Measurement of body temperature:
Instruments used to measure body temperature:
1. Liquid-filled
The traditional thermometer is a glass tube with a bulb at one end containing a liquid which expands in a uniform manner with temperature.

The tube itself is narrow (capillary) and has calibration markings along it.

i) Range 95/110°F

ii) Range 35/42°C
The liquid is often mercury, but alcohol thermometers use a colored alcohol.
Medically, a maximum thermometer is often used, which indicates the maximum temperature reached even after it is removed from the body.

Medical thermometer has a notch to prevent mercury from return back quickly
To use the thermometer, the bulb is placed in the location where the temperature is to be measured and left long enough to be certain to reach thermal equilibrium—typically three minutes. Maximum-reading is achieved by means of a constriction in the neck close to the bulb. As the temperature of the bulb rises, the liquid expands up the tube through the constriction. When the temperature falls, the column of liquid breaks at the constriction and cannot return to the bulb, thus remaining stationary in the tube. After reading the value, the thermometer must be reset by repeatedly swinging it sharply to shake the liquid back through the constriction.

2. Electronic (Electronic clinical thermometers)
Since compact and inexpensive methods of measuring and displaying temperature became available, electronic thermometers (often called digital, because they display numeric values) have been used. Many
display readings to great precision (0.1 °C or 0.2 °F, sometimes half that), but this should not be taken as guarantee of accuracy: specified accuracy must be checked in documentation and maintained by periodical recalibration. A typical inexpensive electronic ear thermometer for home use has a displayed resolution of 0.1 °C, but a stated accuracy within ±0.2 °C when new.

To change Fahrenheit to Celsius (°F to °C): \( C = \frac{F-32}{1.8} \)

The band thermometer is applied to the patient's brow. It is typically a band coated with different temperature-sensitive markings using liquid-crystal or similar technology; at a given temperature the markings (numerals indicating the temperature) in one region are at the right temperature to become visible. This type gives an indication of fever, but is not considered accurate.

Normal Body temperature:
The ideal core body temperature is 98.6°F or 37.0°C. However, the value 98.2±1.3°F or 36.8±0.7°C is considered to be the normal body temperature (normo-thermia or euthermia) range for oral measurement. The differences between core temperature and measurements at different locations, known as clinical bias:
- Temperature in the anus (rectum/rectal), vagina, or in the ear (otic) is about 37.6 °C (99.7 °F)
- Temperature in the mouth (oral) is about 36.8 °C (99.2 °F)
- Temperature under the arm (axillary) is about 36.4 °C (97.6 °F)
Variation in body temperature
1. Time of day: diurnal rhythm variation can result in a difference of at least 1.0°C depending upon the time of day or night when a temperature is taken. The lowest body temperature is measured around 3 a.m. in the morning, while the highest is recorded at around 6 p.m. in the afternoon. The time of day when the body temperature is likely to reproduce the most accurate and constant reading is between 12 noon and 6:00 pm.
2. An individual’s level of activity: exercise is associated with increase body temperature.
3. Age
4. Gender: Women tend to have higher rectal body temperatures, or temperatures taken directly inside the body cavity, than men,
5. Hormones:
The hormones that increase body temperature (thermogenic hormone):
A. Epinephrine.
B. Thyroxin.
C. Progesterone: it may cause increase body temperature during ovulation.
6. Body sit:
A. Different site of body: Extremities and testes have lower temperature than the center of the body.
B. Location of measurement: rectal has higher and axillary has lower temperature than oral.

Method of obtaining temperature
1. Remove carefully from outer case and clean in cold soapy water if there is no mild disinfectant available. Under no circumstances whatsoever is either ‘hot or boiling’ water to be used since this will ‘burst’ the mercury sensor.
2. Check that the magnified image of the ‘mercury column’ is below 36° C (96°F) on the graduated scale, if not, reset the ‘mercury column’ by repeated ‘upward/downward flicks of the wrist’ until in these positions.
3. Place the thermometer in the desired orifice:
A. Oral Temperature:
To obtain an oral temperature, place the thermometer in the sublingual pocket and have the patient close his mouth around it. Instruct him not to bite down. Leave the thermometer in place 3 to 4 minutes and breath normally through the nose, furthermore, the patient should also refrain from talking. If the patient has been eating, drinking, smoking, brushing his teeth, or chewing gum within the past 15 minutes, wait at least 15 minutes to take the temperature.
B. Rectal temperature:
To obtain a rectal temperature, lubricate the bulb and the area up to 1 inch above it. Use a lubricated probe cover with an electronic thermometer. Turn the patient on his side, fold back the bedding and separate the buttocks so that you can easily see the anal opening. Insert the thermometer approximately 1.5 inches into the anus. Hold the thermometer in place for 3 to 4 minutes.

C. Axillary temperature:
To obtain an axillary temperature, place the thermometer in a dry axilla. Keep the arm close to the body to ensure contact with the bulb or probe for 5 minutes. Clean the thermometer / dispose if the plastic cap. Thank the patient, and wash your hands.

Precautions:
1. Oral temperatures are contraindicated for an unconscious patient, for children/infants under the age of 10 years, or when the patient must breathe through the mouth.
2. The rectal method of obtaining the temperature is contraindicated if the patient has diarrhea, rectal disease, or has recently had rectal surgery.
3. Axilla site is recommended for children under the age of 10 years and elderly care patients.
4. It should be carefully noted that temperatures taken with the glass/mercury thermometer using the axilla site can read lower by at least 1.0°C by comparison to the Oral site; the reason is due to the round shape of the mercury ‘bulb end’ of the thermometer that cannot be in full contact with the flat surface of the axilla.
5. Rectum is only selected when either of the other two sites is not available.
SENSORY FUNCTIONS

1. Tactile sensibility.
Use a wisp of cotton-wool or a fine camel-fir brush. If it is desired to test the sensibility or the skin to light touch over a hairy part, it is essential to shave it, as the sensibility of the hairs themselves is so acute. Tell the patient to say ‘Now’ every time he feels a touch. Compare corresponding points on opposite sides of the body, and employ every now and then a negative test, asking the patient if he feels you touch him, in order to prevent his making random replies. The appreciation of pressure touch should then be tested; this may be done by touching him with the point of a finger or any blunt object. It is important that its temperature should not differ much from that of the skin, and the pressure must not be so heavy as to give pain or discomfort. Ask him also to localize the stimulus by describing or in other way indicating the exact position of the spot touched. This is important, as a patient may be able to feel the stimulus and yet not be able to localize it.

2. Two point discrimination.
Ability to discriminate between two points is tested by the use of dividers, or two pins. The patient is asked whether he is being touched with one or both points. Normally 2 to 4 mm of separation of the points is appreciated on the palmar surfaces of the thumb and fingers, a wider separation being required on the forearm and lower limb.

A method frequently used to test tactile discrimination is to determine a person’s so-called “two-point” discriminatory ability by Aesthesiometer.
In this test, two needles are pressed lightly against the skin at the same time, and the person determines whether one point or two points of stimulus is/are felt. On the tips of the fingers, a person can normally distinguish two separate points even when the needles are as close together as 1 to 2 millimeters. However, on the person’s back, the needles usually must be as far apart as 30 to 70 millimeters before two separate points can be detected. The reason for this difference is the different numbers of specialized tactile receptors in the two areas.

### 3. Detection of Vibration.

All tactile receptors are involved in detection of vibration, although different receptors detect different frequencies of vibration.

1. **Pacinian corpuscles**
   
Pacinian corpuscles can detect signal vibrations from 30 to 800 cycles/sec because they respond extremely rapidly to minute and rapid deformations of the tissues. They also transmit their signals over type Aβ nerve fibers, which can transmit as many as 1000 impulses per second.

2. **Meissner’s corpuscles**
   
Low-frequency vibrations from 2 up to 80 cycles/second, in contrast, stimulate other tactile receptors, especially Meissner’s corpuscles, which adapt less rapidly than do Pacinian corpuscles. These signals are transmitted only in the dorsal column pathway. For this reason, application of vibration (e.g., from a “tuning fork”) to different peripheral parts of the body is an important tool used by neurologists for testing functional integrity of the dorsal columns.

When the foot of a vibrating tuning-fork is placed on the surface of the body the vibrations can be felt, provided they are sufficiently strong. A heavy tuning-fork of 128 vibrations a second is generally employed. Make the fork vibrate by striking its prongs gently on a firm object, and place its foot immediately on the part to be tested; ascertain if the patient perceives the vibrations, and if so, ask him to say at once when he ceases to feel them.
- Place base of 128 Hz tuning fork on tip of a finger or toe
- Ask patient ‘Can you feel that buzzing?’
- If they can not, move proximally, testing vibration sense at bony prominences (hallux, medial malleolus … clavicle) until the vibration is detected.

