UNIT 16 ACCOMMODATION AND CONVERGENCE

Structure

16.0 OBJECTIVES

After completing this unit, you should be able to understand:

- how a person is able to focus at objects of varying distances;
- the purpose of accommodation;
- the mechanisms of accommodation;
- the concept of convergence; and
- the relationship between accommodation and convergence.

16.1 INTRODUCTION

Accommodation is the ability of the eye to focus on an object situated at variable distances from the eye, Like a camera, even the eye requires to change it's focal power to be able to form a clew image of objects at different distanccs. In a camera, the position of the focusing lens 'is moved anteriorly or posteriorly to achieve this change in focus. However in the human eye the process is more complex. and needs to be understood in a systematic fashion.

16.2 ACCOMMODATION

Normally, the human eye focuses at objects at infinity, without exerting any power. This means that when a person is observing an object at infinity, the eye is at rest and no effort is required to focus on the object. If the object moves closer from infinity, till a distance of 6 meters from the eye, still no additional power or effort is required to be able to Focus an the object. However when an object moves closer than 6 meters, the light rays entering the eye from the objects are more divergent. In order to bring these divergent light rays into focus over the retina the diopteric power of the eye must be increased. The mechanism by which the eye increases it's diopteric power and hence the ability to focus at an object close to the eye is called Accommodation.

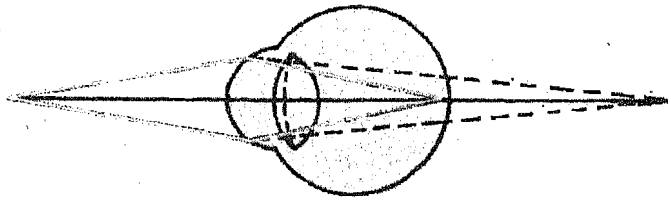


Fig. 16.1: Ray of light focussed behind the retina (clotted line) before accommodation, and on the retina (solid line) with the help of accommodation

16.2.1 Mechanisms

In an animal when the need to change the focal power of the eye arises, different mechanisms are there in different species of animal. The possible mechanisms of accommodation in different animals include:

1) change in the size of the eyeball,
2) change in the position of the lens,
3) change in the curvature of the cornea,
4) change in curvature of the lens.

In a human being and most other mammals, the first three mechanisms are not possible and accommodation occurs by the fourth mechanism only. The curvature of the lens (and hence it's diopteric or focussing power) is changed as a result of a series of neuro-mechanical changes in the eye. These changes are initiated by a trigger factor—the formation of a blurred image on the retina. This results in a electrical signal or impulse being generated and sent to the eye. This impulse cascades the changes of accommodation.

During accon-rmodation the ciliary muscle contracts and in turn the size of the ciliary ring is reduced. This results in the suspensory ligament getting relaxed and the Lens becomes more spherical, with on increase in anteroposterior diameter **and** a decrease of the curvature radius of the anterior surface. The centre of the anterior surface develops a relative bulge.

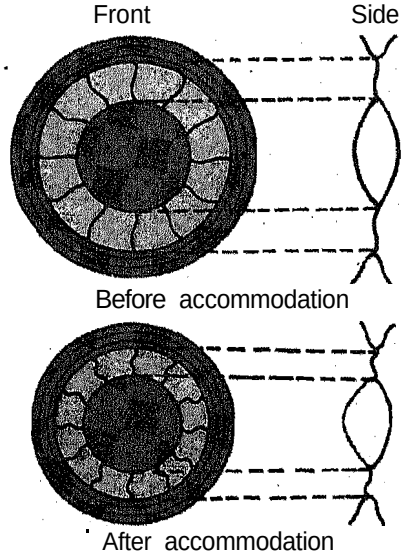


Fig. 163: **Changes in the ciliary body ring, zonules and shape of lens during accommodation**

16.2.2 Theories of Accommodation

A change in the curvature of the lens is caused by several theories:

1) **Gullstrands Theory: A** change in the lens is controlled by the balance between elasticity of the lens capsule and the pull of zonules. It is believed that only the zonules attached to the anterior surface of the lens were efficient, therefore, the anterior surface curvature was the only part that changed.

2) **Fincham's Tin Shell Deformity Theory:** The changes of shape are **a** result of the moulding of **the** capsule.

3) **Jackson Coleman Theory:** During accommodation the ciliary muscle contraction causes an anterior thrust of the vitreous. This vitreous thrust presses on the lens and causes it *to* change shape.

4) **Fischer Theory:** Fischer believed that the lens substance is elastic and interplay of the lens substance and elasticity *of* the capsule determines the shape of the lens

5) **Von Helmholtz Modified Theory:** This is the most accepted theory of accommodation.

