit area, that is lumens per metre<sup>2</sup>, **lm/m<sup>2</sup>** or lux.

# Photometry

## Reflectance

It is the percentage of light reflected by a surface.

Entity	Reflectance (%)
White Paper	95
White Cloth	65
Newspaper	55
Plain Wood	45



# Improving Visibility

- One can improve visibility in several ways:
  - Increase source intensity (increase wattage, change to more efficient type: fluorescent, halogen)
  - Bring target closer to viewer
  - Bring target closer to light source
  - Increase *contrast*, *choose colors* carefully
  - Increase *target size* (big printed books)

# Guidelines for Color Selection

- Choose compatible color combinations. Avoid red/green, blue/yellow, green/blue, red/blue pairs.
- Use high color contrast for character/ background pairs
- Luminosity diminishes in the order white, yellow, cyan, green, magenta, red, blue.
- Use white, yellow, cyan or green against a dark background.



# Guidelines for Color Selection

## Color Rendition

- Light sources vary in their ability to accurately reflect the true colors.
- The color rendering index (CRI) scale is used to compare the effect of a light source on the color appearance of its surroundings.
- A scale of 0 to 100 defines the CRI.
- CRIs in the range of 75-100 are considered excellent, while 65-75 are good. The range of 55-65 is fair, and 0-55 is poor.



Tungsten WB



Auto WB



White Fluorescent WB



DPP "white click" WB

# Lighting Design Considerations

- For visual comfort and to meet visual demands the following should be considered (Grandjean, 1980):
  - A suitable level of illumination
  - A balance of surface luminance
  - Avoidance of glare
  - Uniformity of lighting

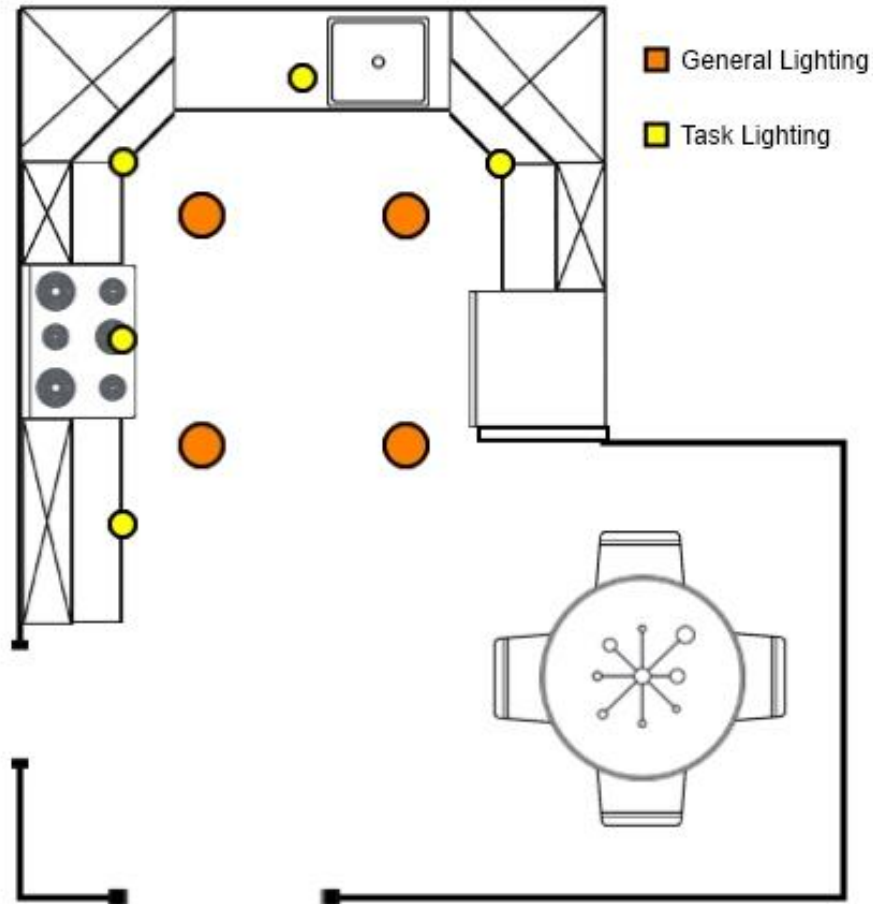
# Illumination Level

- The amount of light needed is a function of:
  - The nature of the *task*
  - The *worker* (age and visual health),
  - The reflectance of the task *background*.

\*General lighting throughout room  
 † Illumination on tasks  
 ‡ Illumination on tasks obtained by combination of general and local lighting

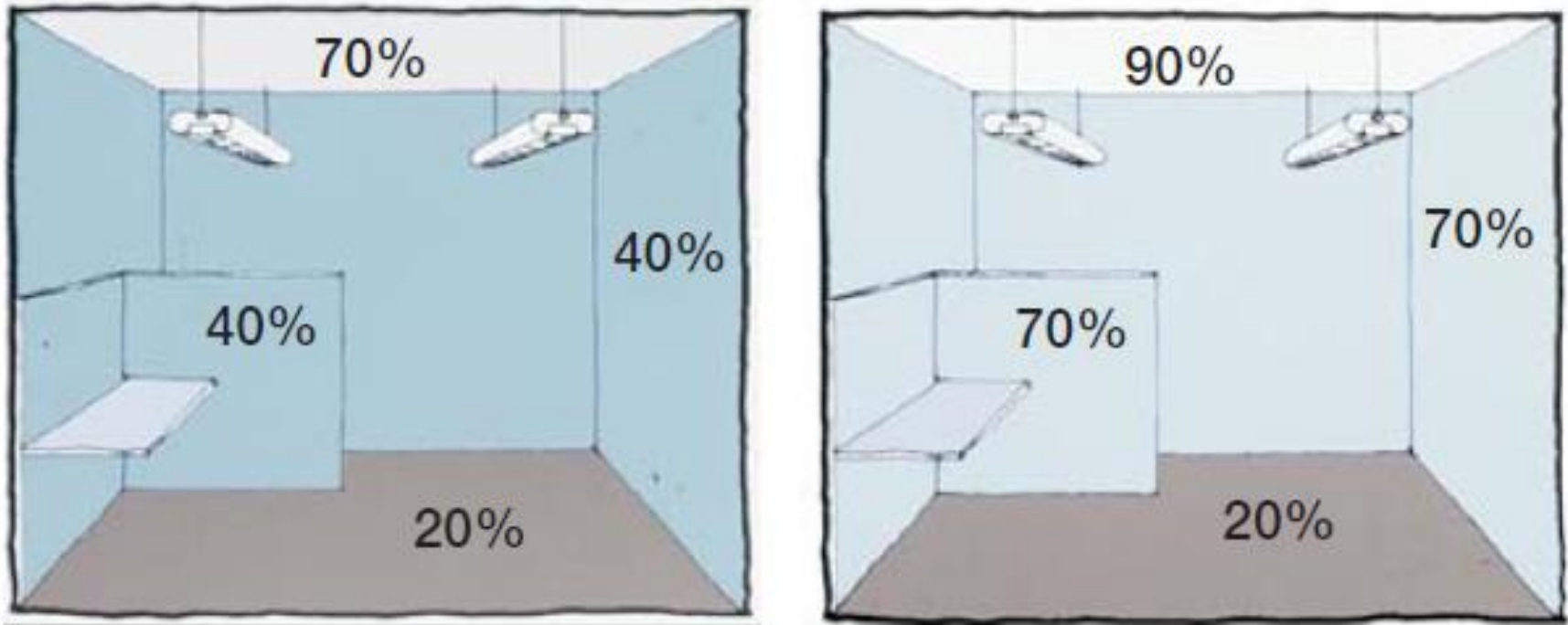
Category	Range of Illuminance lx, (fc)	Type of Activity
A	20-30-50*, (2-3-5)*	Public Areas with dark surroundings
B	50-75-100*, (5-7.5-10)*	Simple orientation for short temporary visits
C	100-150-200*, (10-15-20)*	Working spaces where visual tasks are performed only occasionally
D	200-300-500†, (20-30-50)†	Performance of visual task of high contrast e.g. reading books
E	500-750-1000†, (50-75-100)†	Performance of visual task of medium contrast e.g. poorly printed materials
F	1000-1500-2000†	Performance of visual task of low contrast e.g. difficult inspection
G	2000-3000-5000‡	Performance of visual task of low contrast over prolonged period
H	5000-7500-10000‡	Performance of visual task of low contrast over prolonged period, small size
I	10000-15000-20000‡	Performance of visual task of extremely low contrast over prolonged period, small size

# Illumination Level



\*General lighting throughout room  
† Illumination on tasks  
‡ Illumination on tasks obtained by combination of general and local lighting

# Balance of Surface Luminance



A small increase in room reflectances produces a big improvement in efficiency. The lighter room provides 55% more light on the work surface for the same energy or uses 70% less energy to provide equivalent brightness. The lighter room also provides better brightness ratios, comfort and daylight distribution.

