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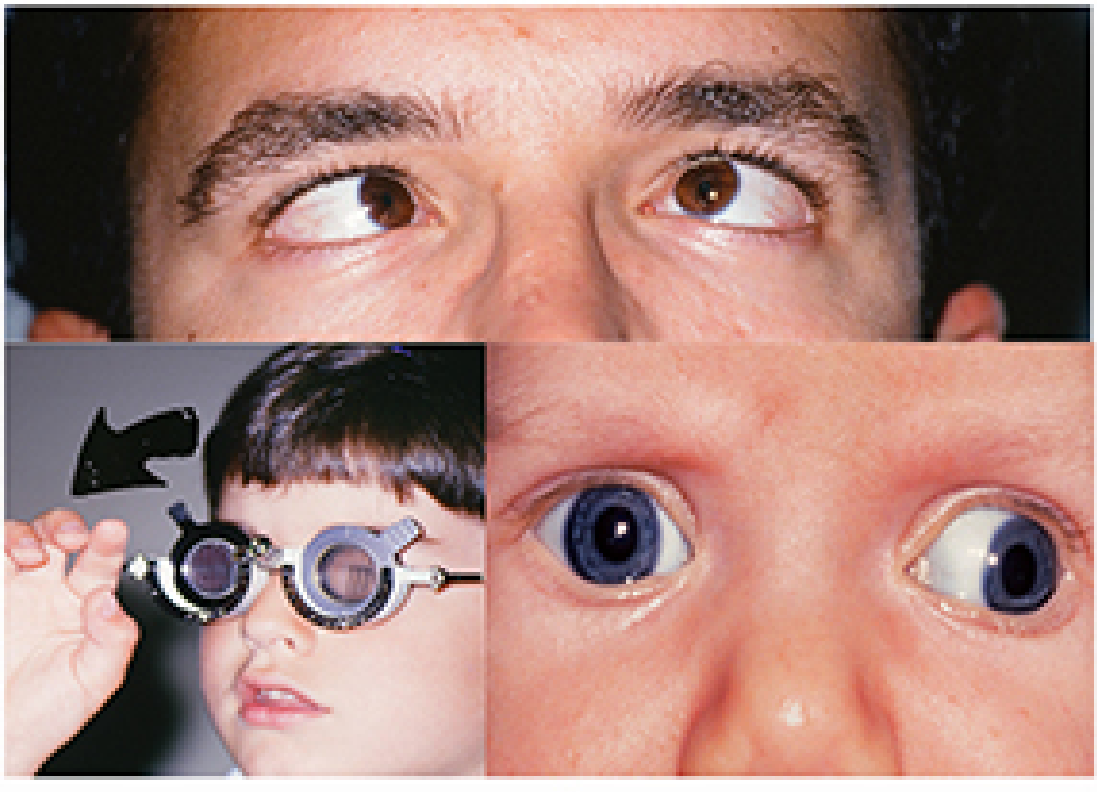
Wills Eye Strabismus Atlas

Leonard B Nelson
Robert A Catalano



SECOND EDITION

Foreword
Julia A Haller

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3 Physiology of Ocular Motility

THE CARDINAL POSITIONS OF GAZE

The insertion of each extraocular muscle is unique in both its location and the angle it subtends with the globe. For each muscle there is a singular position of the eye in which that muscle alone has a mechanical advantage and will act as the primary mover of the eye. There are six extraocular muscles; therefore, six such positions called the "cardinal positions of gaze" exist (Fig. 3.1). Because each position is unique for a given muscle, the strength of a muscle can be tested by asking the patient to look in the direction of the muscle's individual cardinal position. The cardinal positions of gaze are determined by having the muscles contract for maximal vertical or horizontal effect by aligning the muscle and the optical axes. Table 3.1 summarizes the muscles that act in the six cardinal positions of gaze for each eye.

It is important to know the distinction between the actions of a muscle and the cardinal positions of gaze. The primary, secondary and tertiary actions of a muscle describe the movement of the eye when the muscle contracts with the eye in the primary position (see Chapter 2). With the exception of the horizontal rectus muscles, the directions the eye is pulled by the actions of a muscle (from the primary position) do not correspond to the cardinal position in which the eye is placed to test the strength of that muscle.