Note. The tuning fork is firmly tapped on the palm and then placed at the distal interphalangeal joint of the index finger (2A), the ulnar styloid (2B), and the lateral epicondyle (2C).

Neurophysiological studies have demonstrated the existence of very sensitive, rapidly adapting mechanoreceptive free nerve endings that elicit only the tickle and itch sensations. Furthermore, these endings are found almost exclusively in superficial layers of the skin, which is also the only tissue from which the tickle and itch sensations usually can be elicited. These sensations are transmitted by very small type C, unmyelinated fibers similar to those that transmit the aching, slow type of pain this is why pain inhibits itching.

The purpose of the itch sensation is presumably to call attention to mild surface stimuli such as a flea crawling on the skin or a fly about to bite, and the elicited signals then activate the scratch reflex or other maneuvers that rid the host of the irritant.

Itch can be relieved by scratching if this action removes the irritant or if the scratch is strong enough to elicit pain.

5. Sensibility to pain.

Pain may be evoked either by a cutaneous stimulus, as the prick of a pin, or by pressure on such deeper structures, as the muscles or bones. Sensibility to superficial and to pressure pain should be tested separately.

(a) Superficial pain. The point of a steel pin or needle may be used as the stimulus. Care must be taken that the patient distinguishes between the sharpness of the point (that is, its relative size) and the pain which the prick evokes; it often happens that even when sensibility to pain is abolished he can recognize that the stimulus is pointed, and thus confuse the observer by calling it `sharp'.
(b) Pressure pain is examined by squeezing the muscles or the tendo Achilles. Abolition of pressure pain is often the most prominent sensory disturbance in **Tabes dorsalis**, also known as **syphilitic myelopathy**.

6. Thermal sensibility.

It is conveniently examined by using test-tubes containing hot and cold water. The part to be tested is touched with each in turn, and the patient says whether each tube feels hot or cold. It is often important to determine the thresholds for heat and cold, i.e. the lowest temperature that feels warm and the highest that is cold. This can be done by noting the temperatures of the water in the tubes on thermometers contained in them; to do this, it is better to use large copper or glass test-tubes.

6. **Sense of position**.

The patient's eyes being carefully shut, take hold of one of his limbs and move it about in various directions through the air, finally leaving it in some definite position, say semi-flexed and slightly elevated; then ask him to put the corresponding limb in a similar position. If there is no paralysis of the latter, and yet the patient is unable to imitate with it the position of the other, then there is reason to believe that the sense of position is impaired.

In the case of the hand the patient may he told that the fingers of one hand will be moved, and that he must imitate with the other the position in which they have been placed. In the case of the foot he may be told that the great toe will be placed pointing upwards or downwards, and that he must try to tell which it is.

7. The recognition of size, shape and form.
These faculties can be tested most accurately in the hands with the eyes closed. To test size, place in the patient's palm objects of the same shape, but of different sizes, as small rods or matches of different length. Two objects should be applied consecutively, and he is asked to say which is the larger.
To test the power of recognizing form, familiar objects, as coins, a pencil, a penknife, scissors, etc., are placed in the hand, and the patient is asked to identify them or to describe their form.
Astereognosis refers to the inability to recognize objects placed in the hand

Anesthesia: absence of touch appreciation, Hypoesthesia: decrease of touch appreciation
Hyperesthesia: exaggeration of touch sensation, which is often unpleasant
An-algesia: absence of pain appreciation, Hypo-algesia: decrease of pain appreciation, Hyper-algesia: exaggeration of pain appreciation, which is often unpleasant
Par-esthesia: abnormal sensations perceived without specific stimulation.
Dys-esthesia (or hyperalgesia): painful sensations elicited by a non-painful cutaneous stimulus such as a light touch or gentle stroking over affected areas of the body. Often perceived as an intense burning.

Deep Tendon Reflexes
Hypo-reflexia
Hypo-reflexia is an absent or diminished response to tapping.
Hypo-reflexia usually indicates a disease that involves one or more of the components of the two-neuron reflex arc itself.

Hyperreflexia
Hyperreflexia refers to hyperactive or repeating (clonic) reflexes.
Hyperreflexia usually indicate an interruption of corticospinal and other descending pathways that influence the reflex arc due to a supra-segmental lesion, that is, a lesion above the level of the spinal reflex pathways.
By convention the deep tendon reflexes are graded as follows:
- 0 = no response; always abnormal
- 1+ = a slight but definitely present response; may or may not be normal
- 2+ = a brisk response; normal
- 3+ = a very brisk response; may or may not be normal
- 4+ = a tap elicits a repeating reflex (clonus); always abnormal
Whether the 1+ and 3+ responses are normal depends on what they were previously, that is, the patient's reflex history; what the other reflexes are; and analysis of associated findings such as muscle tone, muscle strength, or other evidence of disease. Asymmetry of reflexes suggests abnormality.

**Technique**

All of the commonly used deep tendon reflexes are presented here in a group. In a screening examination you will usually find it more convenient to integrate the reflex examination into the rest of the examination of that part of the body; that is, do the upper extremity reflexes when examining the rest of the upper extremity. When an abnormality of the reflexes is suspected or discovered, however, the reflexes should be examined as a group with careful attention paid to the technique of the examination.

Valid test results are best obtained when the patient is relaxed and not thinking about what you are doing. After a general explanation, mingle the specific instructions with questions or comments designed to get the patient to speak at some length about some other topic. If you cannot get any response with a specific reflex—ankle jerks are usually the most difficult—then try the following:

- Several different positions of the limb.
- Get the patient to put slight tension on the muscle being tested. One method of achieving this is to have the patient strongly contract a muscle not being tested.
- In the upper extremity, have the patient make a fist with one hand while the opposite extremity is being tested.
- Reinforcement technique
  - Upper extremities
    - clench teeth
    - squeeze thigh
  - Lower extremities
    - lock fingers and pull one against the other
- Jendrassik maneuver:
  Patient locks fingers together and pulls hard as you tap the quadriceps tendon
  - Voluntary LMN innervation of the arm "overflows" to increase the excitability of the LMN pool of the lower extremities
  - (makes easier to elicit the reflex)
- If the reflex being tested is the knee jerk or ankle jerk, have the patient perform the "Jendrassik maneuver," a reinforcement of the reflex. The patient's fingers of each hand are hooked together so each arm can forcefully pull against the other. The split second before you are ready to tap the tendon, say "pull."
- In general, any way to distract the patient from what you are doing will enhance the chances of obtaining the reflex. Having the patient count or give the names of children are examples.

The best position is for the patient to be sitting on the side of the bed or examining table. The Babinski reflex hammer is very good. Use a brisk but not painful tap. Use your wrist, not your arm, for the action. In an extremity a useful maneuver is to elicit the reflex from several different positions, rapidly shifting the limb and performing the test. Use varying force and note any variance in response.
Note the following features of the reflex response:

- Amount of hammer force necessary to obtain contraction
- Velocity of contraction
- Strength of contraction
- Duration of contraction
- Duration of relaxation phase
Response of other muscles that were not tested. When a reflex is hyperactive, that muscle often will respond to the testing of a nearby muscle. A good example is reflex activity of a hyperactive biceps or finger reflex when the brachioradialis tendon is tapped. This is termed "overflowing" of a reflex.

After obtaining the reflex on one side, always go immediately to the opposite side for the same reflex so that you can compare them.

**Jaw Jerk**

Place the tip of your index finger on a relaxed jaw, one that is about one-third open. Tap briskly on your index finger and note the speed as the mandible is flexed

**Biceps Reflex**

The forearm should be supported, either resting on the patient's thighs or resting on the forearm of the examiner. The arm is midway between flexion and extension. Place your thumb firmly over the biceps tendon, with your fingers curling around the elbow, and tap briskly. The forearm will flex at the elbow.

**Triceps Reflex**

Support the patient's forearm by cradling it with yours or by placing it on the thigh, with the arm midway between flexion and extension. Identify the triceps tendon at its insertion on the olecranon, and tap just above the insertion. There is extension of the forearm.

**Brachioradialis Reflex**

The patient's arm should be supported. Identify the brachioradialis tendon at the wrist. It inserts at the base of the styloid process of the radius, usually about 1 cm lateral to the radial artery. If in doubt, ask the patient to hold the arm as if in a sling—flexed at the elbow and halfway between pronation and supination—and then flex the forearm at the elbow against resistance from you. The brachioradialis and its tendon will then stand out.

Place the thumb of the hand supporting the patient's elbow on the biceps tendon while tapping the brachioradialis tendon with the other hand. Observe three potential reflexes as you tap.

