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SOME OBSERVATIONS ON THE ACTS OF  
CLOSING AND OPENING THE EYES

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Section I—Varieties of Eye Closure

*Introductory.*—Although the eyes can be directed to any point in the field of vision, the ocular muscles act under certain well-defined limitations.

In the first place the two eyes must always act together.

Secondly, so long as the eyes are open, the ocular muscles are always in the primary position for fixation.

Thirdly, no muscle is allowed to act to its full extent. The movement of the eye-ball in any direction is always arrested before the pupil reaches the eyelid.

These limitations, necessary for normal vision, are not inherited. They are not present in the new born infant. During the first few weeks of life each eye can move separately, there is no fixation, the eyes can be turned completely under the lids in any direction. By the age of about three months co-ordinate movements have become the rule rather than the exception, fixation is established, and the pupils do not move under the lids when the eyes are open. In the course of time the nervous pattern becomes so firmly fixed that an adult is usually unable to vary it by any voluntary effort.

Now and again exceptions occur, persons who can either move one eye in some particular direction whilst the other remains stationary, or can, at will, turn up the eyes so that the corneae are completely hidden under the upper lids whilst the eyes remain open.

In these persons it may be found that the particular abnormal movement was begun in childhood, as was the case in a man whom I saw recently. As a child he had been shown the trick of turning up the eyes and had practised it until he could do it quite easily. (Fig. 1, *a* and *b*.) In all other respects his eye movements were normal.

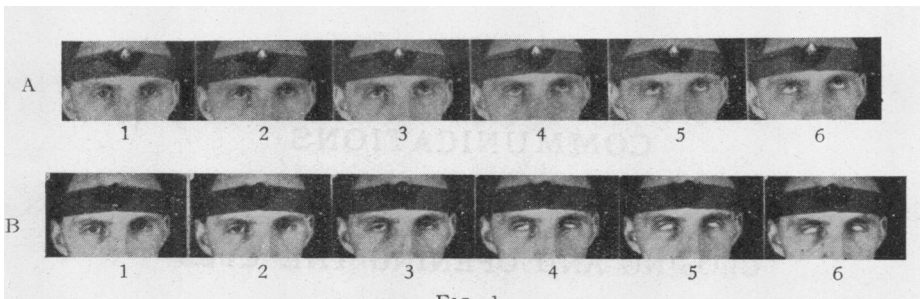


FIG. 1.

*Voluntary "turning up" of eyes in normal man.*

Row A.—Shows normal act of looking up.

Row B.—Shows the same man "turning up the eyes" with open lids, a trick learned in childhood. Note the slight lowering of the upper lid at the onset of movement.

(Consecutive cinematograph pictures in each row—ordinary rate. Read from left to right.)

For the efficient working of the visual apparatus close co-operation between the movements of the eyes and those of the eyelids is essential. This, also, is not present in the new-born, and is only acquired with the onset of fixation and co-ordination of the eye movements. The lids, during vision, must act bilaterally, and in following the elevation and depression of the eyeballs must not cover the pupils. The limitations are, however, somewhat less than those imposed on the ocular muscles. Thus, most people can close one eyelid alone as in "winking." It is, however, comparatively rarely that even this action is absolutely unilateral.

Whilst much has been written on the movements of the eyes and of the eyelids in ordinary vision, comparatively little attention appears to have been given to the conditions present when the lids are closed. It is the purpose of this paper to bring together some recorded observations on the subject, together with the results of some personal investigations.

### The Varieties of Closure of the Eyelids

The eyelids are completely closed throughout sleep and at frequent intervals when awake.

Whilst the act is mechanically always the same, yet its special purpose, the circumstances giving rise to it, and the nervous mechanisms involved, differ widely on different occasions.

It is possible to distinguish at least three kinds of eye closure, which for purposes of description may be called:—

- |                      |   |               |
|----------------------|---|---------------|
| I. Blinking.         | } | (Bilateral.)  |
| II. Closures of rest |   |               |
| III. Winking.        |   | (Unilateral.) |

*N.B.*—In all of these closure is complete. Partial closure, as when depressing the eyeball will not be considered.