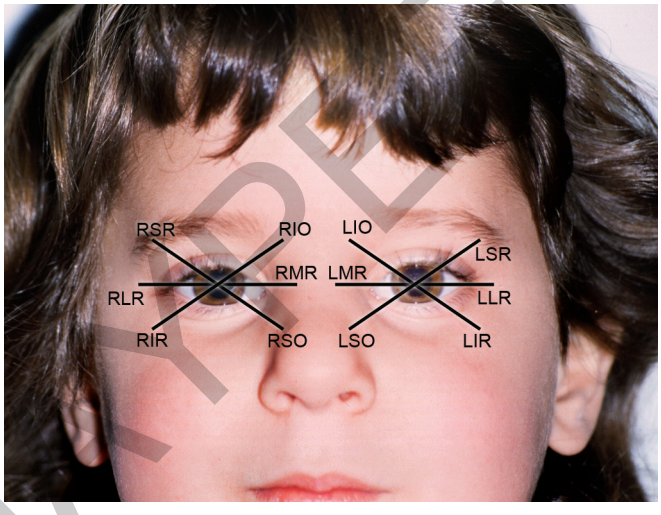

Fig. 3.1: Primary muscles that act in the six cardinal positions of gaze for each eye. *RSR: Right superior rectus; RLR: Right lateral rectus; RIR: Right inferior rectus; RSO: Right superior oblique; RMR: Right medial rectus: RIO: Right inferior oblique; LIO: Left inferior oblique; LMR: Left medial rectus; LSO: Left superior oblique; LIR: Left inferior rectus; LLR: Left lateral rectus; LSR: Left superior rectus.

Table 3.1: Conjugate movements of the eyes into the cardinal positions of gaze

Movement	*Responsible Muscles**
Up and right	RSR and LIO
Straight right	RLR and LMR
Down and right	RIR and LSO
Down and left	RSO and LIR
Straight left	RMR and LLR
Up and left	RIO and LSR

*RSR: Right superior rectus; RLR: Right lateral rectus; RIR: Right inferior rectus; RSO: Right superior oblique; RMR: Right medial rectus: RIO: Right inferior oblique; LIO: Left inferior oblique; LMR: Left medial rectus; LSO: Left superior oblique; LIR: Left inferior rectus; LLR: Left lateral rectus; LSR: Left superior rectus

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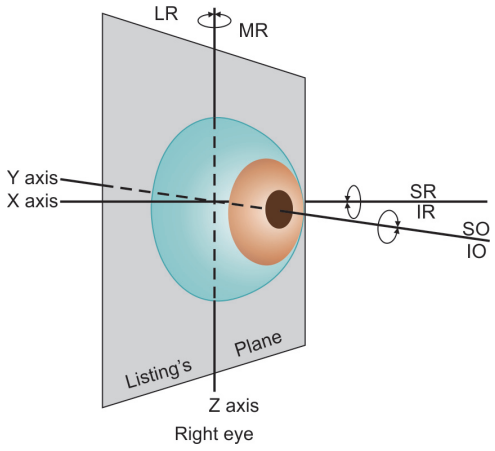

Fig. 3.2: The three primary axes of Fick [vertical (Z), horizontal (X), and anteroposterior (Y)] and the muscles that control movement about each of these axes for the right eye. *LR: Lateral rectus; MR: Medial rectus; SR: Superior rectus; IR: Inferior rectus; SO: Superior oblique; IO: Inferior oblique.

Table 3.2: Agonist synergist and antagonist relationships

Position	*Agonist*	*Synergists*	*Antagonists*
Adduction	Medial rectus	Superior rectus Inferior rectus	Lateral rectus Superior oblique Inferior oblique
Abduction	Lateral rectus	Superior oblique Inferior oblique	Medial rectus Superior rectus Inferior rectus
Elevation	Superior rectus	Inferior oblique	Inferior rectus Superior oblique
Depression	Inferior rectus	Superior oblique	Superior rectus Inferior oblique
Incycloduction	Superior oblique	Superior rectus	Inferior oblique Inferior rectus
Excycloduction	Inferior oblique	Inferior rectus	Superior oblique Superior rectus

MONOCULAR EYE MOVEMENTS

Agonist and Antagonist Relationships

The actions of the extraocular muscles are exquisitely balanced. Fick[1] first noted that any movement of the eye can be described as a rotation about a vertical (Z), a horizontal (X), or an anteroposterior (Y) axis; these axes have come to be known as the three "primary axes of Fick" (Fig. 3.2). Horizontal movements occur about the Z axis, vertical about the X axis, and torsional about the Y axis. The X and Z axes constitute the two-dimensional "Listing's plane", the center of which is the center of ocular rotation.