1. Brachioradialis reflex: flexion and supination of the forearm.
2. Biceps reflex: flexion of the forearm. You will feel the biceps tendon contract if the biceps reflex is stimulated by the tap on the brachioradialis tendon.
3. Finger jerk: flexion of the fingers.

The usual pattern is for only the brachioradialis reflex to be stimulated. But in the presence of a hyperactive biceps or finger jerk reflex, these reflexes may be stimulated also.

**Finger Jerk**

Have the patient gently curl his fingers over your index finger, much as a bird curls its claws around the branch of a tree. Then raise your hand, with the patient's hand now being supported by the curled fingers. Tap briskly on your fingers so that the force will transmit to the patient's curled fingers. The response is a flexion of the patient's fingers.

**Knee Jerk**

Let the knees swing free by the side of the bed, and place one hand on the quadriceps so you can feel its contraction. If the patient is in bed, slightly flex the knee by placing your forearm under both knees by contraction of the quadriceps with extension of the lower leg. If the reflex is hyperactive there is sometimes concomitant adduction of the ipsilateral thigh. Adduction of the opposite thigh and extension of the opposite lower leg also can occur simultaneously if those reflexes are hyperactive. Note that this so-called crossed thigh adduction or leg extension tells you that the reflexes in the opposite leg are hyperactive. They tell you nothing about the state of the reflex in the leg being tested. Use the Jendrassik maneuver if there is no response.

**Ankle jerk reflex**
With the patient sitting, place one hand underneath the sole and dorsiflex the foot slightly. Then tap on the Achilles tendon just above its insertion on the calcaneus. If the patient is in bed, flex the knee and invert or evert the foot somewhat, cradling the foot and lower leg in your arm. Then tap on the tendon. If no response is obtained, have the patient face a chair and kneel on it with the knees resting against the back of the chair, the elbows on the top of the back, and the feet projecting over the seat. First dorsiflex the foot slightly and tap on the tendon. Use the Jendrassik maneuver if this doesn't work. This position is well suited to observing the relaxation phase of the reflex in patients with suspected thyroid disease.

Clinical Significance
Absent stretch reflexes indicate a lesion in the reflex arc itself. Associated symptoms and signs usually make localization possible:

1. Absent reflexes and sensory loss in the distribution of the nerve supplying the reflex: the lesion involves the afferent arc of the reflex—either nerve or dorsal horn.
2. Absent reflex with paralysis, muscle atrophy, and fasciculations: the lesion involves the efferent arc—anterior horn cells or efferent nerve, or both.

Peripheral neuropathy is today the most common cause of absent reflexes. The causes include diseases such as diabetes, alcoholism, amyloidosis, uremia; vitamin deficiencies such as pellagra, beriberi, pernicious anemia; remote cancer; toxins including lead, arsenic, isoniazid, vincristine, diphenylhydantoin. Neuropathies can be predominantly sensory, motor, or mixed and therefore can affect any or all components of the reflex arc. Muscle diseases do not produce a disturbance of the stretch reflex unless the muscle is rendered too weak to contract. This occasionally occurs in diseases such as polymyositis and muscular dystrophy.

Hyperactive stretch reflexes are seen when there is interruption of the cortical supply to the lower motor neuron, an "upper motor neuron lesion." The interruption can be anywhere above the segment of the reflex arc. Analysis of associated findings enables localization of the lesion. The stretch reflexes can provide excellent clues to the level of lesions along the neuraxis.

Lists the segmental innervation of the common stretch reflexes.
For example, if the biceps and brachioradialis reflexes are normal, the triceps absent, and all lower reflexes (finger jerk, knee jerk, ankle jerk) hyperactive, the lesion would be located at the C6–C7 level, the level of the triceps reflex. The reflex arcs above (biceps, brachioradialis, and jaw jerk) are functioning normally, while the lower reflexes give evidence of absence of upper motor neuron innervation.

**Segmental Innervation of Stretch Reflexes**

<table>
<thead>
<tr>
<th>Reflex</th>
<th>Nerve or root</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaw jerk</td>
<td>Trigeminal nerve</td>
</tr>
<tr>
<td>Biceps</td>
<td>C5–C6</td>
</tr>
<tr>
<td>Brachioradialis</td>
<td>C5–C6</td>
</tr>
<tr>
<td>Triceps</td>
<td>C6–C7–C8</td>
</tr>
<tr>
<td>Finger jerk</td>
<td>C8–T1</td>
</tr>
<tr>
<td>Knee jerk</td>
<td>L3–L4</td>
</tr>
<tr>
<td>Ankle jerk</td>
<td>S1</td>
</tr>
</tbody>
</table>

Superficial reflexes
Superficial reflexes are motor responses to scraping of the skin. Superficial reflexes are graded simply as present or absent, although markedly asymmetrical responses should be considered abnormal as well.
Superficial reflexes are a polysynaptic reflex. 
Superficial reflexes can be abolished by ① severe lower motor neuron damage or ② destruction of the sensory pathways from the skin that is stimulated.

Classic examples of superficial reflexes include:

1. The abdominal reflex includes contraction of abdominal muscles in the quadrant of the abdomen that is stimulated by scraping the skin tangential to or toward the umbilicus. This contraction can often be seen as a brisk motion of the umbilicus toward the quadrant that is stimulated.
2. The cremaster reflex is produced by scratching the skin of the medial thigh, which should produce a brisk and brief elevation of the testis on that side.
3. The normal plantar response occurs when scratching the sole of the foot from the heel along the lateral aspect of the sole and then across the ball of the foot to the base of the great toe. This normally results in flexion of the great toe (a "down-going toe") and, indeed, all of the toes. The evaluation of the plantar response can be complicated by voluntary withdrawal responses to plantar stimulation.
4. The "anal wink" is a contraction of the external anal sphincter when the skin near the anal opening is scratched. This is often abolished in spinal cord damage (along with other superficial reflexes).

"Pathological reflexes" Babinski reflex (Extensor Plantar Reflex)

The best known (and most important) of the so-called "pathological reflexes" is the Babinski response (up going toe; extensor response). The full expression of this reflex includes extension of the great toe and fanning of the other toes. This is actually a superficial reflex that is elicited in the same manner as the plantar response (i.e., scratching along the lateral aspect of the sole of the foot and then across the ball of the foot toward the great toe). This is a primitive withdrawal type response that is normal for the first few months of life and is suppressed by supraspinal activity sometime before 6 months of age.

Positive (Abnormal Finding): Dorsiflexion of the big toe and hyperextension of other toes

Negative (Normal in Adults): Brisk plantar flexion; often associated with dorsiflexion of the foot at the ankle

Damage to the descending tracts from the brain (either above the foramen magnum or in the spinal cord) promotes a return of this primitive protective reflex, while at the same time abolishing the normal plantar response. The appearance of this reflex suggests the presence of an upper motor neuron lesion.

Examination of Hearing

Sound wave:

Sound: it is the sensation produced when longitudinal vibration of the molecules in the external environment, i.e., alternate phase of condensation and rarefaction of the molecules, strike the tympanic membrane.

The speed of sound in air is about (344m/s) at 20°C at sea level. The speed of sound increase with:

1. Temperature.
2. Altitude.
3. Media: for example, the speed of the sound wave is (1450m/s) at 20°C in fresh water and is even greater in salt water.

The characters of the sound:

1. Pitch of the sound (is correlated with the frequency).
   
   Frequency: is the number of waves per unit of time.
   
   The greater the frequency, the higher the pitch.

2. Loudness of the sound (is correlated with the amplitude)
   
   The greater the amplitude, the louder the sound.

   The amplitude of a sound wave can be expressed in terms of the maximum pressure change at the eardrum, but a relative scale is more convenient. The decibel scale is such a scale.

   The intensity of a sound expressed in BelS which is the logarithm of the ratio of the intensity of that sound and a standard sound. The unit of the intensity is a decibel (dB) which is 0.1 bel. Therefore:

   \[ \text{Number of dB} = 10 \log \left( \frac{\text{intensity of sound}}{\text{intensity of standard sound}} \right) \]

   Sound intensity is proportionate to the square of sound pressure. Therefore:

   \[ \text{Number of dB} = 20 \log \left( \frac{\text{pressure of sound}}{\text{pressure of standard sound}} \right) \]

   The standard sound reference level adopted by the Acoustical Society of America corresponds to decibels at a pressure level of 0.000204 dyne/cm², a value that is just at auditory threshold for the average human. It is important to remember that the decibel scale is a log scale. Therefore, a value of zero deci-bel does not mean the absence of sound but a sound level of intensity equal to that slandered.

   The 0 to 140 decibel range from threshold pressure to a pressure that is potentially damaging to the organ of Corti actually represents a 10 million-folds variation in sound pressure. The ears can barely distinguish an approximately 1-decibel change in sound intensity.
The sound frequencies audible to humans range from about 20 to a maximum of 20,000 cycle per second (Hz).