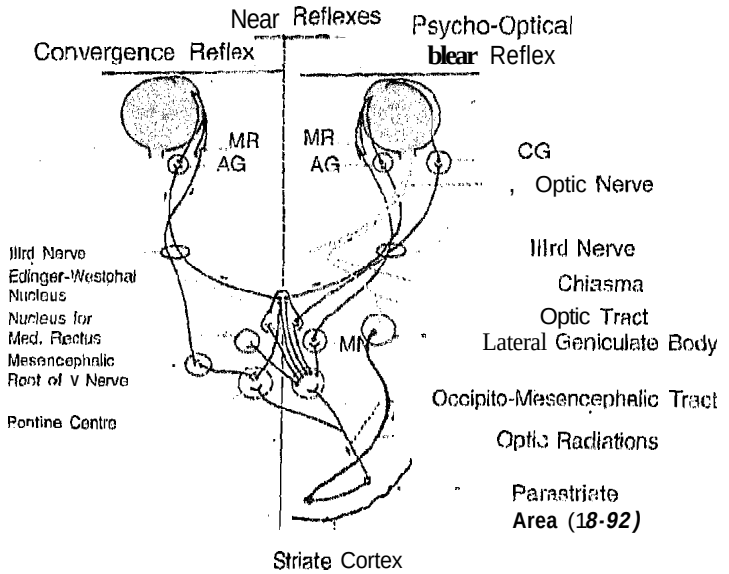
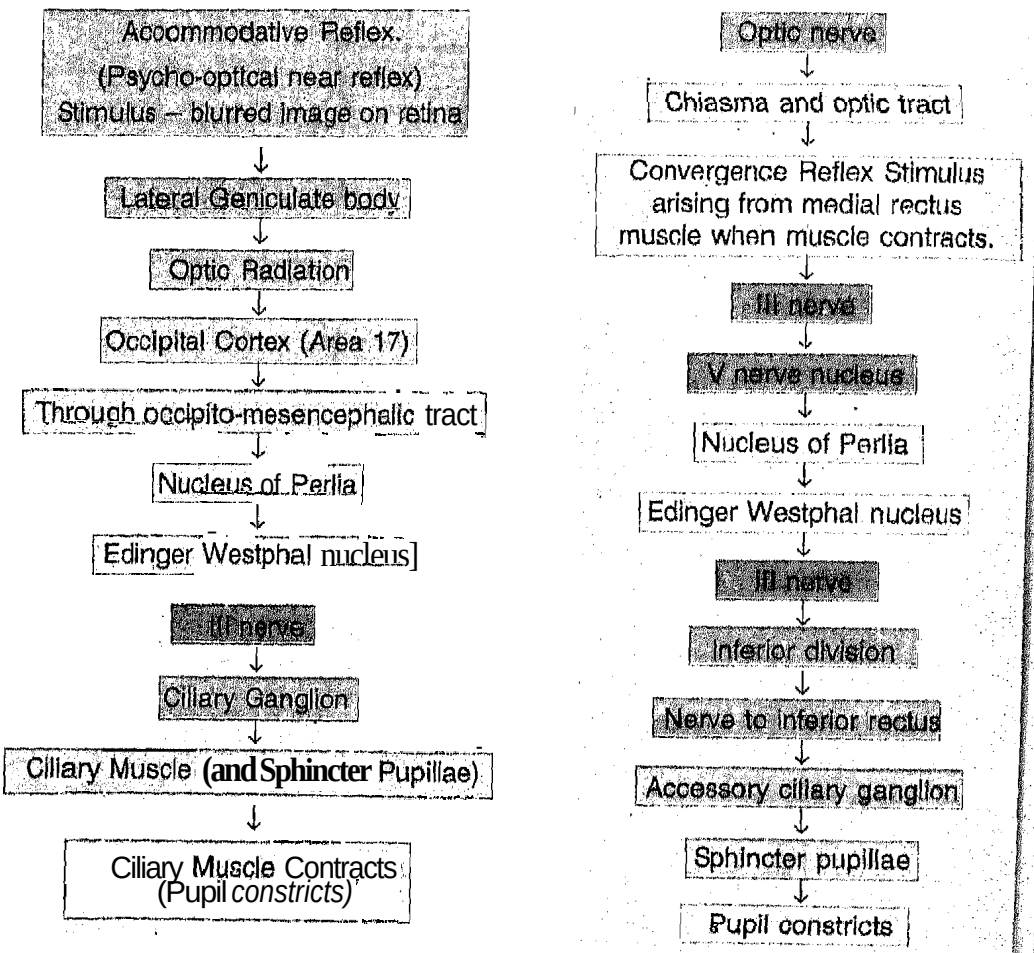


Fig. 16.3: The nerve paths of the two components of the near reflex. The afferent pathway for the convergence reflex is indicated as running up the IIIrd nerve; this is not certain. That for the accommoation reflex follows the visual fibres to the striate area of the calcarine cortex (area 17), is relayed to the parastriate area (19), whence the efferent path travels to the Edinger—Westphal nucleus via the occipito-mesencephalic tract and the pontine centre for convergence. AG, accessory ganglion; CG, ciliary ganglion; MN. nucleus for medial rectus; MR, medial rectus.