Ocular motility is so finely balanced that the six muscles of the eye can be divided into three pairs; each pair controls movement about one of the axes of Fick. As shown in Figure 3.2, the two muscles in each pair oppose each other. The primary muscle that moves an eye in a given direction (e.g. rotation upward about the X axis performed by the superior rectus) is called the "agonist". The muscle that opposes the action of the agonist (in this instance the inferior rectus) is called an "antagonist". The "synergist" is the muscle that acts in concert with the agonist to produce a given movement. Table 3.2 summarizes agonist, antagonist and synergist relationships.

Sherrington's Law

"Sherrington's law of reciprocal innervation" describes the relationship between an agonist and an antagonist during normal movement of the eye. It states that stimulation of a muscle to contract is accompanied by inhibition of contraction of its antagonists.[2] On abduction of the right eye (Fig. 3.3) the right lateral rectus muscle is stimulated while the right medial rectus muscle is inhibited. Sherrington's law, applying as it does to agonist and antagonist muscles, describes a **monocular** phenomenon concerning the actions of muscles in an **individual** eye. Exceptions to this law are responsible for the aberrant ocular movements seen in some pathologic conditions. Two important examples are "Duane's retraction syndrome", in which co-contraction of the medial and lateral rectus muscles of the same eye occurs, and "Parinaud's syndrome", in which rhythmic contractions of the medial and lateral rectus muscles (retraction nystagmus) occurs on attempted upward gaze (see Chapter 13).

Ductions

"Ductions" are monocular eye movements about one of the axes of Fick. Appropriate prefixes define the direction in which the eye is rotating. "Abduction" is movement of the eye temporally (Fig. 3.3) and "adduction" is movement nasally (Fig. 3.4), both of which occur about the Z axis. "Supraduction" is upward rotation (Fig. 3.5), "infraduction" is downward rotation (Fig. 3.6), and both occur about the X axis. "Excycloduction" (extorsion) is defined as temporal rotation of the 12:00 meridian of the cornea (Fig. 3.7; also see Fig. 2.12), and "incycloduction" (intorsion) is a nasal rotation of the 12:00 meridian of the cornea (Fig. 3.8; also see Fig. 2.11), both of which occur about the Y axis.

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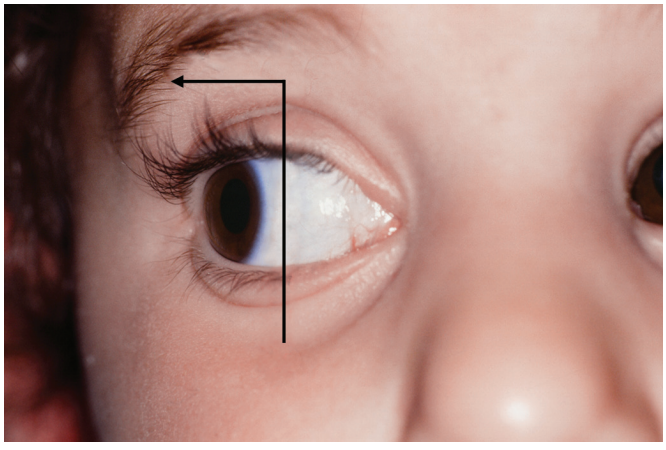

Fig. 3.3: Abduction of the right eye.

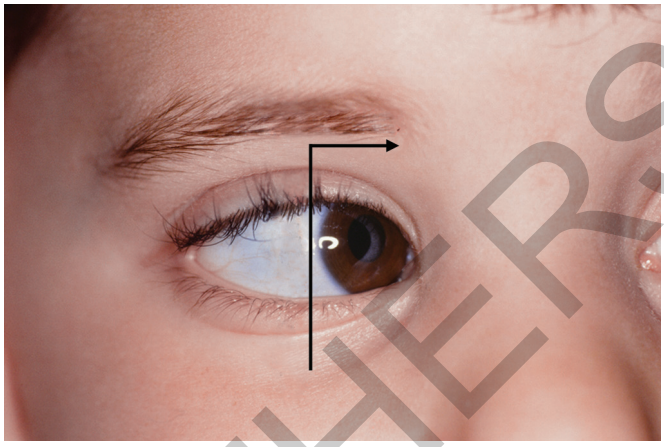

Fig. 3.4: Adduction of the right eye.