In old age, this frequency range is usually shortened to 50 to 8000 cycles/sec or less.

In other animals, notably bats and dogs, much higher frequency is audible.

The Threshold of the human’s ear varies with the pitch of the sound, the greatest sensitivity being in the 1000 to 4000 Hz range.

The pitch of the average male voice in conversation is about 120 Hz and that of the average female voice about 250 Hz.

The number of pitches that can be distinguished by an average individual is about 2000, but trained musicians can improve on this figure considerably. Pitch discrimination is best in the 1000 to 3000 Hz range and is poor at high and low pitches.

Masking:

It is common knowledge that the presence of one sound decreases an individual’s ability to hear other sounds. This phenomenon is known as masking.

It is believed to be due to the relative or absolute refractoriness of previously stimulated auditory receptors and nerve fibers to other stimuli.

The degree to which a given tone masks other tones is related to its pitch.

The masking effect of the background noise in all but the most carefully soundproofed environments raises the auditory threshold by a definite and measurable amount.

Sound transmission:
The ear converts sound waves in the external environment into action potentials in the auditory nerve. The waves are transformed by the eardrum and auditory ossicles into movements of the footplate of the stapes. These movements set up waves in the fluid of the inner ear. The action of the waves on the organ of Corti generates action potentials in the nerve fibers.

Tympanic membrane:

In response to the pressure changes produced by sound wave on the external surface, the tympanic membrane moves in and out.

The membrane therefore functions as a (resonator) that reproduces the vibration of the sound source. It stops vibration almost immediately when the sound wave stops; i.e. it is very nearly (critically damped).

Middle ear (Ossicular system):

The ossicles of the middle ear suspended by ligament in such a way the combined malleus and incus act as a single lever, having its fulcrum approximately at the border of the tympanic membrane. The articulation of the incus with the stapes causes the stapes to push forward on the cochlear fluid every time the tympanic membrane and the handle of the malleus move and to pull backward on the fluid every time the malleus moves outward.
The ossicular lever system does not increase the movement distance of the stapes, as it commonly believed. Instead, the system actually reduces the distance but increase the force of movement about 1.3 times. In addition, the surface area of the tympanic membrane is about 55 mm², whereas the surface area of the stapes average 3.2 mm². This 17-fold difference times the 1.3-fold ratio of the lever system causes about 22 times as much pressure to be exerted on the fluid of the cochlea as is exerted by the sound wave against the tympanic membrane.

Because fluid has far greater inertia than air, it is easily understood that increased amounts of pressure are needed to cause vibration in the fluid. Therefore, the tympanic membrane and ossicular system provide impedance matching between the sound waves in air and the sound vibrations in the fluid of the cochlea.

Indeed, the impedance matching is about 50 to 75 percent of perfect for sound frequencies between 300 and 3000 cycles/sec, which allows utilization of most of the energy in the incoming sound waves.

**Hydraulic action of TM**

<table>
<thead>
<tr>
<th>Area of Tympanic Membrane</th>
<th>Area of Footplate of Stapes</th>
</tr>
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<tbody>
<tr>
<td>55 sq.mm</td>
<td>3.2 sq.mm</td>
</tr>
</tbody>
</table>

Total Transformer Ratio

\[ = 17.1 \times 1.3 \]

\[ = 22.1 \]

**Tympanic reflex (attenuation reflex):**

Tympanic reflex occurs after a latent period of only 40 to 80 milliseconds to cause contraction of the stapedius muscle and, to a lesser extent, the tensor tympani muscle.

Loud sounds initiate a reflex contraction of these muscles generally called the tympanic reflex.

Stapedius muscle (pull stapes outward) ► prevent excessive movement of stapes.

Tensor tympani (pull Malleus inward) ► pull tympanic membrane inward ► tense tympanic membrane.

The functions of tympanic reflex are:
1) To protect the cochlea from damaging vibrations caused by excessively loud sound. This *attenuation reflex* can reduce the intensity of lower-frequency sound transmission by 30 to 40 decibels, which is about the same difference as that between a loud voice and a whisper.

2) To mask low-frequency sounds in loud environments. This usually removes a major share of the background noise and allows a person to concentrate on sounds above 1000 cycle per second, where most of the pertinent information in voice communication is transmitted.

3) To decrease a person's hearing sensitivity to his or her own speech. This effect is activated by collateral signals transmitted to these muscles at the same time that the brain activates the voice mechanism.

**Deafness:**
It is a condition wherein the ability to detect certain frequencies of sound is completely or partially impaired. Hearing impairments are categorized by: their type, by their severity, by the age of onset and by the site.

1. **By their types:**
   A. **Conductive hearing loss**
   A conductive hearing impairment is an impairment resulting from dysfunction in any of the mechanisms that normally conduct sound waves through the outer ear (external ear), the eardrum or the bones of the middle ear.
   The abnormality reduces the effective intensity of the air-conducted signal reaching the cochlea, but it does not affect the bone-conducted signal that does not pass through the outer or middle ear.
   Examples of abnormalities include: 1) occlusion of the external auditory canal by cerumen (ear wax) or a mass, 2) middle ear infection and/or fluid, 3) perforation of the tympanic membrane, or 4) ossicular abnormalities.

   ![Conductive and Sensorineural Hearing Loss](image)

   **B. Sensori-neural hearing loss**
   A sensori-neural hearing impairment is one resulting from dysfunction in:
   1 Sensory: Sensory the inner ear, especially the cochlea where sound vibrations are converted into neural signals
   2 Neural: either ① Neural auditory nerve (vestibule-cochlear N: VIII Cranial) ② the brain.
   C. Mixed
   Mixed hearing loss has conductive and sensori-neural components.

2. **By severity:**
   The severity of a hearing impairment is ranked according to the additional intensity above a nominal threshold that a sound must be before being detected by an individual; it is (measured in decibels of hearing loss, or dB).
Hearing impairment may be ranked as mild, moderate, moderately severe, severe or profound as defined below:
A. **Mild:**
   For adults: between 26 and 40 dB HL. For children: between 20 and 40 dB HL
B. **Moderate:** between 41 and 55 dB HL
C. **Moderately severe:** between 56 and 70 dB HL
D. **Severe:** between 71 and 90 dB HL
E. **Profound:** 91 dB HL or greater

3. **By age:**
The age at which hearing loss occurs is crucial for the acquisition of a spoken language.

A. **Pre-lingual deafness**
   Pre-lingual deafness is hearing impairment that is sustained prior to the acquisition of language
B. **Post-lingual deafness**
   Post-lingual deafness is hearing impairment that is sustained after the acquisition of language

4. **By the site:**
A. **Unilateral hearing impairment:**
   People with unilateral hearing impairment have impairment in only one ear.
B. **Bilateral hearing impairment:**
   People with bilateral hearing impairment have impairment in both ears.

How to detect hearing loss?

I. **Using tuning fork:**
A. **Rinne's test:**
   Definition:
   Rinne's test is a hearing test that compares the perception of sounds as it compares the patient's ability to hear a tone conducted via air and bone through the mastoid process. Thus, one can quickly screen for the presence of conductive hearing loss. It should always be accompanied by a Weber's test that is used to detect a sensori-neural hearing loss, confirming the nature of hearing problem.

   **Purpose:**
   To evaluate a patient's hearing ability by air conduction compared to that of bone conduction.

   **Equipment:**
   Tuning fork

   **Procedure:**
   1. Explain the procedure to the patient to promote cooperation.
   2. Sit the patient in a chair comfortably.
   3. Strike a 512 Hz tuning fork softly (knees or elbows slightly not the table) otherwise the vibrations will be excessive and cause the patient discomfort.
   4. Place the vibrating tuning fork on the base of the mastoid bone. Hold the fork for 2-3 seconds to allow sufficient time to make a mental note of the stimulus intensity.
   5. Ask the client to tell you when the sound is no longer heard.
   6. After the sound is no longer appreciated the vibrating top is held one inch from the external auditory meatus.
   7. The patient is asked whether the sound is louder behind or in front – referring to bone and air conduction respectively.

   **Interpretation of Results**
   Normal: A patient with normal hearing will hear the tone of the vibration longer and louder when the tuning fork is held next to the ear than that against the mastoid bone.
Positive Hearing Loss or “Reversed Rinne”: When a patient hears a louder and longer tone when the vibrating tuning fork is held against the mastoid bone than when it is held next to the ear.

Compares air conduction with bone conduction
normally air conduction > bone conduction (Rinne positive test)
• BC > AC = conductive hearing loss
• AC > BC but impaired = sensori-neural hearing loss

B. Weber’s Test
Definition: Weber’s test is a quick hearing test that is performed with Rinne’s test.
Purpose: The Weber test is used to determine a patient’s hearing ability by bone conduction and is useful in detecting a unilateral (one-sided or asymmetrical) conductive hearing loss and unilateral sensori-neural hearing loss.