# Avoidance of Glare

## Glare

- Glare is a sensation caused by luminance in the visual field that are too bright. Discomfort, annoyance, or reduced productivity can result. A bright object in front of a dark background (too much contrast ) usually causes glare.



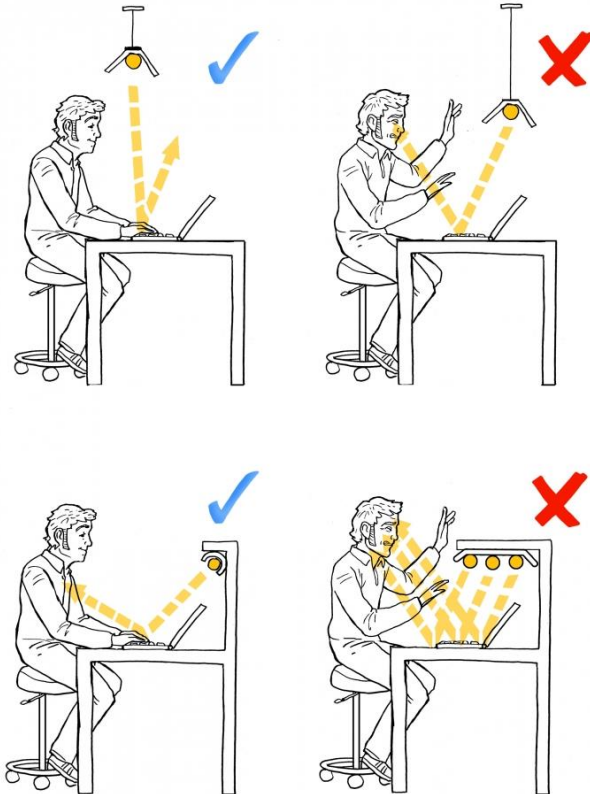
# Avoidance of Glare

- Glare can be reduced by choosing a suitable combination of direct and indirect lighting.
- With direct lighting, most of the light is directed towards the target in the form of a cone. This produces hard shadows and sharp contrasts between illuminated and non-illuminated areas.
- Indirect lighting is reflected off other surfaces in a room and produces a smoother transition between surface luminances and reduces shadows.



# Avoidance of Glare

- All lamps should have glare shields or shades and the line of sight from the eye to the lamp should have an angle greater than 30 degrees to the horizontal.
- Overhead lamps should not reflect off desktops or work surfaces into the operator's eyes



# Uniformity of Lighting

- Fluctuating luminances can be more disturbing than static contrasts.
- Incandescent bulbs radiate light fairly uniformly over time, whereas fluorescent lamps are known to flicker.
- Fluorescent lamps work by passing an electric current through a gas in a glass tube.
- The gas emits visible (almost monochromatic) light and ultraviolet radiation periodically in accordance with the mains frequency.

# Uniformity of Lighting

Compact fluorescent desk lights allow workers to control their own lighting to accommodate their individual visual needs. "Articulated" task lights, which allow adjustment in all three

planes, are extremely effective without being expensive and are preferable to undercabinet lights for illuminating the task. In particular, they offer flexibility for different workers and different task requirements, and allow for lower levels of ambient light from the ceiling-mounted light fixtures.

See Figure 1(a)

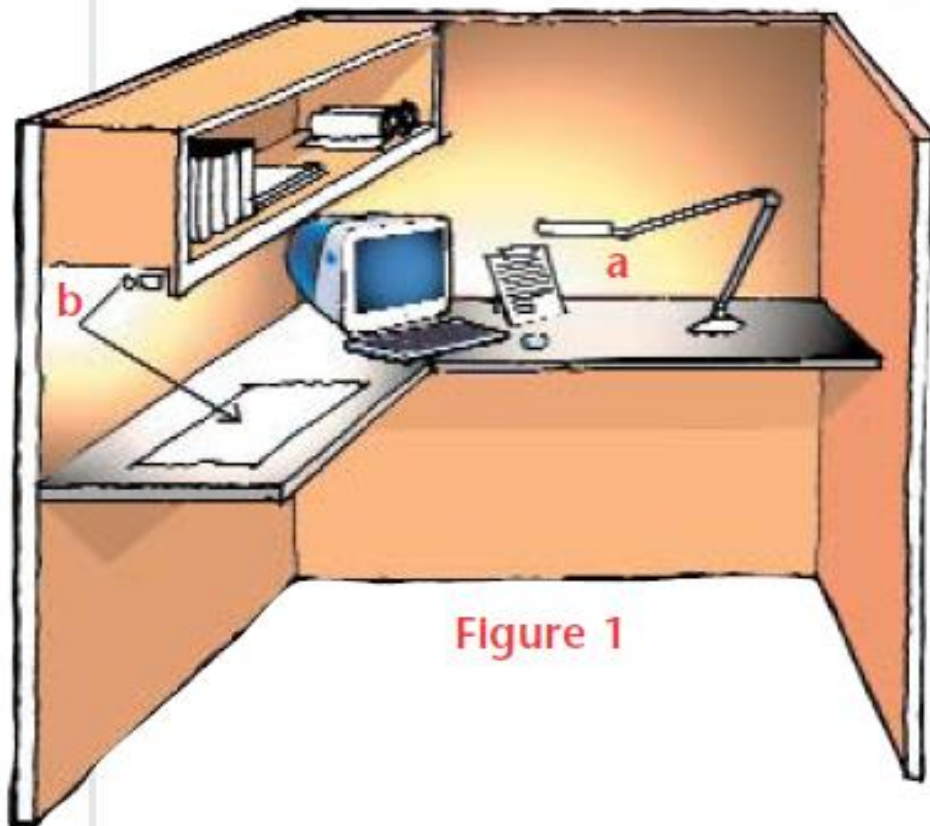


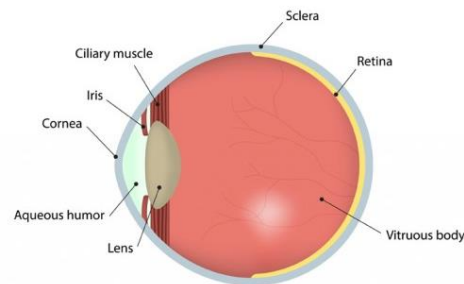
Figure 1

# Visual Discomfort: Complaints

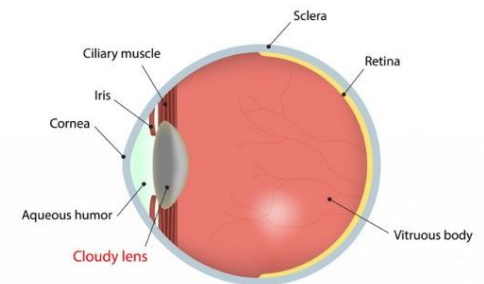
- Eye Strain - Largest Single Complaint
- Burning / Itching Eyes
- Headaches
- Cataracts