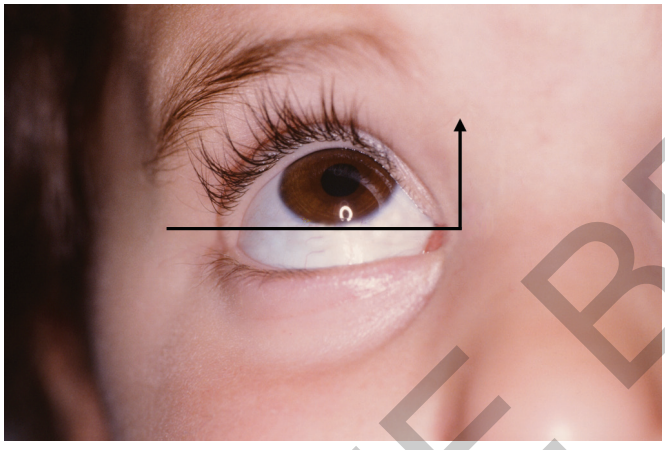

Fig. 3.5: Supraduction of the right eye.

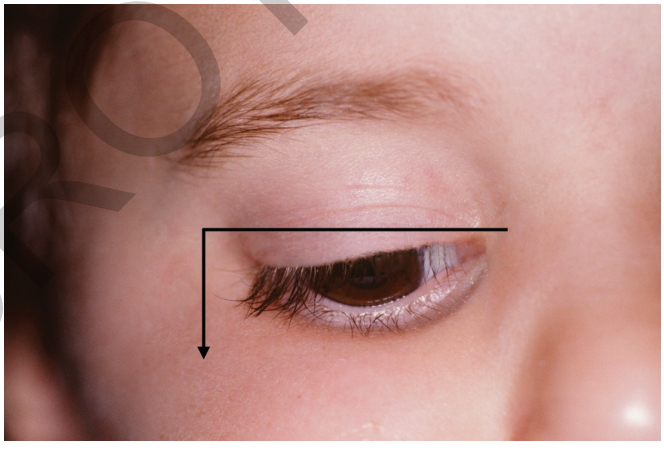

Fig. 3.6: Infraduction of the right eye.

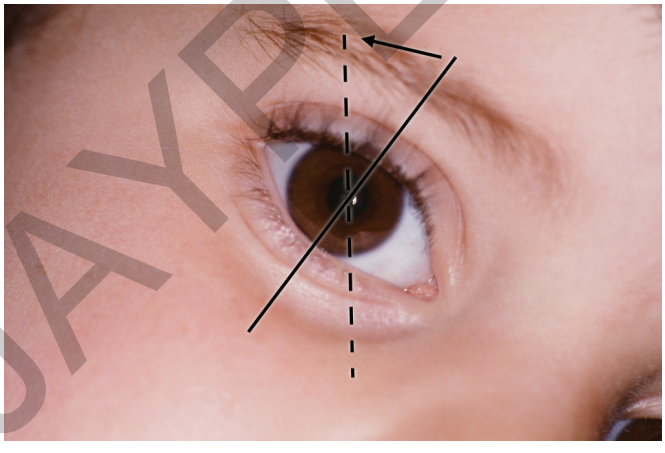

Fig. 3.7: Excycloduction of the right eye.

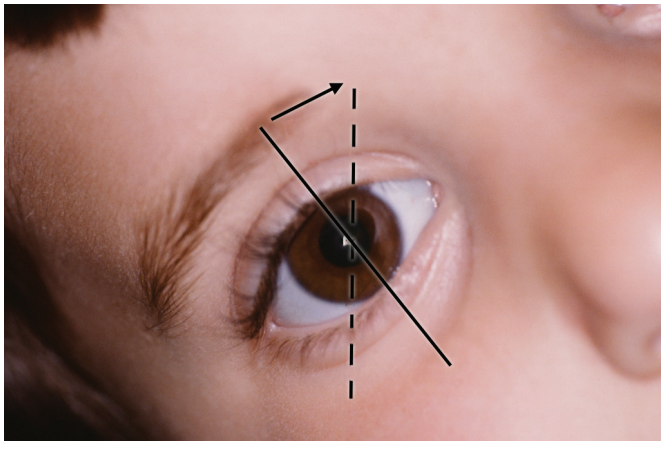

Fig. 3.8: Incycloduction of the right eye.

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BINOCULAR EYE MOVEMENTS

Ductions describe monocular movements, and agonists and antagonists refer to different muscles in the same eye that act in concert or against each other. Different terms are used to describe movements of the two eyes together, and a special term, "yoke muscles", is given to the corresponding muscles of the two eyes that affect movement of both eyes into a specific gaze position. The muscle pairs listed in Table 3.1 that turn the eyes into the six cardinal positions of gaze are yoke muscles.