Equipment: Tuning Fork
Procedure
1. Explain the procedure to the patient to promote cooperation.
2. Sit the patient in a chair comfortably.
3. Strike a 512 Hz tuning fork softly (knees or elbows slightly not the table) otherwise the vibrations will be excessive and cause the patient discomfort.
4. Place the vibrating tuning fork on the middle of the patient’s head.
   Hold the fork for 2-3 seconds to allow sufficient time to make a mental note of the stimulus intensity.
5. Ask client if the sound is heard better in one ear or the same in both ears.

**Interpretation of Results:**

- **Normal Response:** sound is heard equally at both ears.
- **Sensori-neural Hearing Loss:** loudest sound in unaffected ear. This is because the affected ear is less effective at picking up sound even if it is transmitted directly by conduction into the inner ear.
- **Conductive Hearing Loss:** Loudest sound in affected ear (hears vibrations only). This is because the conduction problem masks the ambient noise of the room, whilst the well-functioning inner ear picks the sound up via the bones of the skull causing it to be perceived as a louder sound than in the unaffected ear.

**B. Weber test:**

- A, Normal—sound is equally loud in both ears; sound does not lateralize.
- B, Conductive loss—sound lateralizes to “poorer” ear owing to background room noise, which masks hearing in normal ear. “Poorer” ear (the one with conductive loss) is not distracted by background noise, thus has a better chance to hear bone-conducted sound.
- C, Sensorineural loss—sound lateralizes to “better” ear or unaffected ear. Poorer ear (the one with nerve loss) is unable to perceive the sound.

**2. Audiometry (Pure Tone Audiometry):**

An audiogram is the best test for hearing.

Air conduction is measured by placing earphones over both ears. Each ear is tested individually to determine its hearing threshold (pitches) at 250, 500, 1000, 2000, 4000, 6000, and 8000 cps or Hertz (Hz). The numbers running from left to right across the top of the graph. They run from low to high, from left to right.

Hearing is measured in decibels (dB), which is a logarithmic scale from -10 to 120 dB. The hearing threshold is defined as the quietest sound heard by the person when being tested. The numbers running from the top to the bottom of the graph indicate loudness levels. Numbers closer to the top relate to soft sounds (like a pin dropping) while numbers at the bottom refer to much louder sounds (like a plane flying overhead).

A normally hearing person would expect to have a threshold of 20dB or better and this represents no hearing loss on the audiogram. The Every 6dB increase measured represents a doubling of sound pressure level. To the human ear (perceptually), every 10dB increases sounds twice as loud. For example, 20 dB
sounds twice as loud as 10dB but 40dB sounds twice as loud as 30dB and 8 times as loud as 10dB (i.e. 10 to 20 to 30 to 40 is $2 \times 2 \times 2 = 8$ times as loud).

It is important to note that hearing is NOT measured in percentages.

An audiometer is a special instrument that is used to measure the acuity of hearing. Hearing loss audiometry includes quantitative testing for a hearing deficit. An audiometer is used to measure and record thresholds of hearing by air conduction and bone conduction tests. The test results determine if hearing loss is conductive, sensorineural, or a combination of both. Hearing loss audiometry includes quantitative testing for a hearing deficit.
Audiometer also helps to determine the degree of deafness.
Right severe unilateral (one-sided) hearing loss

severe-profound hearing loss

Mild sloping to severe hearing loss

Moderate hearing loss

Severe high frequency hearing loss
Examination of the eye

Theoretical part:
The wave length of visible light ranges from approximately 397 nm to 723 nm.
The images of objects in the environment are focused on the retina.
The light rays striking the retina generate potentials in rods and cones.
Impulses initiated in the retina are conducted to the cerebral cortex, where they produce the sensation of vision.

Principles of optics:
Light rays are (reflected) when they pass from one medium into a medium of a different density, except when they strike perpendicular to the interface.

Convex Lens (عدسة محدبة) focuses light rays (which is called convergence of light rays).

Concave Lens (عدسة مقعرة) diverges light rays (which is called diverges light rays).
Parallel light rays striking a biconvex lens are reflected to a point (principal focus) behind the lens.
The principal focus is on a line passing through the centers of curvature of the lens, the principal axis.
The distance between the lens and the principal focus is the principal focal distance (focal length).
For practical purposes, light rays from an object that stick a lens more than 6 meters (20 ft) away are considered to be parallel.
The rays from an object closer than 6 meters are diverging and are therefore brought to a focus farther back on the principal axis than the principal focus. Biconcave lenses cause light rays to diverge.

The principal focus (F), focal length (f), principle axis (R)

Increasing the curvature of a lens will increase its refractive power.
The refractive power of a lens is conveniently measured in Diopters,
The number of Diopters being the receptors of the principal focal distance in meters

\[ P = \frac{1}{f} \]

Where \( P \): the converging power measured in diopters.
F: the focal distance in meters

For example, lens with a principal focal distance of 0.25 meters gas a refractive power of (1 / 0.25), or 4 diopters.

The human eye has a refractive power of approximately 60 diopters at rest.

**Eye structures:**

The cornea and lens provide the converging power of the eye.

**A. Cornea:**

The cornea is the avascular, transparent outer surface of the eye.

The absence of blood vessels in the cornea allows light to pass through unhindered. Because it has no blood vessel, the cornea receives oxygen and nutrients via diffusion through the aqueous humor.

The cornea is responsible for approximately two-thirds of the refractive power of the eye, and its refractive power cannot be altered physiologically.

**B. Lens:**

Like the cornea, is avascular and transparent. Unlike the cornea, the refractive power of the lens is under physiologic control.

As individual ages, the lens develops opacities called (cataracts). Normal vision can be restored by surgically removing the opaque lens and replacing it with a plastic lens.

**Retinal Image:**

In the eye, light is actually refracted at the anterior surface of the cornea and at the anterior and the posterior surface of the lens.

The process of refraction can be represented diagrammatically, however, without introducing any appreciable error, by drawing the rays of light as if all refraction occurs at the anterior surface of the cornea. If all the refractive surfaces of the eye are algebraically added together and then considered to be one single lens, the optics of the normal eye may be simplified and represented schematically as a “reduced eye.” This is useful in simple calculations. In the reduced eye, a single refractive surface is considered to exist, with its central point 17 millimeters in front of the retina and a total refractive power of 59 diopters when the lens is accommodated for distant vision.

\[ P = \frac{1}{f} \]

Since 17 mm = 0.017 meter then \( P = \frac{1}{0.017} \), \( P = 58.8 \) diopters

This true when the object is 6 meter and more

About two thirds of the 59 diopters of refractive power of the eye is provided by the anterior surface of the cornea (not by the eye lens). The principal reason for this is that the refractive index of the cornea is markedly different from that of air, while the refractive index of the eye lens is not greatly different from the indices of the aqueous humor and vitreous humor.
It should be noted that the retinal image is inverted. The connections of the retina receptors are such that from birth any inverted image on the retina is viewed right side up and projected to the visual field on the side opposite to the retinal area stimulated. This perception is present in infant and is innate. If retinal image are turned right side up by means of special lenses, the objects viewed look as if they are upside down.

**The near response:**

When the object distance is less than 6 meters, then some changes occur to the eye to keep the object image falls on the retina includes. Changes in viewing distance as part of the near triad (the near reflex), consists of: 1. accommodation, 2. miosis, 3. convergence

1. **Accommodation:**
   - When the ciliary muscle is relaxed, parallel light rays striking the optically normal (emmetropic) eye are brought to a focus on the retina.
   - As long as this relaxation is maintained, rays from objects closer than 6 meters from the observer are brought to a focus behind the retina, and the objects appear blurred.
   - The problem of bringing diverging rays from close objects to a focus on the retina can be solved by increasing the distance between the lens and the retina or by increasing the curvature or refractive power of the lens.
   - The process by which the curvature of the lens is increased is called (accommodation).
   - At rest, the lens is held under by lens ligaments. Because the lens substance is malleable and the lens capsule has considerable elasticity, the lens is pulled into a flattened shape.