#### I. BLINKING.

This is the term in general use at the present time for that form of closure of the eyelids which occurs at frequent intervals whilst awake. It is involuntary, and usually of brief duration. The time during which the pupils are covered has been variously estimated at from 0.13 to 0.2 seconds. (Garten.<sup>1</sup> V. Gilse.<sup>2</sup>)

As this is less than the duration of the retinal after-image vision is not interrupted and as a rule the individual is unaware of the act.

Blinking occurs under a variety of circumstances and may be sub-divided into two kinds:—

- A. Of reflex origin.
- B. Of uncertain origin.

#### A. BLINKING OF REFLEX ORIGIN.

This occurs in three forms, each of which differs in certain respects from the other two. Rademaker and Garcin<sup>3</sup> have recently gone into this subject at some length and the following account is largely based on their observations. They use the following names for the three varieties:

- (1) The corneal reflex.
- (2) The dazzle reflex.
- (3) The menace reflex.

(1) In this, the tactile group, the term corneal is used not because stimulation of the cornea is the only way of calling it forth, but because this is the place at which the threshold is lowest. The term is meant to cover all acts of blinking due to contact on or about the eye.

(2) The term "dazzle reflex" explains itself. Sudden exposure to a marked increase of light is the stimulus.

(3) The "menace reflex" (*réflexe de clignement à la menace*) is not due either to contact or to excessive light. It is produced by an unexpected and threatening object suddenly coming into the near field of vision.

In the "corneal reflex" (1), the centripetal path is the fifth nerve, the centrifugal the seventh. The centre is subcortical. It persists in the experimental thalamus animal. That it has connections with the cortex in man is shewn by the pain that is felt on touching the cornea, and the strong spasm of the lids which occurs when such pain is produced. It is also said that it may be lost in man in cortical lesions of the Rolandic area.

In the other two reflexes the fifth nerve takes no part, the centripetal path in each being the optic. Of these the "dazzle reflex" (2) appears to be subcortical via the optic nerve, with the anterior corpora quadrigemina as centre; the outgoing path being the association fibres to the facial nucleus.

According to Rademaker and Garcin<sup>4</sup> it may be lost in certain mesencephalic lesions which give no other external signs.

The "menace reflex" (3) is cortical and requires the presence not only of the occipital lobe, but of its connection with the Rolandic area. This reflex may be lost when the "corneal" and "dazzle" reflexes persist.

Rademaker and Garcin<sup>4</sup> refer to seven cases of organic cerebral lesions in which this reflex was lost in the temporal field of the opposite eye, though there was no hemianopsia.

By closing the lids, a dual purpose is served. The exposed surface of the eyes acquires a protective cover similar to that over the body elsewhere, and the deeper seated retina a screen which interrupts rays of harmful intensity.

On the other hand, if it interrupts vision, it removes for the time the most important means of protection which the organism as a whole has against approaching danger.

Thus for instance, the 'menace' reflex in its most localised form is the mere momentary closure of the lid when a moving object passes near to the eye. On the other hand, if the unexpected object creates alarm, the protective reaction called forth is much wider than the mere blinking reflex.

In these three kinds of reflex blinking the closure of the lids is usually of minimum force and brief duration, so as not to interrupt vision. If the stimulus is noxious, such as an intense light or 'a piece of grit in the eye,' local danger is paramount, and the orbicular muscles are forcibly contracted. This tight closure of the eyelids continues, or is repeated at frequent intervals until the noxious stimulus has been removed.

### B. BLINKING OF UNCERTAIN ORIGIN.

This is the common form of blinking which occurs at frequent intervals during waking hours without the intervention of any obvious stimulus of touch, dazzle or menace. Various views as to its nature have from time to time been brought forward. It has been suggested that it has some mechanical effect in directing the flow of lacrymal secretion towards the tear duct. This view is no longer generally accepted. Another is that it regulates and equalises the state of moisture of the surface of the eye, and that any change in this respect calls forth the ordinary corneal reflex. A third is that it is the response to external stimuli such as slight changes of temperature in the surrounding air, minute particles, smoke etc., insufficient to give rise to conscious sensations, but enough to set up a reflex when coming in contact with the highly sensitive corneal surface.