Versions

Any movements of the two eyes in the same direction at the same time and of approximately the same magnitude are called "conjugate movements". "Versions" are conjugate binocular eye movements brought about by contraction of yoke muscles. "Dextroversion" is movement of both eyes to the right (Fig. 3.9), and "levoversion" is movement to the left (Fig. 3.10). Elevation of both eyes is called "supraversion" (Fig. 3.11), and depression is called "infraversion" (Fig. 3.12). "Levocycloversion" is rotation of both eyes so that the 12:00 meridian of each cornea is rotated to the left (Fig. 3.13),and "dextrocycloversion" is a rotation to the right of the 12:00 meridian of each cornea (Fig. 3.14).

Vergences

"Vergences" are binocular movements in which the eyes move in opposite directions, or "disjugately". "Convergence" is the nasal rotation of each eye (Fig. 3.15), and "divergence" is temporal rotation (Fig. 3.16). "Positive vertical divergence" (right sursumvergence) occurs when the right eye moves up while the left eye moves down (Fig. 3.17). "Negative vertical divergence" (right deorsumvergence) is the opposite movement (Fig. 3.18). "Incyclovergence" (conclination) occurs when the 12:00 meridian of both eyes rotates nasally (Fig. 3.19). "Excyclovergence" (disclination) is temporal rotation of both eyes (Fig. 3.20).

Hering's Law

"Hering's law" is the law of yoke muscles, pertaining to binocular eye movements. When one muscle in a pair of yoke muscles is stimulated the other is simultaneously and equally stimulated.[3] Similarly, inhibition of a muscle is associated with inhibition of its yoke. This law applies to all voluntary and some involuntary eye movements. On dextroversion (Fig. 3.21), the right lateral rectus and its yoke, the left medial rectus, are stimulated while the yoked right medial and left lateral rectus muscles are inhibited, as confirmed electromyographically (Fig. 3.22). Yoke pairs change for disjugate or vergence movements, and with convergence both medial rectus muscles contract while the lateral rectus muscles relax (Figs 3.23 and 3.24). On head tilt, the vestibular ocular reflex causes rotation of the eyes in a direction opposite the head tilt to keep the eyes aligned vertically. Sherrington's law describes the antagonist relationship between the incycloductors and excycloductors of a given eye, whereas Hering's law describes the relationship between the two eyes that allows both eyes to move conjugately and rotate together opposite the head tilt (Figs 3.25 and 3.26). An exception to Hering's law is "dissociated vertical deviation" (DVD) which can occur in congenital esotropia (see Chapter 8).

Clinical Applications of Hering's Law

According to Hering's law, the amount of innervation going to corresponding yoke muscles to achieve a desired position of gaze is the same. In paralytic strabismus, a paretic muscle will not contract as well as its yoke, which receives the same innervation, causing a misalignment of the eyes. Excessive stimulation is needed for fixation with a paretic muscle in its field of action. The excessive innervation causes the ocular misalignment to be greater when the paretic muscle fixates. The "primary deviation" is the deviation of the paretic eye with the sound eye fixating. The "secondary deviation" is the deviation of the sound eye when the eye with the paretic muscle is fixating. As noted, the secondary deviation is always greater than the primary deviation.

The patient that is the subject of Figures 3.27 to 3.29 has a paretic right superior rectus muscle and demonstrates the distinction between primary and secondary deviations. When she fixates a fixed object above her, equal innervation goes to both superior recti, according to Hering's law. When she fixates with her sound left superior rectus muscle (Fig. 3.27) a small right hypotropia

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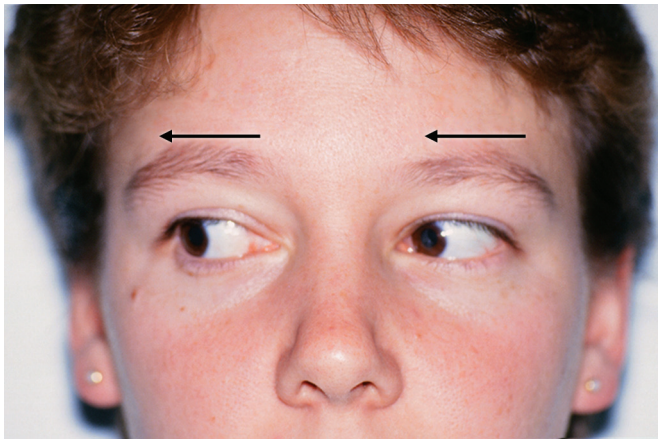

Fig. 3.9: Dextroversion.