Healthy Lens

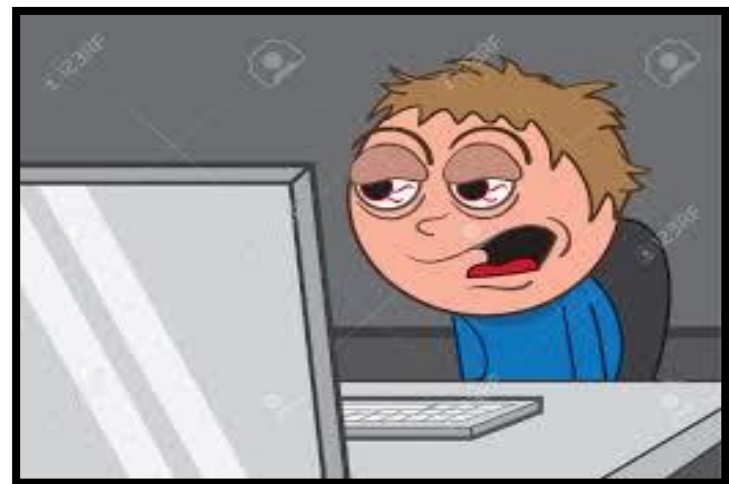
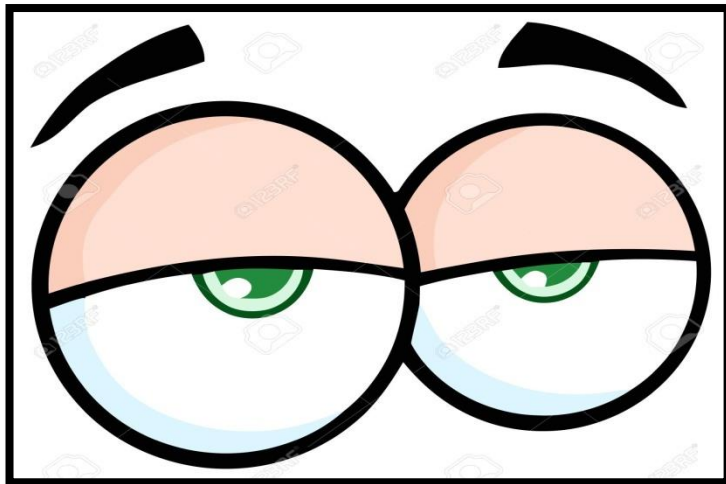


Cloudy Lens



# Visual Discomfort: Causes

- Eye Muscle Strain / Fatigue
- Dry Eyes
- Uncorrected Vision Problems
- Vision Correcting Eyewear - Focusing Difficulties



# Visual Discomfort: Consensus

- No Evidence That VDT Work Leads to Visual Damage
- No Proven Correlation Between VDT Usage and Cataracts
- Eye Muscle Strain / Fatigue
  - Lighting / Glare
  - Monitor Height & Distance to Eyes
  - Visual Concentration on Monitor
- Dry Eyes
  - VDT Environment Less Humid
  - Eye Blink Rate: 3.6 / Min VDT vs. 18.4 / Min Normal

# Visual Discomfort: Control Measure

## Lighting / Glare

- VDT: 50 fc / 500 Lux Optimum Light Level
- Office: 100 fc / 1,000 Lux Optimum Light Level
- Don't Place VDT Directly Under Bright Overhead Lights
- Provide Indirect Lighting and Supplement With Task Lighting
- Place VDT Parallel to Windows
- Low Reflective Walls / Work Surfaces
- Anti-Glare Screens: Last Resort Only

# Visual Discomfort: Control Measure

## 8 STEPS TO MANAGE DRY EYE

### 1. Check your medications.

Talk to your doctor to see if prescription drugs might be causing your dry eyes

**2. Nutrition.** Eat three healthy and sensible meals and snacks every day

**3. Avoid pollution and irritants.** Avoid rubbing your eyes which can disturb the tear film and transfer irritants to your eye

**4. Balance your hormones.** Try eating more whole grains, less sugar, and fewer processed foods. This will help to control insulin levels and keep inflammation under control

### 5. Take Special care with contact lenses.

Contact lenses can soak up the fluid in your eye. Keep lenses clean, and try not to wear them all the time.

**6. Use artificial tears** to provide more moisture and lubrication for the surface of your eye

**7. Hydrate and humidify.** If you are dehydrated, the fluid in your eyes can be depleted, so drink lots of liquids

**8. Blink!** Try to blink every five seconds, especially when staring at your computer screen or digital device

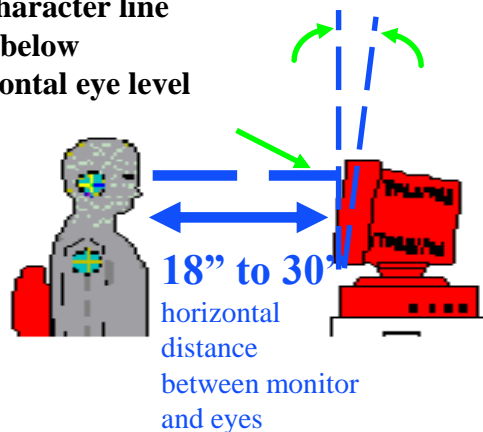


# Visual Discomfort: Control Measure

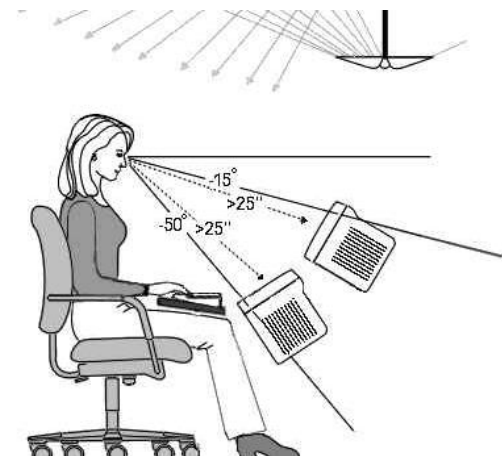
## Lighting / Glare

- Ensure Monitor Display Quality
  - Adjustable Brightness and Contrast
  - High Resolution
- Adjust Monitor Height and Distance
  - Top Character Line on Screen 15 - 20 Degrees below Horizontal Eye Level
  - Eye to Screen Distance 18" - 30"