Accommodative Pathway
Near Reflex



Changes in the Eye During Accommodation

Associated Actions (Synkinetic Movements)

1) Convergence: Both eyes are rotated inwards. (medial rectus action)

2) Pupil constriction by sphincter pupillae muscle (parasympathetic). This also helps to increase the depth of focus and cur of excess light from near objects.

(The depth of focus of eye with 4 mm pupil is from infinity to 30 mts whereas the depth of focus of eye with 2 mm pupil is from infinity to 15 mts)

Other changes in the eye are:

1) Increase in curvature of anterior surface of lens.

2) Anterior pole of lens moves forwards without any change in the posterior pole.

3) The anterior chamber depth decreases.

4) The lens thickness increases in the centre.

5) Anterior capsule becomes loose

6) Lens becomes tremulous due to loss of tension on the lens by zonules.

7) Purkinje image 3 becomes smaller (showing increased curvature of the anterior surface of the lens.)

Physical and Physiological Accommodation

Accommodation depends upon:

a) a power of the ciliary muscle

b) ability of the lens to change its shape.

Physical Accommodation is the actual physical deformation in the lens power. It is measured in diopters, e.g., if the focussing power of the eye is increased by ID, the accommodation is 1D.

Physiological Accommodation contractile power of the ciliary muscle required to change the focussing power of the eye by 1D. Measured in Myodiopter.

In younger age both are equal. In old age the lens capsule becomes more stiff, hence the physical accommodation becomes less than the physiological (more muscle power is required to cause change in the diopteric power).

Change in Power of Physical Accommodation with Age

Age	Amplitude of Accommodation	Near Point
10 years	14 D	7 cm
36 years	7 D	14 cm
45 years	4 D	25 cm
60 years	1 D	100 cm

This change is due to sclerosis of the lens and loss of elasticity of the capsule.

Range and Amplitude of Accommodation

Punctum Remotum (Far Point): Farthest point which can be focussed on the retina when the eye is at rest. In Emmetrope it is at infinity,

Punctum Proximum (Near Point): Nearest point which can be focussed on the retina after full accommodation.

The distance between the near point and far point is called **the Range of Accommodation**. This is a measure of the distance over which the accommodation is active and is measured in meters.

The difference in the refractivity (diopteric power) of the eye in the two conditions is called the **Amplitude of Accommodation** and is measured in diopters.

When accommodation is at rest it is called **Static Refraction.**

When accommodation is exercised it is called **Dynamic Refraction.**

Where:

r = distance of far point,

p = distance of near point

R= refractive power of the eye when accommodated for far point

P= refractive power of the eye when accommodated for near point

Amplitude of accommodation A = P – R

Range of accommodation a = r – p

In Ernmetropic Far point (r) is at infinity, average near point (p) of an adult = 10 cm.

∴ range of accommodation a = r – p = ∞ –10 cm.

Since static refraction (R)=0 and near point accommodation (P) = 1mt / 10 = 10D
Amplitude A = P – R = 10 – 0 = 10 D

In hypermetropia, the person has to accommodate to see objects at a distance roo. Hence the static refraction (R) > 0. A hypermetrope of +5D will have a far point 1/5 mt behind the eye (–5 D). The near point will still be 10 cm (the dynamic refraction being 100/10 = 10D)

Here the Amplitude of accommodation = 10 – (–5) = 15D

Range of accommodation = r –p = ∞ – 10

i.e. The range of accommodation is the same but the amplitude required to focus at the near point is increased. Hence he has lo make more effort to see near objects clearly.

In Myopes the far point r is closer. For a myope of –5D, the far point = 100/5 = 20 cm away. If his near point is 10 a n the range of accommodation a = r–p = 20-10 = 10 cm.

At the near point p, accoinmodation required = 100/10 = 10D, at far point (r) 20 cm, the accommodation = 100/20 = 5D.

Hence the Amplitude = 10–5D = 5D

i.e. in myopes the range and amplitude of accommodation is decreased.