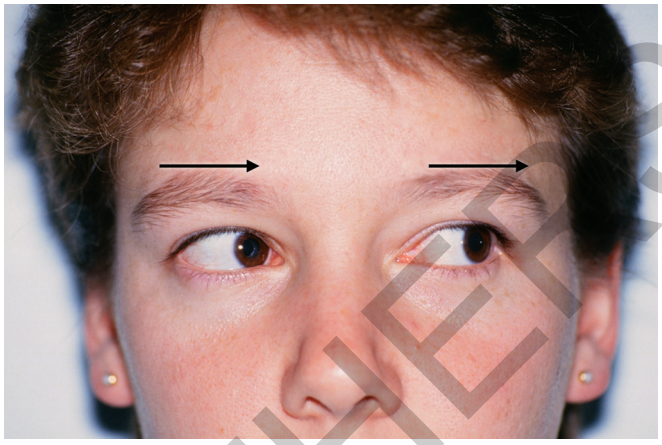

Fig. 3.10: Levoversion.



Fig. 3.11: Supraversion (elevation).



Fig. 3.12: Infraversion (depression).

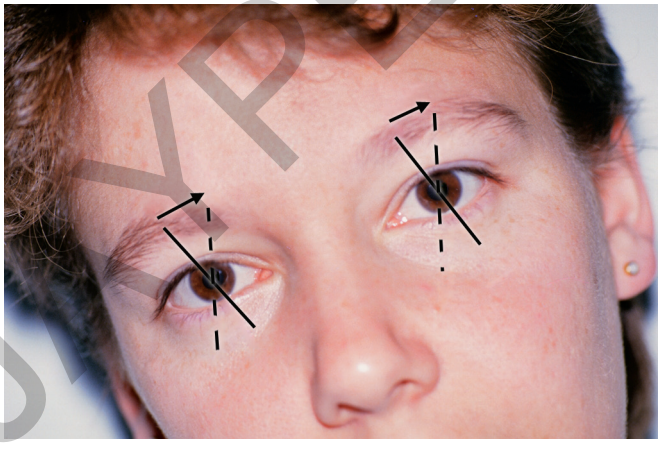

Fig. 3.13: Levocylcoversion.

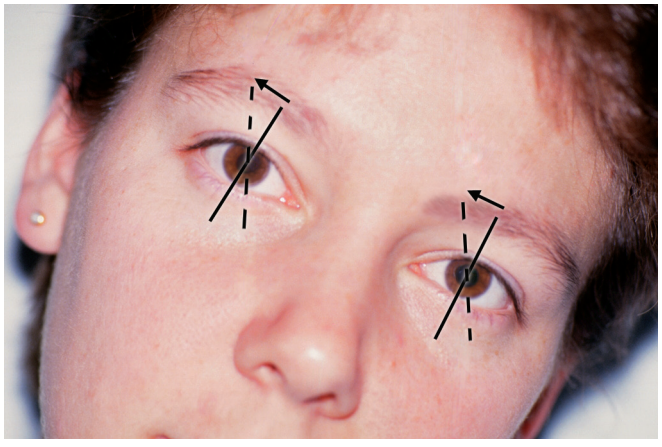

Fig. 3.14: Dextrocycloversion.

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Fig. 3.15: Convergence.

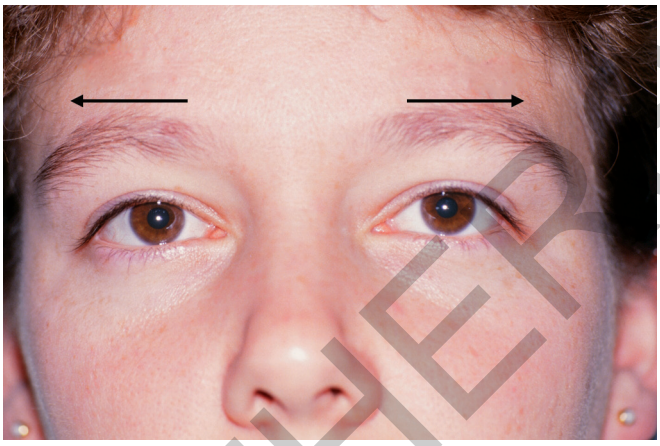

Fig. 3.16: Divergence.



Fig. 3.17: Positive vertical divergence (right sursumvergence).

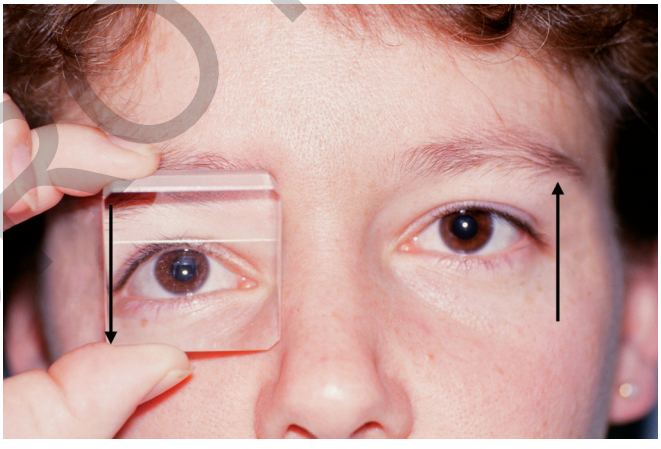

Fig. 3.18: Negative vertical divergence (right deorsumvergence).