When viewing distant objects, the lens is made relatively thin and flat and has the least refractive power. For near vision, the lens becomes thicker and rounder and has the most refractive power. These changes result from the activity of the ciliary muscle that surrounds the lens. The lens is held in place by radially arranged connective tissue bands (called zonule fibers) that are attached to the ciliary muscle. The shape of the lens is thus determined by two opposing forces:
1. The elasticity of the lens, which tends to keep it rounded up (removed from the eye, the lens becomes spheroidal),
2. The tension exerted by the zonule fibers, which tends to flatten the lens. When viewing distant objects, the force from the zonule fibers is greater than the elasticity of the lens, and the lens assumes the flatter shape appropriate for distance viewing. The changes during accommodation:
   a. contraction of ciliary muscles,
   b. approximation of ciliary muscles,
   c. relaxation of zonula fibers (suspensory ligaments),
   d. increase curvature of anterior surface of the lens. Focusing on closer objects requires relaxing the tension in the zonule fibers, allowing the inherent elasticity of the lens to increase its curvature. This relaxation is accomplished by contraction of the ciliary muscle. Unfortunately, changes in the shape of the lens are not always able to produce a focused image on the retina, in which case a sharp image can be focused only with the help of additional corrective lenses.

The ciliary muscle is controlled almost entirely by parasympathetic nerve signals transmitted to the eye through the third cranial nerve.

In young individuals, change in shape may add as many as 12 diopters to the refractive power of the eye.

Accommodation is an active process, requiring muscular effort, and can therefore be tiring. Indeed, the ciliary muscle is one of the most used muscles in the body.

The degree to which the lens curvature can be increased is, of course, limited and light rays from an object very near the individual cannot be brought to a focus on the retina even with the greatest of effort.

The nearest point to the eye at which an object can be brought into clear focus by accommodation is called the (near point of vision). The near point recedes through life, slowly at first and then rapidly with advancing age, from approximately 9 cm at age 10 to approximately 83 cm at age 60. This recession is due principally to increasing hardness of the lens, with a resulting loss of accommodation due to the steady decrease in the degree to which the curvature of the lens can be increased. By the time a normal individual reaches age 40 to 45, the loss of accommodation is usually sufficient to make reading and close work difficult. This condition, which is known as (presbyopia), can be corrected by wearing glasses with convex lenses.

2. Miosis (or pupillary constriction):
Stimulation of the parasympathetic nerves excites the pupillary sphincter muscle, thereby decreasing the pupillary aperture; this is called miosis. Conversely, stimulation of the sympathetic nerves excites the radial fibers of the iris and causes pupillary dilation, called mydriasis.

The size of the pupillary aperture is controlled by two opposing smooth muscles, Sphinctor pupillae (muscle fibers arranged concentrically around the pupil). Dilator pupillae (muscle fibers arranged radially around the pupil).

The sphincter muscle changes its tonus in response to two types of physiologic stimuli:
The **pupillary light reflex** (or pupillary accommodation reflex) is a reflex that controls the diameter of the pupil. When light is directed into one eye or when an object is close to the eye; the pupil constricts (pupillary light reflex). Thus, the pupillary light reflex regulates the intensity of light entering the eye. A smaller pupil produces a sharper image on the retina. The pupil of the other eye also constricts (**consensual light reflex**). Consequently, the light response is sometimes lost while the response to accommodation remains intact (**Argyll Robertson Pupil**).

The amount of light that enters the eye through the pupil is proportional to the area of the pupil or to the square of the diameter of the pupil. The limits of papillary diameter are about 1.5 millimeters on the small side and 8 millimeters on the large side. Therefore, because light brightness on the retina increases with the square of pupillary diameter, the range of light and dark adaptation that can be brought about by the pupillary reflex is about 30 to 1 (that is, up to as much as 30 times change in the amount of light entering the eye).

3. **Convergence:**
The gaze of the two eyes shifts toward the center of the head to keep both eyes focused on the objects.

**Common defects of the image-forming mechanism (Errors of refraction):**
In which distant objects cannot be seen clearly, are caused by variations in the converging power of the cornea, lens or both:

1. **Myopia (nearsightedness):**
   In the nearsighted eye,
   1. the eyeball is too long (antero-posterior distance of the eye ball is too long) or
   2. the cornea is too steep (has too much curvature). As a result, the light entering the eye is not focused correctly on the retina; the focal point is in front of the retina. Nearsighted persons have more trouble seeing distant objects as clearly as near objects, and distant objects look blurred (the object can be seen clearly if it is moved closer to the eye). This problem is often noticed in school-age children who complain of having trouble seeing the chalkboard.
   In severe myopia; the far point may be only 10 to 15 cm from the eye.
Because the objects must be brought near to the eye to be seen clearly (i.e. they are able to do fine work without magnifying glasses).

Myopia is said to be genetic in origin. In human there is a positive correlation between sleeping in a lighted room before the age of two and the subsequent development of myopia. In young adults human the extensive close work involved in activities such as studying accelerates the development of myopia. This defect can be corrected by glasses with **biconcave lens**, which make parallel light ray diverge.

![Emmetropia, Myopia, Corrected Myopia](image1.png)

2. **Hyperopia (farsightedness):**
Farsighted individuals typically develop problems reading up close before the age of 40. The farsighted eye is usually 1) slightly shorter than a normal eye and 2) may have a flatter cornea (has less curvature). Thus, the light of distant objects focuses behind the retina. Farsighted persons usually have trouble seeing objects that are close to them and near objects look blurred.

![Emmetropia, Hyperopia, Corrected Hyperopia](image2.png)
In young age, farsightedness gives rise to no symptoms because the natural accommodation of the eye is strong, correcting mild to moderate degrees of farsightedness. As age advances the power of accommodation becomes less, the farsighted person starts to find difficulty in seeing first close objects, and later both close and far object. Sustained accommodation even when viewing distant objects can partially compensate for the defect, but the prolonged muscular effort is tiring and may cause headaches after performing close work and blurring of vision. The prolonged convergence of the visual axes associated with the accommodation may lead eventually to squint (strabismus).

The defect can be corrected by using glasses with convex lens, which aid the refractive power of the eye in shorting the focal distance.

3. Astigmatism:

Causes of astigmatism:
1. Corneal: due to an irregularly shaped cornea
2. Lenticular: due to an irregularly shaped lens.

Types of astigmatism:
A. In regular astigmatism: the principal meridians are 90 degrees apart (perpendicular to each other). Regular astigmatism results from an oblong, or egg or football-shaped, cornea; it will be divided into:
   1. Myopic astigmatism: One or both principal meridians of the eye are nearsighted. (If both meridians are nearsighted, they are myopic in differing degree.)
   2. Hyperopic astigmatism: One or both principal meridians are farsighted. (If both are farsighted, they are hyperopic in differing degree.)
   3. Mixed astigmatism. One principal meridian is nearsighted, and the other is farsighted.
B. In irregular astigmatism: the principal meridians are not perpendicular. Irregular astigmatism causes light to be distorted from the uneven surface of the cornea, which typically manifests as multiple images from a single object.
It is one where rays that propagate in two perpendicular planes have different foci, so that part of the retinal image is blurred and distorted (for example, a point seen as a line and a line appears to have a halo on either side of it).

To correct for astigmatism, a cylindrical surface is ground with a spherical surface to produce a lens with maximum and minimum refractive powers 90 degrees from each other.

**Color vision:**
The Young–Helmholtz theory of color vision in humans postulates the existence of three kinds of cones; each containing a different photo-pigment and that are maximally sensitive to one of the three primary colors, with the sensation of any given color being determined by the relative frequency of the impulses from each of these cone systems. The correctness of this theory has been demonstrated by the identification and chemical characterization of each of the three pigments.
One pigment (the blue-sensitive, or short-wave, pigment) absorbs light maximally in the blue-violet portion of the spectrum. Another (the green-sensitive, or middle-wave, pigment) absorbs maximally in the green portion. The third (the red-sensitive, or long-wave, pigment) absorbs maximally in the yellow portion. Blue, green, and red are the primary colors, but the cones with their maximal sensitivity in the yellow portion of the spectrum are sensitive enough in the red portion to respond to red light at a lower threshold than green. This is all the Young–Helmholtz theory requires.

Perception of White Light: About equal stimulation of all the red, green, and blue cones. The suffix “–anomaly” denotes color weakness and the suffix “–anopia” color blindness. The prefixes ‘prot-’, ‘deuter-’ and ‘tri-’ refer to defects of red, green, and blue cone system, respectively.

**Color blindness**
Normal color vision uses all three types of light cones correctly and is known as **trichromacy**. People with normal color vision are known as **trichromats**.

**Dichromate**
Individuals with only two normal cone systems; the third color category is simply not seen. Dichromacy can match their color spectrum by mixing only two primary colors.

Dichromacy exists in following forms:
1. protanopia, in which all color matches can be achieved by using only green and blue light (NO red)
2. deuteranopia (most common), in which all matches can be achieved by using only blue and red light (NO green)
3. tritanopia, in which all color matches can be achieved by using only green and red light (NO blue)

**Monochromate**
Individuals with only one cone system
Monochromate match their color spectrum by varying the intensity of only one.