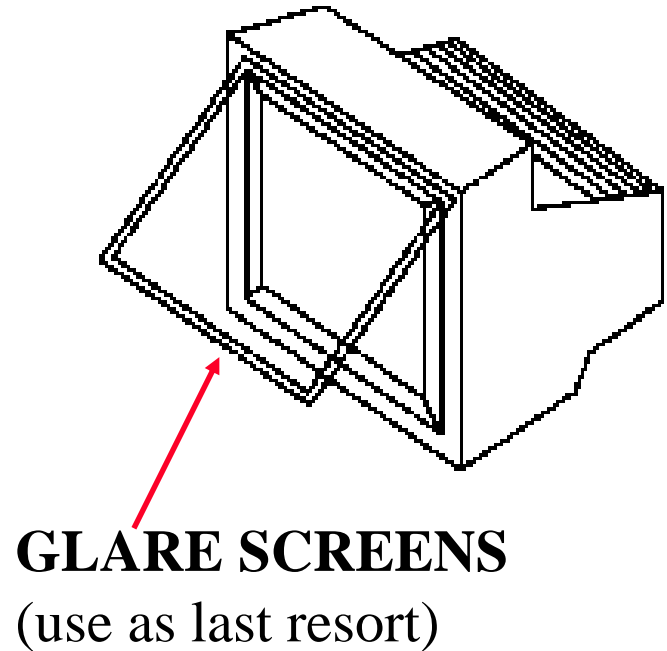
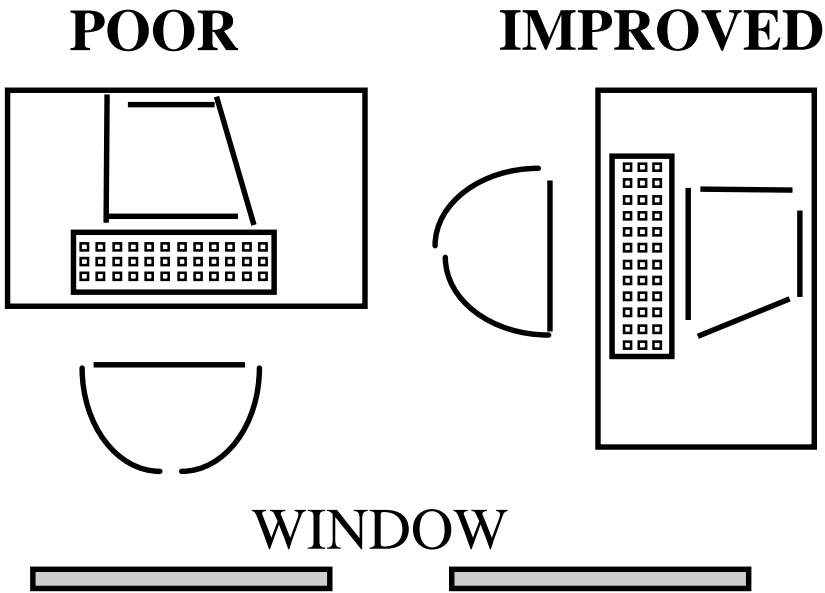
top character line  
at or below  
horizontal eye level



adjust monitor tilt  
to minimize glare

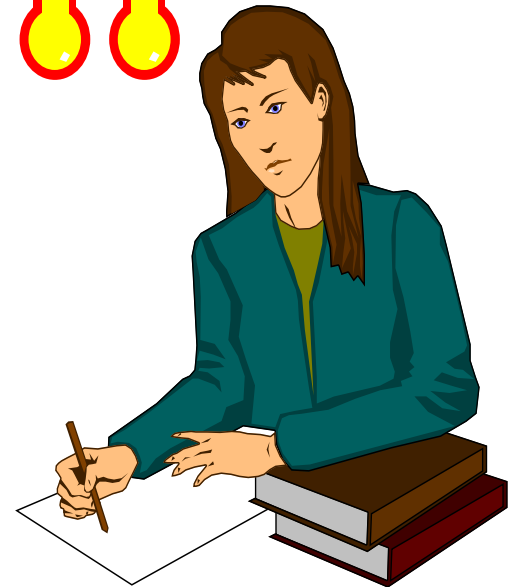
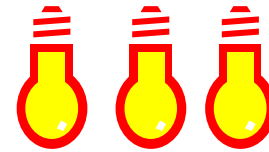


# Visual Discomfort: Control Measure



# Visual Discomfort: Control Measure

**use correct lighting level  
for the task performed**



# Visual Discomfort: Control Measure

- Eye: Strain / Fatigue / Dryness
  - Eye Focusing / Muscle Defatigue Exercises
    - 1 Min. Rest / Exercise Break After 15 Min. Continuous VDT Work
  - Remember to Blink Eyes Frequently
  - Contact Lens Wearers Should Supplement Own Tears Via Eye / Rewetting Drops

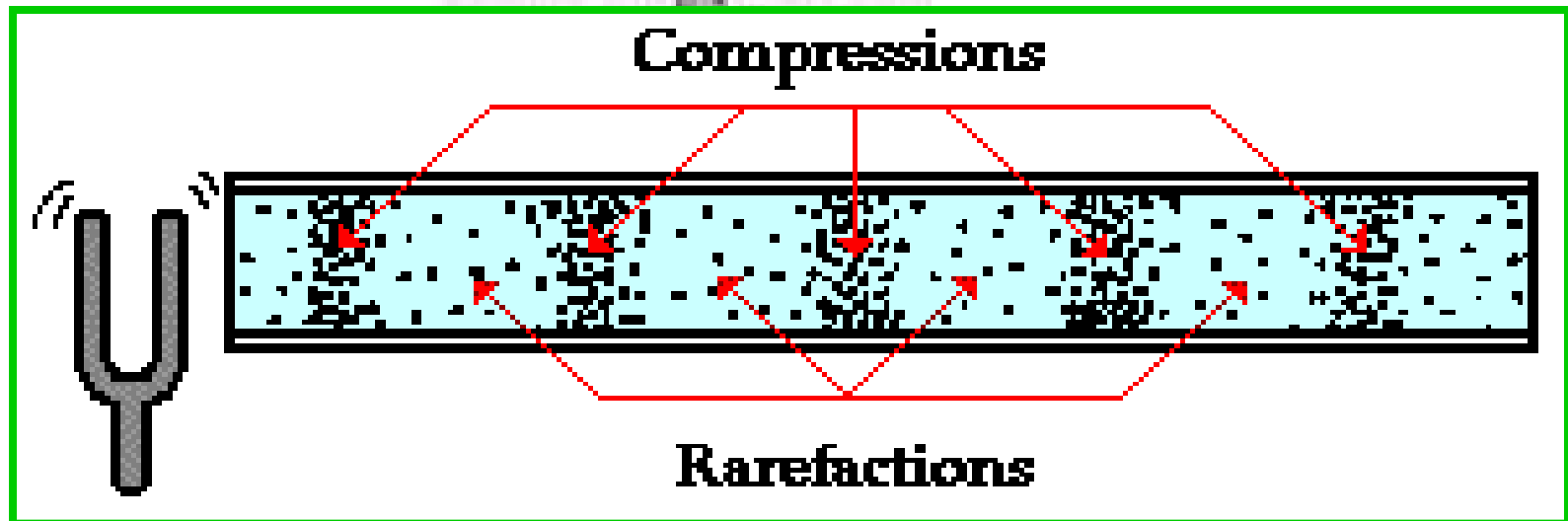
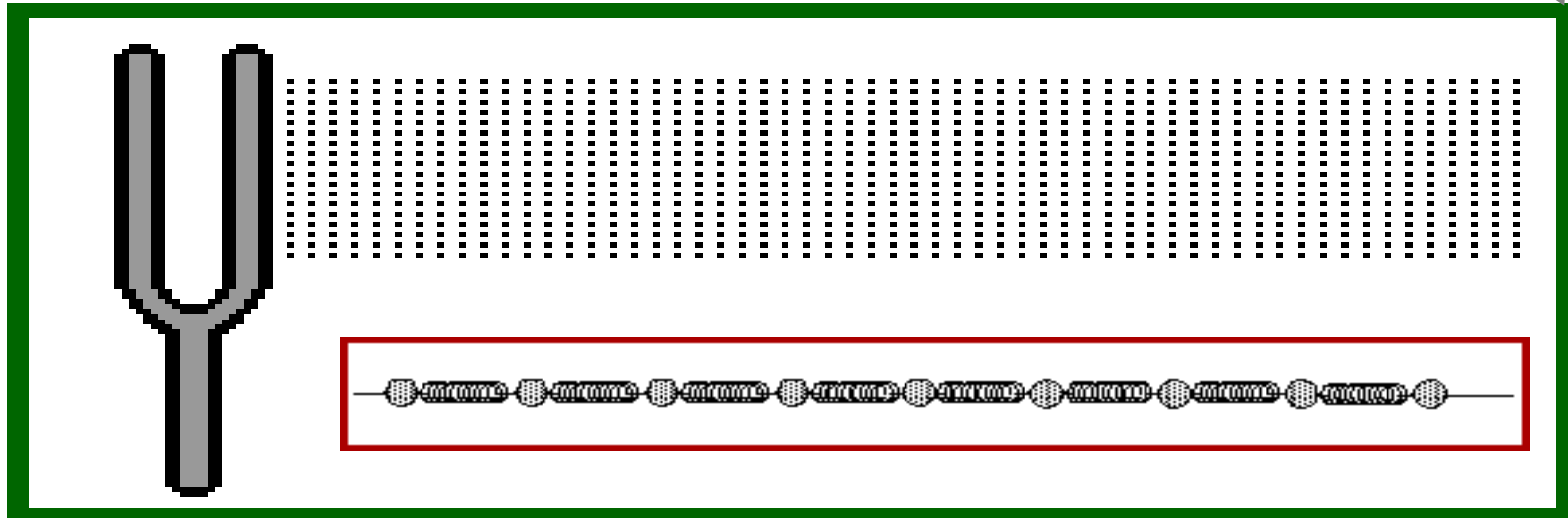
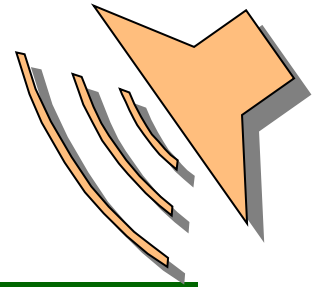
# Noise