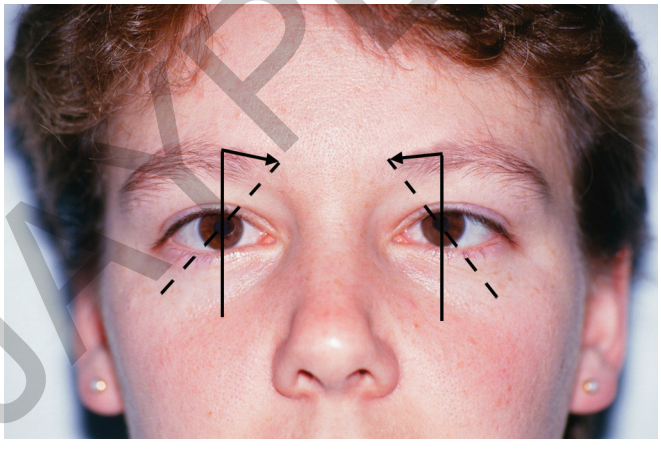

Fig. 3.19: Incyclovergence (conclination).

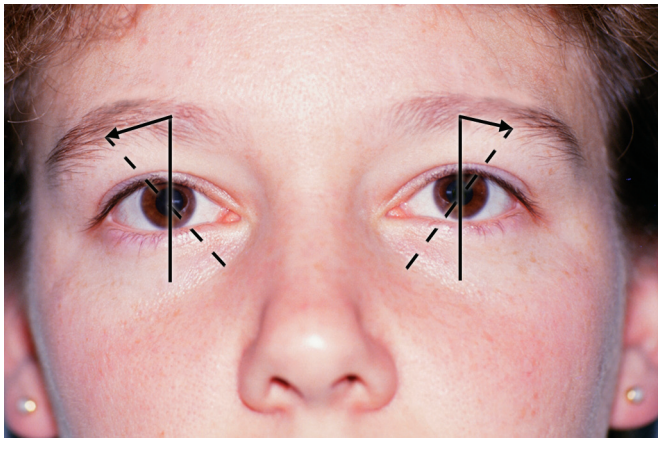

Fig. 3.20: Excyclovergence (disclination).

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(the primary deviation) is evident (Fig 3.28). In order to fixate with the right eye, excessive stimulation of the right superior rectus is needed, which in turn leads to excessive stimulation of the left superior rectus (Fig. 3.29). The hypotropia of the right eye with the paretic right eye fixating (the secondary deviation) is larger (Fig. 3.30). In paralytic strabismus, the greater the stimulation is, the greater the misalignment becomes.



Fig. 3.21: Dextroversion.

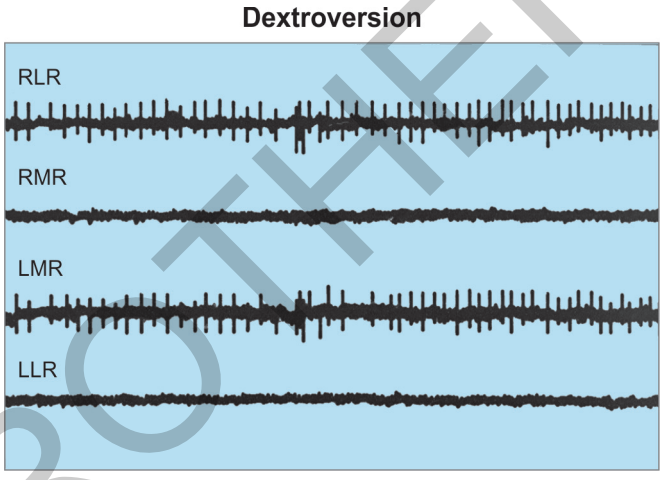

Fig. 3.22: Electromyograph of individual in Figure 3.21. On dextroversion the right lateral rectus (RLR) and its yoke the left medial rectus (LMR) are stimulated, and the yoked right medial rectus (RMR) and left lateral rectus (LLR) muscles are inhibited.



Fig. 3.23: Convergence.