**Anomalous Trichromacy**
The different anomalous conditions are:
- **protanomaly**, which is a reduced sensitivity to red light,
- **deuteranomaly** which is a reduced sensitivity to green light and is the most common form of color blindness
- **tritanomaly** which is a reduced sensitivity to blue light and is extremely rare.

The effects of anomalous trichromatic vision can range from almost normal color perception to almost total absence of perception of the ‘faulty’ color.
There is general agreement that worldwide 8% of men and 0.5% of women have a color vision deficiency. The 8% of color blind men can be divided approximately into 1% deuteranopes, 1% protanopes, 1% protanomalous and 5% deuteranomalous. Approximately half of color blind people will have a mild anomalous deficiency, the other 50% have moderate or severe anomalous conditions.

**Optic nerve neural pathway:**
The axon of the ganglion cells pass caudally in the optic nerve and optic tract to end in the lateral geniculate body, a part of the thalamus. The fibers from each nasal hemi-retina decussate in the optic chiasm. In the geniculate body, the fibers from the nasal half of one retina and the temporal half of the other synapse on the cells whose axons from the geniculocalcarine tract. This tract passes to the occipital lobe of the cerebral cortex. The primary visual receiving area (primary visual cortex, Brodmann’s area 17). Some ganglion cell axon pass from the optic tract to the

1. Pretectal region of the midbrain.
2. The superior colliculus, where they form a connection that mediate papillary reflexes and eye movements.
3. Other axons pass directly from the optic chiasm to the suprachiasmatic nuclei in the hypothalamus, where they from connections that synchronize a variety of endocrine and other circadian rhythms with the light-dark cycle.

**Abnormalities in the field of vision:**
A. **Damage to the optic nerve:** causes loss visual field of one side.
B. **Damage to optic chiasm:** causes prevent the crossing of impulses from the nasal halves of the two retinas to the opposite optic tract. Therefore, the nasal halves of the retina of both eyes are blinded, which means that the person is blind in both temporal field of vision because the image of the field of vision is inverted on the retina by the optical system of the eye; this condition is called bi-temporal hemi-anopia (or heteronymous (opposite sides of the visual fields) hemianopia (half-blindness).
C. **Damage to optic tract:** causes denervate the corresponding half of each retina on the same side as the lesion, and as a result, neither eye can see objects to the opposite side of the head. This condition is known as homo-nymous hemi-anopia. Homonymous: same side of both visual fields.
D. **Damage to optic radiation or the visual cortex:** causes homonymous (same side of both visual fields) hemianopia (half-blindness)
Ophthalmoscope examination of retina (fundoscopic)
I. **Optic disk**:
   1. It is the place where the optic nerve leaves the eye.
   2. It is place where the retinal blood vessels enter it at a 3 mm medial to and slightly above the posterior pole of the globe.
   3. There are no visual receptors overlying the disk, and consequently this spot is blind (blind spot).

II. **Macula lutea**:
   1. It is near the posterior pole of the eye.
   2. It is yellowish pigmented spot.
   3. It contains the fovea centralis: only 0.3 millimeter in diameter which characterized by:
      A. It is a thinned-out, rod-free portion of the retina.
      B. It is composed almost entirely of cones and are densely packed, and each synapses to a single bipolar cell which in turn synapses on a single ganglion cell, providing a direct pathway to the brain.
      C. There are very few overlying cells and no blood vessels.
      D. The fovea is the point where visual acuity is greatest. When attention is attracted to or fixed on an object, the eyes are normally moved so that rays coming from the objects fall on the fovea.

III. **Blood vessels**:
The arteries, arterioles, and veins in the superficial layers of the retina near its vitreous surface can be seen through the ophthalmoscope. Since this is the one place in the body where arterioles are readily visible, ophthalmoscope examination is of great value in the diagnosis and evaluation of diabetes mellitus, hypertension, and other diseases that affect blood vessels. The retinal vessels supply the bipolar and ganglion cells, but the receptors are nourished for the most part by capillary plexus in the choroids. This is why retinal detachment is so damaging to the receptor cell.
FIXATION MOVEMENTS OF THE EYES

Fixation movements of the eyes

Perhaps the most important movements of the eyes are those that cause the eyes to “fix” on a discrete portion of the field of vision. Fixation movements are controlled by two neuronal mechanisms.

The first of these mechanisms allows a person to move the eyes voluntarily to find the object on which he or she wants to fix the vision, which is called the voluntary fixation mechanism.

The voluntary fixation movements are controlled by a cortical field located bilaterally in the premotor cortical regions of the frontal lobes. Bilateral dysfunction or destruction of these areas makes it difficult for a person to “unlock” the eyes from one point of fixation and move them to another point. It is usually necessary to blink the eyes or put a hand over the eyes for a short time, which then allows the eyes to be moved.

The second is an involuntary mechanism, called the involuntary fixation mechanism that holds the eyes firmly on the object once it has been found.

Conversely, the fixation mechanism that causes the eyes to “lock” on the object of attention once it is found is controlled by secondary visual areas in the occipital cortex, located mainly anterior to the primary visual cortex. When this fixation area is destroyed bilaterally in an animal, the animal has difficulty keeping its eyes directed toward a given fixation point or may become totally unable to do so.

To summarize, posterior “involuntary” occipital cortical eye fields automatically “lock” the eyes on a given spot of the visual field and thereby prevent movement of the image across the retinas. To unlock this visual fixation, voluntary signals must be transmitted from cortical “voluntary” eye fields located in the frontal cortices.
Mechanism of Involuntary Locking Fixation—Role of the Superior Colliculi.

The involuntary locking type of fixation discussed in the previous section results from a negative feedback mechanism that prevents the object of attention from leaving the foveal portion of the retina. The eyes normally have three types of continuous but almost imperceptible movements:

1. a continuous tremor at a rate of 30 to 80 cycles/sec caused by successive contractions of the motor units in the ocular muscles;
2. a slow drift of the eyeballs in one direction or another; and
3. sudden flicking movements that are controlled by the involuntary fixation mechanism.

When a spot of light becomes fixed on the foveal region of the retina, the tremulous movements cause the spot to move back and forth at a rapid rate across the cones, and the drifting movements cause the spot to drift slowly across the cones. Each time the spot drifts as far as the edge of the
fovea, a sudden reflex reaction occurs, producing a flicking movement that moves the spot away from this edge back toward the center of the fovea. Thus, an automatic response moves the image back toward the central point of vision. This involuntary fixation capability is mostly lost when the superior colliculi are destroyed.

**Saccadic Movement of the Eyes—A Mechanism of Successive Fixation Points.**

When a visual scene is moving continually before the eyes, such as when a person is riding in a car, the eyes fix on one highlight after another in the visual field, jumping from one to the next at a rate of two to three jumps per second. The jumps are called *saccades*, and the movements are called *opticokinetic movements*. The saccades occur so rapidly that no more than 10 percent of the total time is spent moving the eyes, with 90 percent of the time being allocated to the fixation sites. Also, the brain suppresses the visual image during saccades, so the person is not conscious of the movements from point to point.

**Saccadic Movements During Reading.**

During the process of reading, a person usually makes several saccadic movements of the eyes for each line. In this case, the visual scene is not moving past the eyes, but the eyes are trained to move by means of several successive saccades across the visual scene to extract the important information. Similar saccades occur when a person observes a painting, except that the saccades occur in upward, sideways, downward, and angulated directions one after another from one highlight of the painting to another, and so forth.

**Fixation on Moving Objects—“Pursuit Movement.”**

The eyes can also remain fixed on a moving object, which is called *pursuit movement*. A highly developed cortical mechanism automatically detects the course of movement of an object and then rapidly develops a similar course of movement for the eyes. For instance, if an object is moving up and down in a wavelike form at a rate of several times per second, the eyes at first may be unable to fixate on it. However, after a second or so, the eyes begin to jump by means of saccades in approximately the same wavelike pattern of movement as that of the object. Then, after another few seconds, the eyes develop progressively smoother movements and finally follow the wave movement almost exactly. This represents a high degree of automatic subconscious computational ability by the pursuit system for controlling eye movements.