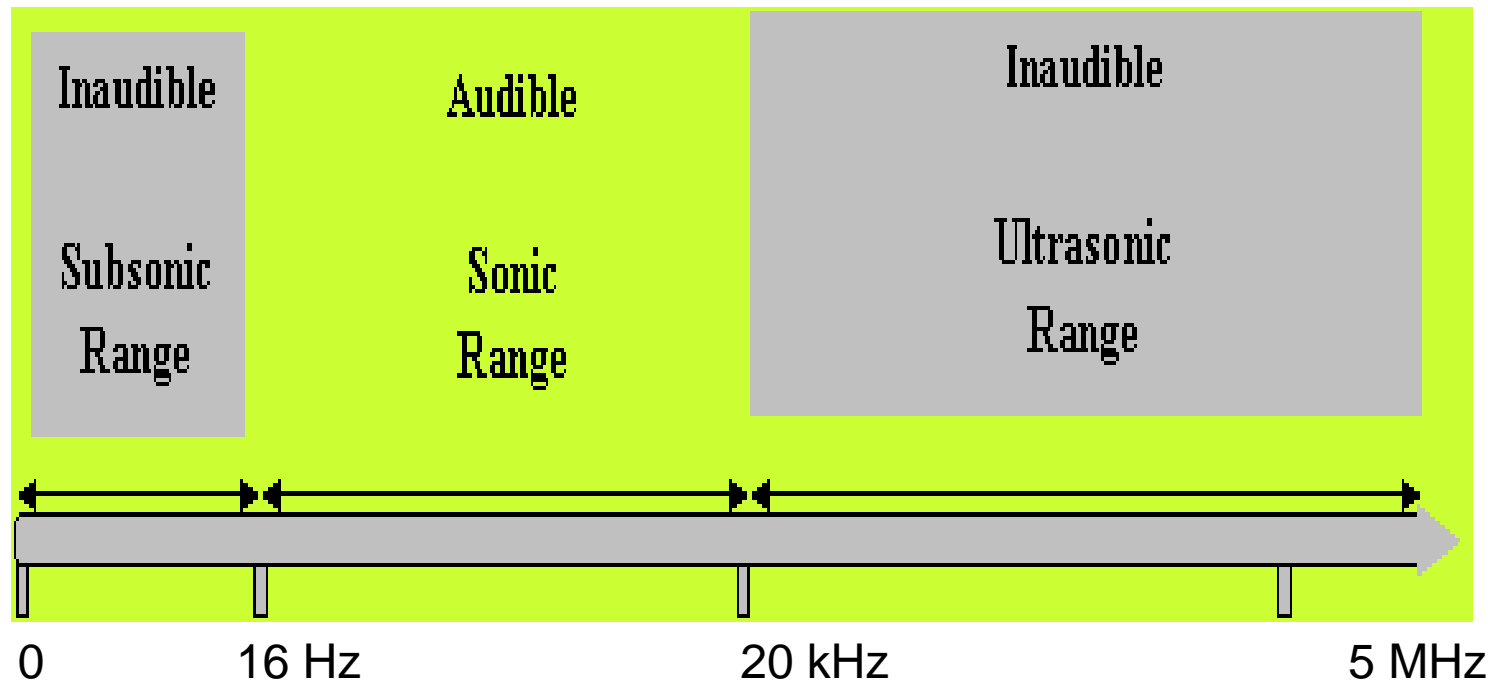
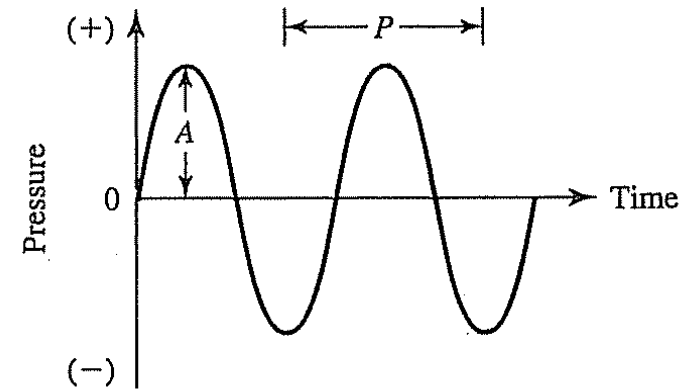


# Sound Propagation



# Amplitude & Frequency

Frequency and amplitude define a pure tone. Their subjective counterparts are pitch and loudness. A healthy young person can hear sounds in the range 16–20 000 Hz.



# Amplitude & Frequency

How Sound Works

## FREQUENCY

› the number of waves that pass a certain point in a given time frame



*high pitch*

How Sound Works

## FREQUENCY

› the number of waves that pass a certain point in a given time frame



*low pitch*

How Sound Works

## AMPLITUDE

› the difference between the high and low pressures created in the air by that sound wave



*high volume*

How Sound Works

## AMPLITUDE

› the difference between the high and low pressures created in the air by that sound wave