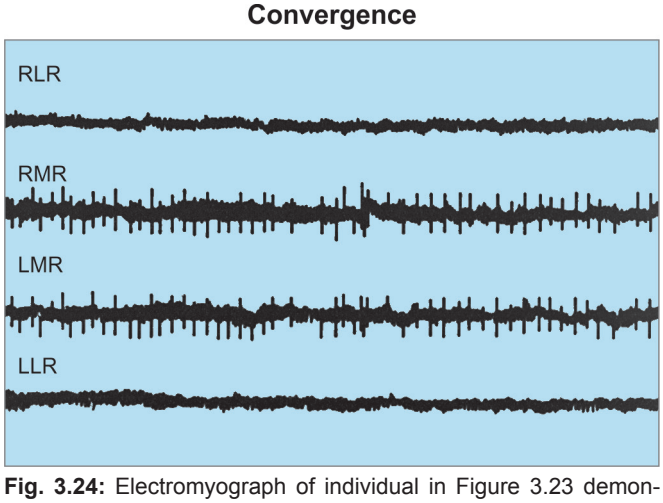

Fig. 3.24: Electromyograph of individual in Figure 3.23 demonstrating that yoke pairs change with disjugate movements. On convergence both medial rectus muscles contract while the lateral rectus muscles relax. (RLR: Right lateral rectus; RMR: Right medial rectus; LMR: Left medial rectus; LLR: Left lateral rectus).

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Fig. 3.25: Levocycloversion upon tilting the head to the right.

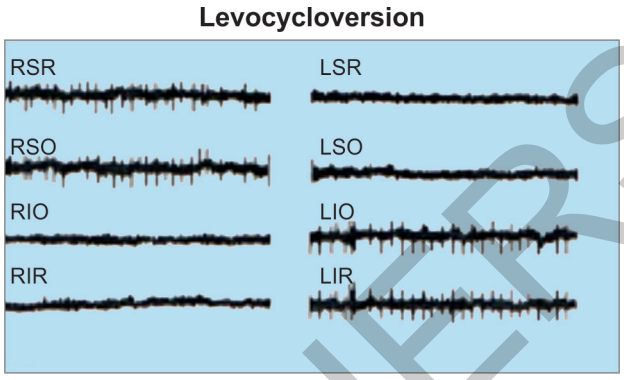

Fig. 3.26: Electromyograph of individual in Figure 3.25 demonstrating both Sherrington's and Herring's laws. According to Sherrington's law the incycloductors the right eye contract while the excycloductors of the same eye relax. According to Herring's law, simultaneous with the actions in the right eye, in the left eye the excycloductors contract and the incycloductors relax. (RSR: Right superior rectus; RSO: Right superior oblique; RIO: Right inferior oblique; RIR: Right inferior rectus; LSR: Left superior rectus; LSO: Left superior oblique; LIO: Left inferior oblique; LIR: Left inferior rectus)

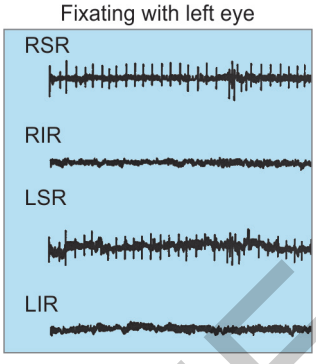

Fig. 3.27: Electromyograph of a patient with a right superior rectus muscle palsy fixating on an object above her with her sound left superior rectus muscle. (RSR: Right superior rectus; RIR: Right inferior rectus; LSR: Left superior rectus; LIR: Left inferior rectus).



Fig. 3.28: A patient with a right superior rectus (RSR) muscle palsy fixating on an object above her with her sound left superior rectus muscle. The primary deviation is a small right hypotropia.

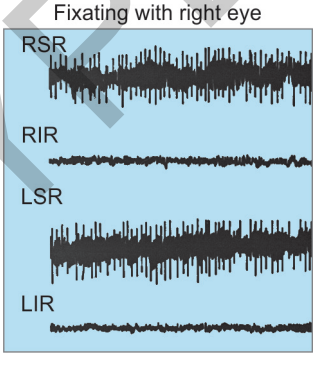

Fig. 3.29: Electromyograph of the patient with paretic right superior rectus muscle fixating on an object above her with her paretic right superior rectus muscle. Note the excessive stimulation of both the right and left superior rectus muscles. (RSR: Right superior rectus; RIR: Right inferior rectus; LSR: Left superior rectus; LIR: Left inferior rectus).



Fig. 3.30: The same patient with a right superior rectus (RSR) muscle palsy fixating on an object above her with her paretic right superior rectus muscle. The secondary deviation is a larger right hypotropia.

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