**Superior Colliculi Are Mainly Responsible for Turning the Eyes and Head Toward a Visual Disturbance.**

Even after the visual cortex has been destroyed, a sudden visual disturbance in a lateral area of the visual field often causes immediate turning of the eyes in that direction. This turning does not occur if the superior colliculi have also been destroyed. To support this function, the various points of the retina are represented topographically in the superior colliculi in the same way as in the primary visual cortex, although with less accuracy. Even so, the principal direction of a flash of light in a peripheral retinal field is mapped by the colliculi, and secondary signals are transmitted to the oculomotor nuclei to turn the eyes. To help in this directional movement of the eyes, the superior colliculi also have topological maps of somatic sensations from the body and acoustic signals from the ears. The optic nerve fibers from the eyes to the colliculi, which are responsible for these rapid turning movements, are branches from the rapidly conducting M fibers, with one branch going to the visual cortex and the other going to the superior colliculi. In addition to causing the eyes to turn toward a visual disturbance, signals are relayed from the superior colliculi through the *medial longitudinal fasciculus* to other levels of the brain stem to cause turning of the whole head and even of the whole body toward the direction of the disturbance. Other types of nonvisual disturbances, such as strong sounds or even stroking of the side of the body, cause similar turning of the eyes, head, and body, but only if the superior colliculi are intact. Therefore, the superior colliculi play a global role in orienting the
eyes, head, and body with respect to external disturbances, whether they are visual, auditory, or somatic

**Neural Mechanism of Stereopsis for Judging Distances of Visual Objects**

Because the two eyes are more than 2 inches apart, the images on the two retinas are not exactly the same. That is, the right eye sees a little more of the right-hand side of the object, and the left eye sees a little more of the left-hand side; the closer the object, the greater the disparity. Therefore, even when the two eyes are fused with each other, it is still impossible for all corresponding points in the two visual images to be exactly in register at the same time. Furthermore, the nearer the object is to the eyes, the less the degree of register. This degree of nonregister provides the neural mechanism for **stereopsis**, an important mechanism for judging the distances of visual objects up to about 200 feet (60 meters).

The neuronal cellular mechanism for stereopsis is based on the fact that some of the fiber pathways from the retinas to the visual cortex stray 1 to 2 degrees on each side of the central pathway. Therefore, some optic pathways from the two eyes are exactly in register for objects 2 meters away; still another set of pathways is in register for objects 25 meters away. Thus, the distance is determined by which set or sets of pathways are excited by nonregister or register. This phenomenon is called **depth perception**, which is another name for stereopsis.
Practical part:
Visual-Acuity:
Assessing the subject’s visual acuity is important as it provides a context for other elements of the exam. Visual acuity is typically assessed by a Snellen chart (which can be hand held or mounted) in the clinical environment, but other charts types (e.g. Allen figures, illiterate E charts, Landolt C, etc) are also used. A pinhole test will improve vision with most refractive errors.

Visual acuity is measured by comparing the person’s ability to see objects at standardized distances. The standard definition of normal visual acuity is 20/20 (US) or 6/6 vision (typically used in Europe & Australia as it refers to meters). Often Snellen Charts will have these values (e.g. 6/6, 6/12, 6/18 etc) along the side.

The chart consists of number of lines of block letters, beginning with a large single letter on the top row. The number of letters on each row increases moving from top to bottom. The size of the letters progressively decreases, allowing for more letters on each subsequent line. The traditional Snellen eye has equal weighting between the black lines and the white space of each letter. Only the letters C, D, E, F, L, N, O, P, T, and Z are used, and the height of the letter is five times the width of the line.

If the eye watches two objects, for example two black dots; it will see them under a certain angle. Obviously, if this angle gets too small, the eye cannot distinguish them from each other. Technically speaking, visual
Acuity is a measure of the eye spatial resolving power and indicates the angular size of the smallest detail that a person visual system can resolve. A person with 6/6 (when expressed in meters) normal vision can resolve a spatial pattern where each element within the pattern subtends a visual angle of one minute of arc angle i.e. 1/60th of a degree at the eye (in minutes of arc. One minute, 1′, of arc is 1/60°), when viewed at 6 meters away. This represents the minimum angle of resolution (MAR).

In 1863, Professor Hermann Snellen quantitatively the lines by comparison of the visual acuity of person with that of assistant who had perfect vision. Thus (6/60) vision meant that the patient could see at 6 meters what Snellen’s assistant could see at 60 meters. The essence of correct identification of the letters on the Snellen chart is to see the clear spaces between the black elements of the letter. The angular spacing between the bars of the E is 1 minute for 6/6 letter. The entire letter has an angular height of 5 minutes. To calculate the height, X, of a 6/6 letter equation:

\[ \tan(5 \text{ minute}) = \frac{[X \text{ meters}]}{[6 \text{ meters}]} \]

From this equation \( X = 0.887 \text{ cm} \) for 6/6 and 10 times taller, \( X = 8.87\text{cm} \) for 6/60.

**Visual acuity examination:**

Visual acuity is measured with Snellen’s test-types, a series of letters of varying sizes so constructed that the top letter is visible to the normal eye at 60 meters, and the subsequent lines at 36, 24, 18, 12, 9, 6, and 5 meters respectively. Visual acuity (V) is recorded according to the formula:

\[ V = \frac{d}{D} \]

Where: \( d \), is the distance at which the letters are read.

\( D \), at which they should be read.

The patient is normally placed at a distance of 6 meters from the test types (d=6) and each eye is tested separately. The patient reads down the chart as far as he can. If only the top letter of the chart is visible, the visual acuity is 6/60. A normal person should be able to read at least the seventh line, i.e. a visual acuity of
A person with an uncorrected refractive error may have a subnormal visual acuity, and a rough estimate of his corrected visual acuity may be obtained by asking him to view the chart through a pin-hole aperture. If the visual acuity is less than 6/60, the patient is moved towards the test-types until he can read the top letter. If the top letter is visible at 2 meters, the visual acuity is 2/60. Visual acuities of less than 1/60 are recorded as ‘counting fingers’ (CF), ‘hand movements’ (HM), ‘perception of light’ (PL), or ‘no perception of light’ (no PL).

If the patient wears glasses, the type of lens he is wearing may be determined as follows. Hold the lens in front of the eye and look at an object through it. Then move the lens from side to side and watch the object. If the latter seems to move in the opposite direction to the lens, the lens is convex; if in the same direction, it is concave. Patients with myopia use concave (diverging) lenses and those with hypermetropia convex (converging) ones.

In order to tell whether a lens is spherical or cylindrical, look at a straight object through it and then slowly twist the lens round. If the lens is cylindrical, the object will appear to take up an oblique position. Patients who are astigmatic need cylindrical lenses.

Prescriptions for eyeglasses are measured in diopters. The measurement starts at zero ("plano"), with four quarters to a diopter: 0.25 (a quarter diopter), 0.50 (one half a diopter), 0.75 (3/4 of a diopter), and 1.00 (one diopter). The higher the numbers, the higher (stronger) the prescription.

Here are estimates for the approximate correction needed for each line seen on the Snellen chart:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Estimated prescription</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/3</td>
<td>Plano (zero)</td>
</tr>
<tr>
<td>6/4.5</td>
<td>Plano</td>
</tr>
<tr>
<td>6/6</td>
<td>Plano to -0.25</td>
</tr>
<tr>
<td>6/9</td>
<td>-0.50</td>
</tr>
<tr>
<td>6/12</td>
<td>-0.75</td>
</tr>
<tr>
<td>6/15</td>
<td>-1.00 to -1.25</td>
</tr>
<tr>
<td>6/30</td>
<td>-1.75 to -2.00</td>
</tr>
<tr>
<td>6/60</td>
<td>-2.00 to -2.50</td>
</tr>
</tbody>
</table>

**Color sense**

This is most easily tested by the use of pseudo iso-chromatic plates, the best-known being those of Ishihara Chart. People with defective color vision confuse certain colors. Pseudo iso-chromatic plates are so constructed that a person with normal color vision will read one number on a plate, while a person with defective color vision will read a different number on the same plate.

Two Ishihara charts: Right: In this chart, the normal person reads “74,” but the red-green color-blind person reads “21.” Left: In this chart, the red-blind person (prot-anope) reads 2,” but the green-blind person (deuter-anope) reads “4.” The normal person reads “42.”
Examination of the Pupils:
The following points must be noted about the pupils in every case:
1.  Size: Compare the size of the two pupils, first in a bright light and then in a dim light.
2. Shape: Note whether the pupil is circular in outline, as it should be, or whether its contour is irregular:
3. Mobility:
   (a) Reaction to light.
   Examine each eye separately: Place the patient opposite a bright light, be sure his accommodation is relaxed, and cover the eye with the hand. Leave it covered until the pupil dilates, then withdraw the hand and watch the pupil closely. It should contract almost immediately, then dilate again a little, and, after undergoing slight oscillations, settle down to its normal size.
   The test may also be carried out by concentrating light upon the pupil with an electric torch.
   (b) Reaction to accommodating: The pupils become smaller on accommodating for a near object. Hold up one finer close to the patient's nose. Ask him to look away at a distant object. Then suddenly tell him to look at your finger. As the eyes converge to accomplish this pupils should come decidedly smaller.
Pupillary Light Reflex examination

Normal sized pupil

Pupil starting to dilate

Half Dilated Pupil

A Very Dilated Pupil