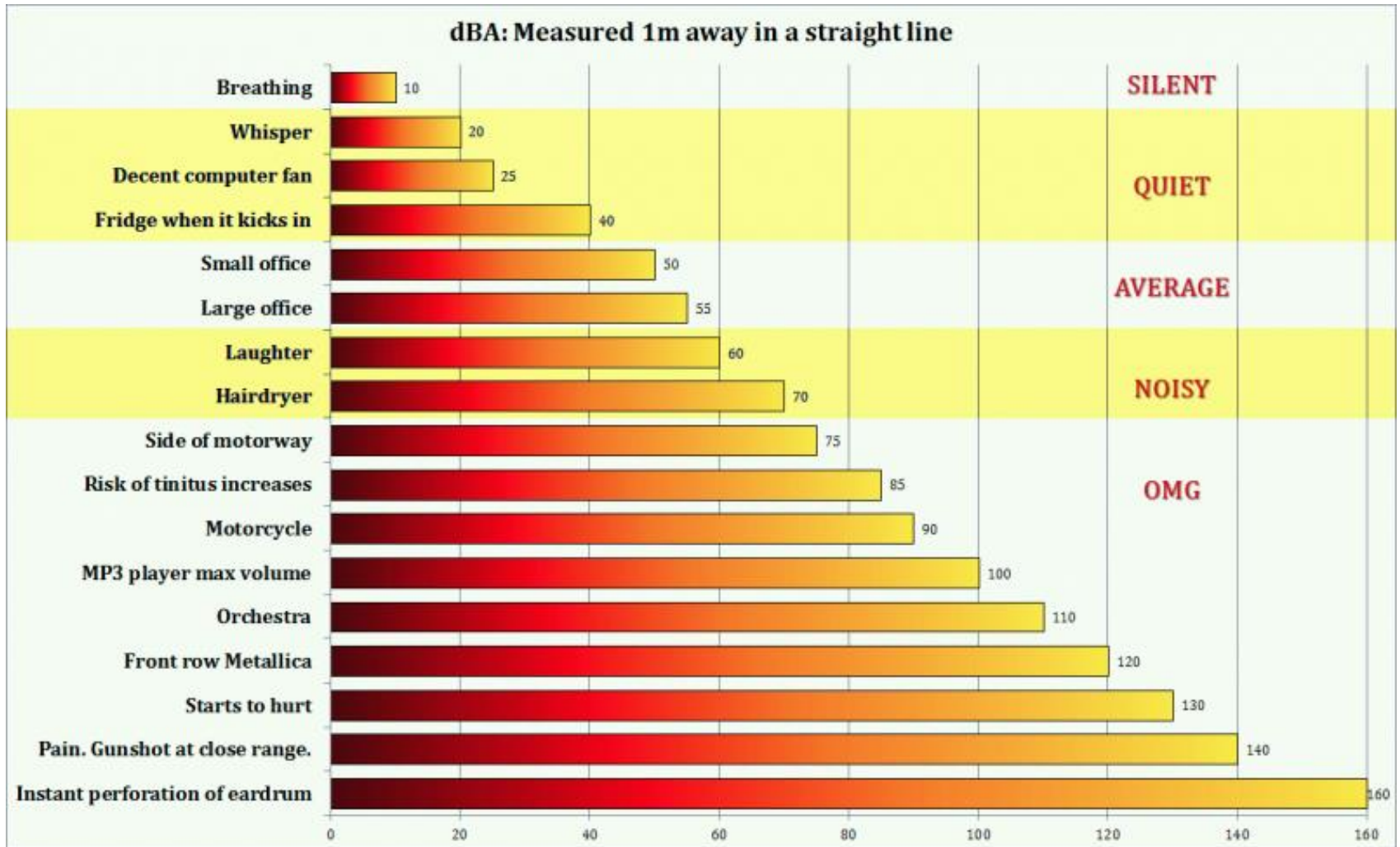


*low volume*

# Levels and Decibels

- The amplitude of sound is evaluated by measuring the sound pressure level (SPL).
- The range of SPLs to which the human ear is sensitive is so wide (0.00002 to 20 N/m<sup>2</sup>) that linear scaling would present a problem.
- For this reason a logarithmic scale – the decibel scale – is used.
- The smallest noticeable difference in intensity between two sounds is about 1 decibel.

# Levels and Decibels



# Levels and Decibels



# Noise Pollution



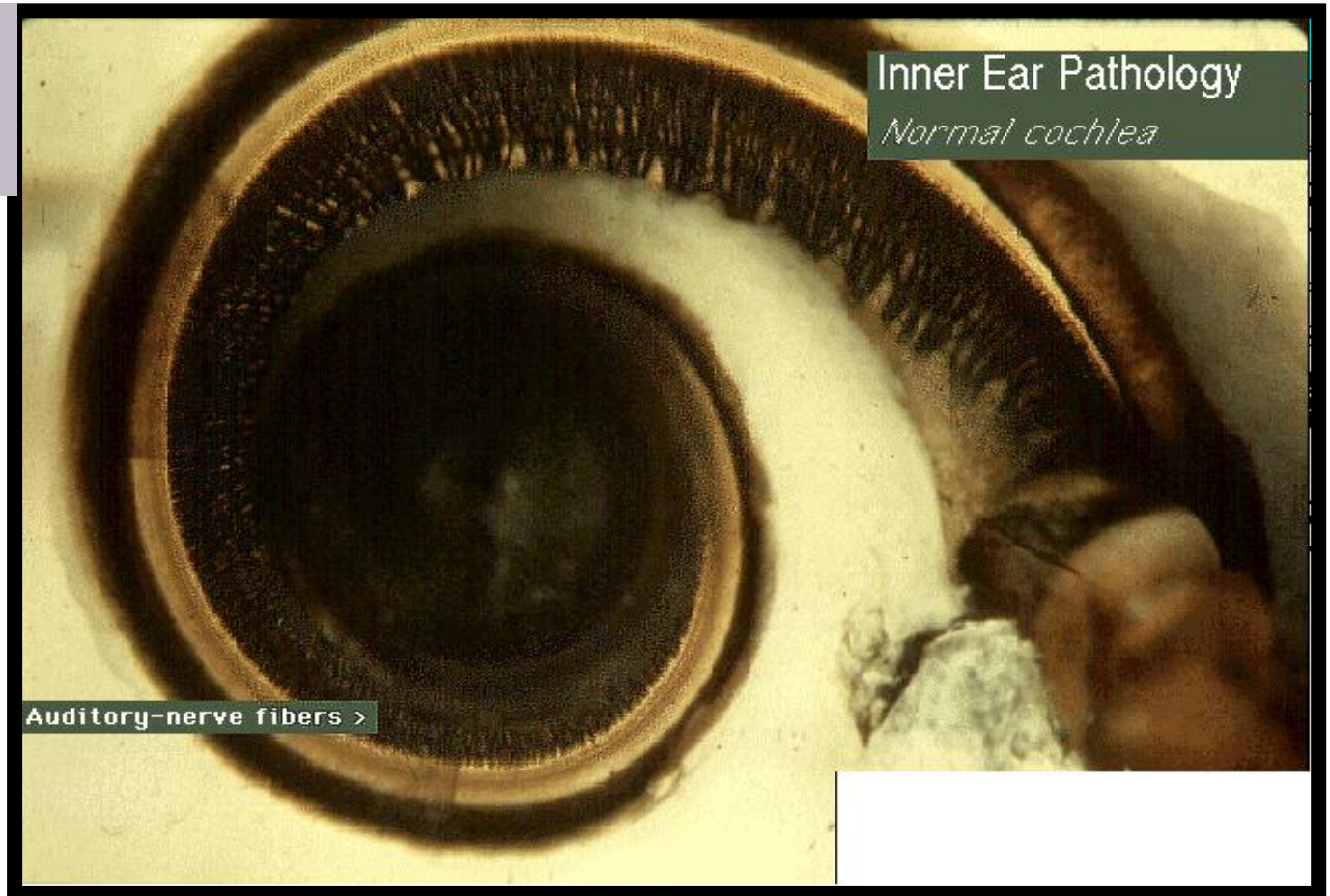
- **Noise pollution** is displeasing human, animal or machine-created sound that disrupts the activity or balance of human or animal life.
- The source of most outdoor noise worldwide is mainly construction and transportation systems, including motor vehicle noise, aircraft noise and rail noise. Poor urban planning may give rise to noise pollution, since side-by-side industrial and residential buildings can result in noise pollution in the residential area.

# Health Effects of Excessive Noise

- **Noise Induced Hearing Loss (NIHL)** - a cumulative effect from repeated exposure and it is due to damage to the hair cells of the cochlea in the inner ear.
- **Tinnitus** - Noise heard in the ear without external cause, frequently accompanies deafness.
- **Temporary Threshold Shift (TTS)** - Damage to the hair cells of the inner ear which can impair hearing temporarily, resulting from exposure to high noise levels.

# Health Effects of Excessive Noise

Healthy  
Cochlea



# Health Effects of Excessive Noise

Damaged  
Cochlea



# Health Effects of Excessive Noise

- **Physical damage** - to the eardrum and ossicles induced by excessively high noises e.g. explosions.
- **Annoyance/stress** - which is difficult to measure and quantify, but may cause psychological effects such as poor concentration, irritability and stress.



# Control Measure for Noise Hazard

**Engineering controls** that reduce sound exposure levels are available and technologically feasible for most noise sources. Engineering controls involve modifying or replacing equipment, or making related physical changes at the noise source or along the transmission path to reduce the noise level at the worker's ear.

Examples of inexpensive, effective engineering controls include some of the following:

- Choose low-noise tools and machinery.
- Maintain and lubricate machinery and equipment (e.g., oil bearings).
- Place a barrier between the noise source and employee (e.g., sound walls or curtains).
- Enclose or isolate the noise source.