When an object is viewed at a point nearer than the near point, it appears blurred.

Errors of Accommodation

a) ***Failure of Accommodation***

Presbyopia – failure of physical (static) accommodation

- Functional or pathological incapacity of ciliary muscle - failure of physiological accommodation:
  1) Insufficiency of accommodation
  2) Ill sustained accommodation
  3) Inertia of accommodation

b) ***Increased Accommodation***

1) Excessive accommodation
2) Spasm of accommodation

Details of the errors will be discussed in the block dealing with refraction.

Check Your Progress 1

1) Describe various mechanisms of accommodation.

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2) Enumerate the theories of accommodation.

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3) Give pathway of accommodation and convergence.

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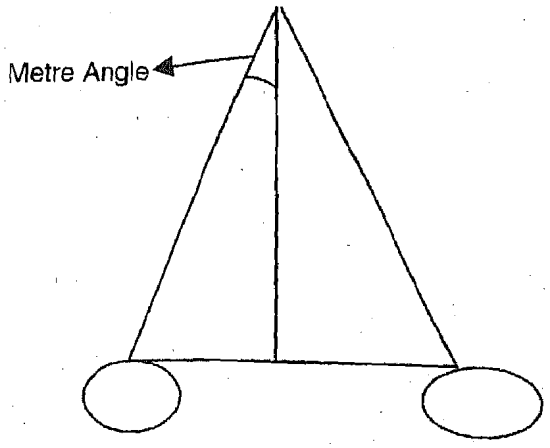
16.3 CONVERGENCE

When accommodation takes place, the eye turns medially because of a reflex movement controlled by occipital cortex. When the eye accommodates for a near object, constriction of the pupil also occurs. Convergence is measured in unit of metre angle (if the object is situated at 1 metre, the angle which the line joining the object with the centre of rotation of either eye makes with the median line is called 1 metre angle), Convergence and near accommodation are associated with miosis. The benefits of convergence are to decrease the spherical

aberrations, increase the depth of focus, and compensation for the relative increase of light entering the eye from a near obunderstand.



A blurred image is the stimulus for accommodation

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Accommodation becomes active

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Convergence adjusts to the accommodation

Accommodation and convergence adjust so **that** in every hypermetrope child convergent squint does not develop. Similarly divergent squint does not develop in every myope. Very high hypermetropes develop convergent squint due to dissociation of two eyes. Infantile or congenital myopia develops latent or divergent squint.

Relation of Accommodation and Convergence

Far point (punctum remotum) of convergence is at α theoretically, when the eyes are at rest, the eyes are usually parallel (convergence = 0).

Near point (punctum proximum) of convergence → nearest point for which convergence is possible.

- Usually this is about 8 cm from the eyes
- Closer to this point, the object will **appear** double, as the eyes give up the effort: of convergence and diverge out slightly.

Range of convergence → the distance between **the** far and near point of convergence,

Amplitude of convergence → the difference in the converging power in both the positions.

The convergence aimed at fusing the image of **both** eyes (to prevent diplopia) is called **fusional convergence.**

Normal fusional convergence = 25-30° (up to 50-60Δ)

Fusional divergence = 5° (10Δ)

Accommodation is the most important stimulus for convergence. The convergence stimulated by accommodation is called **accommodative convergence** (AC).

There is a constant relation between accomlnodation and accommodation convergence for each individual.

This is called the accommodative convergence: accommodation or ACIA ratio.

Usually, this constant is 3.5Δ/D, i.e., for each diopter of accommodation → 3.5Δ accoinmodation convergence occurs.

Check Your Progress 2

Give relation between accommoclation and convergence.

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16.4 LET US SUM UP

In this unit you have learnt during accommodation the lens becomes more spherical, with an increase in anteroposterior diameter and a decrease of the radius of curvature radius. The centre of the anterior surface develops a relative bulge. Thus changing the power of human lens and giving it the ability to focus objects at different distances.

Convergence is a stimulus for accommodation. Once accommodation comes convergence adjusts to accommodation.

Range of convergence is distance between far and near point of convergence. Amplitude of convergence is difference in converging power in both positions. In next unit you will study about electrophysiology of the eye.

16.5 ANSWERS TO CHECK YOUR PROGRESS

Clieck **Your Progress 1**

1) The various mechanisms of accommodation are:

   a) Change in one size of eye ball.

   b) Change in the position of lens.

   c) Change in the curvature of cornea.

   d)' Change in the curvature of lens.

2) The various theories of accommodation are:

   i) Gullstrands theory

   ii) Fincham's Tin Shell Deformity theory

   iii) Jackson Coleman theory

   iv) Fischer theory