# Control Measure for Noise Hazard

**Administrative controls** are changes in the workplace that reduce or eliminate the worker exposure to noise. Examples include:

- Operating noisy machines during shifts when fewer people are exposed.
- Limiting the amount of time a person spends at a noise source.
- Providing quiet areas where workers can gain relief from hazardous noise sources (e.g., construct a sound proof room where workers' hearing can recover).
- Restricting worker presence to a suitable distance away from noisy equipment.
- Controlling noise exposure through distance is often an effective, yet simple and inexpensive administrative control. This control may be applicable when workers are present but are not actually working with a noise source or equipment. Increasing the distance between the noise source and the worker, reduces their exposure.

# Control Measure for Noise Hazard

Hearing protection devices (HPDs), such as earmuffs and plugs, are considered an acceptable but less desirable option to control exposures to noise.



# Control Measure for Noise Hazard

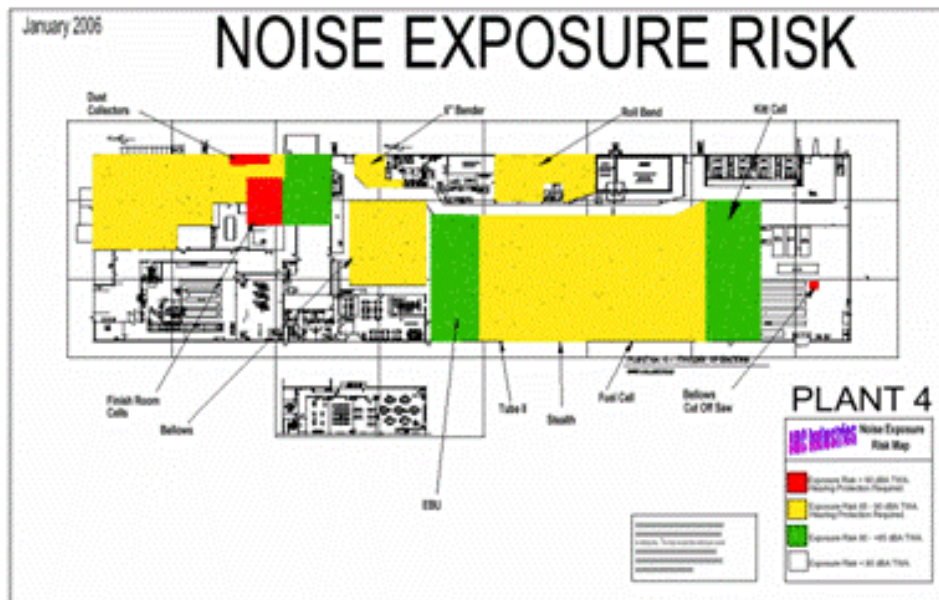
## Ear Plugs Vs Ear Muffs

Earplugs	Earmuffs
<p><b><u>Advantages</u></b> Small &amp; easily carried, convenient to use with other PPE, more comfortable in hot, humid work areas and convenient for use in confined work areas.</p>	<p><b><u>Advantages</u></b> Less attenuation variably among users, designed so that one size fits most hat sizes, may be worn with minor ear infections and not easily misplaced or lost.</p>
<p><b><u>Disadvantages</u></b> Require more time to fit, difficult to insert or remove, may irritate the ear canal, easily misplace, more difficult to see and monitor use, get dirty when your hands are dirty.</p>	<p><b><u>Disadvantages</u></b> Heavier, less portable, inconvenient for use with other PPE, uncomfortable in hot humid work areas, inconvenient for use in confined areas.</p>

# Control Measure for Noise Hazard

An **effective hearing conservation program** must be implemented by employers in general industry. This program strives to –

- prevent initial occupational hearing loss,
- preserve and protect remaining hearing, and
- equip workers with the knowledge and hearing protection devices necessary to protect them.

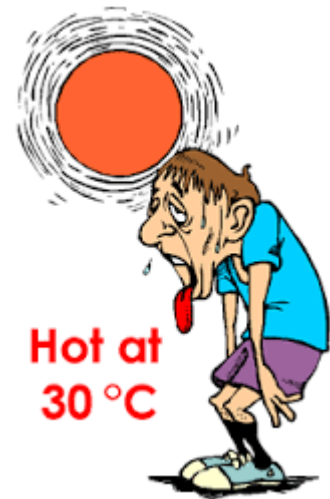


# Control Measure for Noise Hazard

Key elements of an **effective hearing conservation program** include:

- Workplace noise sampling including personal noise monitoring.
- Informing workers at risk from hazardous levels of noise exposure of the results of their noise monitoring.
- Implementing comprehensive hearing protection follow-up procedures for workers who show a loss of hearing (standard threshold shift) after completing baseline (first) and yearly audiometric testing.
- Proper selection of hearing protection based upon individual fit and manufacturer's quality testing indicating the likely protection that they will provide to a properly trained wearer.
- Training and information that ensures the workers are aware of the hazard from excessive noise exposures and how to properly use the protective equipment that has been provided.

# Temperature



# Thermal Balance

*Table 9.1* Basic equation of human thermal balance

$$S = M - E \pm R \pm C - W$$

where

$S$  = Heat gained or lost by the body

$S = 0$  when the body is in thermal balance with the environment

$M$  = Metabolic energy production

$E$  = Heat dissipated through evaporation (sweating)

$R$  = Radiant heat to or from the environment

$C$  = Convection to or from the environment

$W$  = Work accomplished by the worker

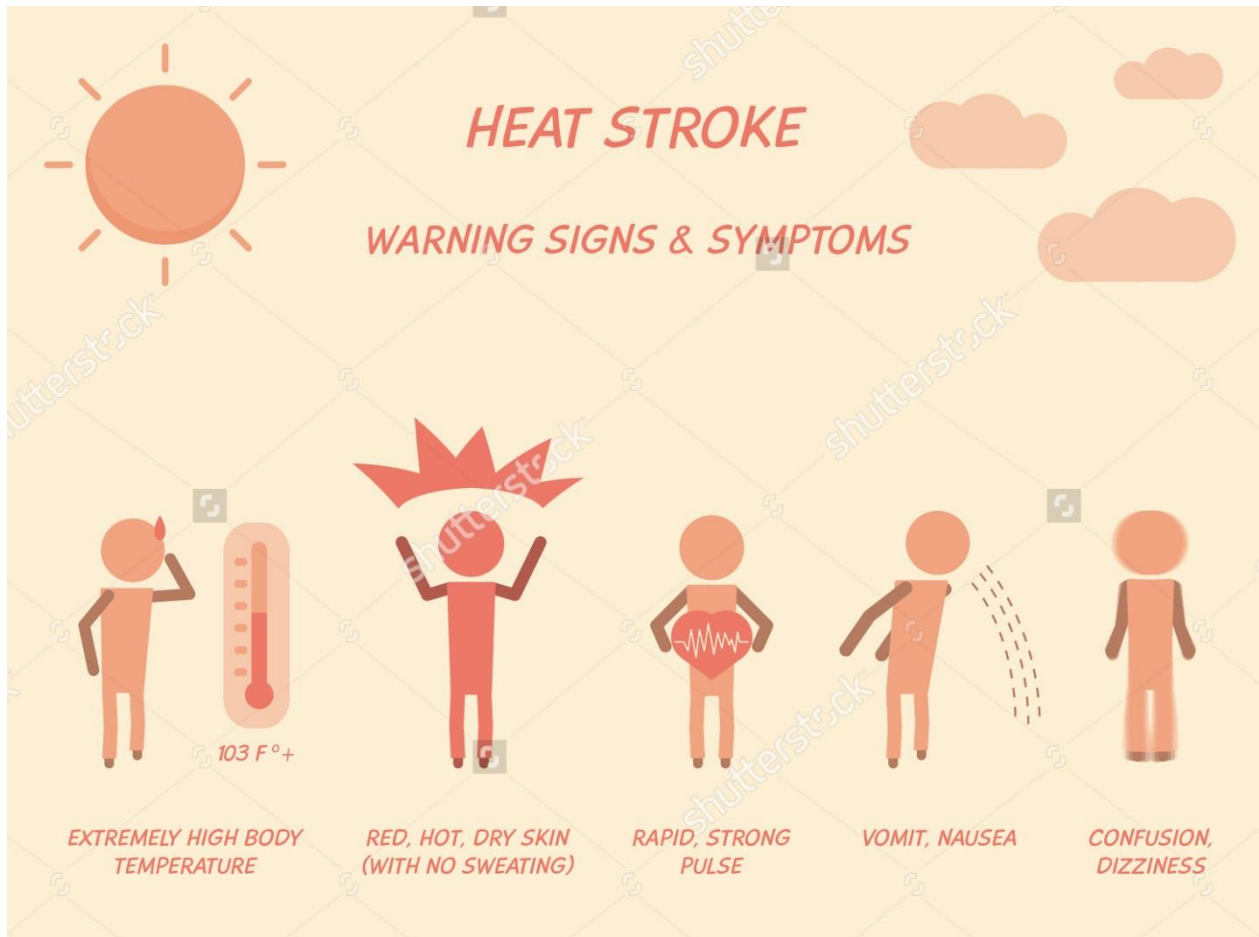
# Heat Illness



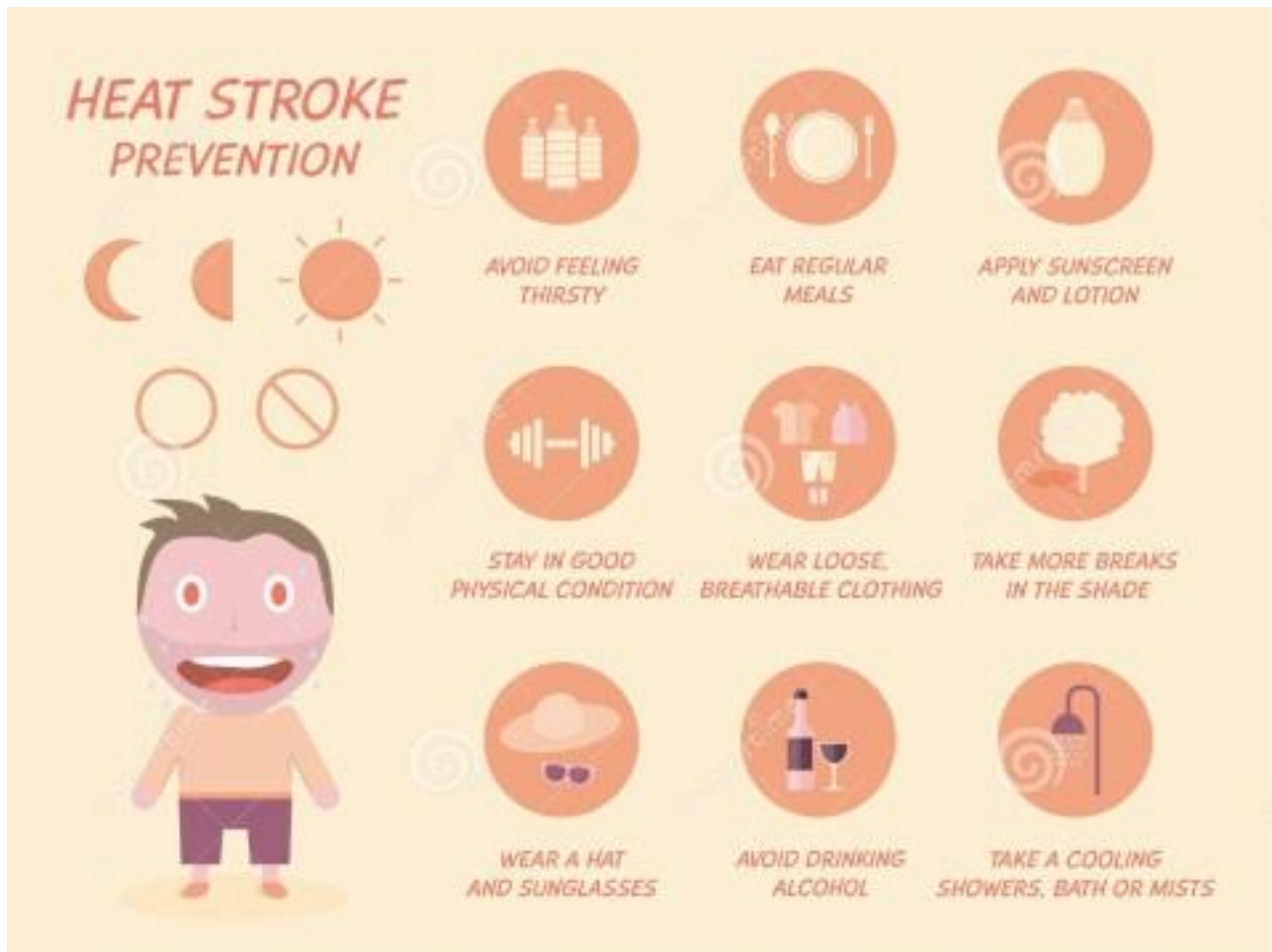
## Heat Hyperpyrexia (Heat Stroke)

- Thermoregulation fails, sometimes suddenly, and core temperature exceeds 41°C.
- The condition may be potentially fatal if untreated. The individual may collapse and will be disorientated. The skin is hot, red and dry.
- Active cooling on rescue from the heat is needed.

# Heat Illness



# Heat Illness



# Heat Acclimatization



- ✓ Heat acclimatization is a physiological process of adaptation rather than a psychological adjustment to life in a hot environment.
- ✓ It involves an increase in the capacity to produce sweat and a decrease in the core temperature threshold value for the initiation of sweating.
- ✓ The maximum rate of sweat production can double from 1 liter/hour in an unacclimatized person to 2 liters/hour in an acclimatized person.
- ✓ A state of acclimatization is best achieved by exercising in the heat and drinking plenty of fluid.



# Heat Acclimatization

- ✓ Increased sweat production enhances evaporative cooling of the skin and thus improves heat transfer from the deep body tissues to the periphery.
- ✓ The risk of dehydration and salt depletion is reduced in an acclimatized person owing to expanded blood volume and a reduction in the salt concentration of the sweat.
- ✓ Acclimatization reduces the skin's blood flow requirements, which reduces the cardiovascular load during work in the heat.

# Heat Stress Management

## Some Basic Steps

- Reduce high relative humidity using dehumidifiers.
- Increase air movement using fans or air conditioners.
- Remove heavy clothing; issue loose-fitting overalls.
- Reduce the work rate.
- Include frequent rest pauses.
- Introduce job rotation.

# Heat Stress Management

## Some Basic Steps

- Carry out outdoor work at cooler times of the day (e.g. early morning).
- Allow 2 weeks for acclimatization.
- Enforce rest breaks and provide drinking water or other fluids.
- Provide shade to reduce radiant heat load (plant trees, build awnings, issue wide-brimmed hats).
- In factories, build cool spots and refuges to lower worker exposure.

# Heat Stress Management

## Work Environment Control

- Air movement of less than 0.1 meter per second can lead to stuffy rooms
- Ventilation (need: 300 cubic feet fresh air per person, per hour.)
- A comfortable temperature range for sedentary work is between 21<sup>0</sup> and 24<sup>0</sup> C
- The optimum range of relative humidity is 40-50%.
- Relative humidity below 20% can cause dryness of the eyes, nose, throat and build up of static charges.
- Humidity above 80% can cause fatigues.

# Heat Stress Management

## Administrative Control

- Limit time in hot or cold situations,
- Provide rest breaks at appropriate intervals in a temperature controlled environment.





**KEEP**

**CALM**

**ITS THE END**

**OF MY**

**SLIDESHOW**