Although the two latter from time to time give rise to reflex blinking, yet there is no doubt that, beside and apart from these, there are frequent acts of blinking which occur without any external stimulus. This variety has recently been investigated by Ponder and Kennedy.<sup>5</sup> From experimental observations on a large number of normal persons they conclude that each individual blinks with a frequency which represents his individual blinking rate, and that, provided external and internal conditions are the same, this rate is practically constant. If however, conditions are altered, particularly if there is any cause of excitement, the rate may increase considerably. If an irritant such as tobacco smoke is present the ordinary rate is increased, so long as the sensory surface of the cornea is intact. If the surface of the eye is, however, made completely anaesthetic by cocaine, blinking still continues at its normal rate for the individual, but is now not increased by such an irritant as tobacco smoke.

Their experiments also discount the view mentioned above that one of the objects of frequent blinking is to lubricate the cornea and prevent undue dryness. They find that in the same person it occurs at the same rate whether in the dry open air or in the moist atmosphere of a Turkish bath. As confirmatory of this one may add that the delicate infantile cornea does not get dry although regular blinking does not occur during the first few months of life, nor does the cornea of the post-encephalitic Parkinsonian, in many of whom the rate of blinking is extremely slow.

Ponder and Kennedy further point out that in persons completely blind from double optic atrophy or other causes, there is a similar regular constant individual rate of blinking.

Their experiments thus show that in addition to reflex blinks arising as occasion requires, there is also a form of blinking

which is not produced ordinarily by sensory stimuli either from the fifth or the second nerves. The question then arises, if the bulk of our daily acts of blinking are not of reflex origin, and not in order to keep the surface of the cornea moist and warm, what is their object?

Two possible explanations suggest themselves; one is the provision of a momentary rest for the retina, the other a momentary rest for the eye muscles. Against each of these Ponder and Kennedy bring the following objections:—

Blinking of a similar kind is found in congenitally blind persons. Further, if resting the retina is the object, it is difficult to see why the rate of blinking should be increased, as it undoubtedly is, by excitement. The question of a rest for the eye muscles will be considered later, in connection with the eye movements on closure.

For the present the actual cause and purpose of this form of blinking must remain unexplained. Ponder and Kennedy conclude from their experiments that it is of central origin.

## II. EYE CLOSURE OF REST.

This group differs from the preceding in two important features. In the first place, closure lasts long enough to interrupt the vision. Secondly, the act is not of reflex origin.

Although the familiar closure of the eyes during sleep is the most important of this group, yet there are other acts of closure which, although not acts of sleep may suitably be considered with it.

All have in common that they are associated with rest rather than with activity and of sufficient duration to ensure a temporary rest at any rate from the effects of visual stimuli.

For purposes of description they may be divided into:—

- A. Those connected with sleep.
- B. Those not connected with sleep.

### A. EYE CLOSURE CONNECTED WITH SLEEP.

(i). *Involuntary closure of the lids as an actual part of the phenomena of sleep.* The eyelids close with the oncoming of sleep whether we will or no. If the occasion is suitable, and sleep is welcome there is no attempt to open them. Full sleep develops at a rate which varies in different persons and according to circumstances.

If however, time and place are unsuitable, and the onset of sleep is anything but desirable, the lids can be, and are at once reopened. This however, becomes more and more difficult as

closure recurs and eventually a powerful effort is necessary to prevent falling asleep.

This is merely a part of the widespread motor phenomena of sleep.

It is not a simple relaxation of the muscles which keep the eyes open, but a tonic stimulation of the orbicularis, together with an inhibition of the levator palpebrae, the converse of what exists during most of the waking hours. Although with the closure of the eyelids at the onset of sleep the receptor for the 'dazzle' and 'menace' blinking reflexes is put out of action, yet it is not so with the so-called " corneal " reflex.

As was mentioned above, its receptor is much wider than the cornea and includes the surface of the skin in the immediate neighbourhood of the eyes. Until the deeper stage of sleep is reached, this protective reflex persists, as is shown by a tightening of the orbicularis if one attempts to raise the eyelid, or even touches it. In this respect, the reaction resembles that produced by a noxious stimulus during full consciousness. In deep sleep, this variety also of blinking reflex is lost, so that the lids can be raised with little or no resistance, and only shut again very gradually.

In deeper stages of unconsciousness, such as deep anaesthesia, or coma from other causes, the eyelids may be open.

The three chief purposes for which the eyes are closed during sleep are :—

- (1) To protect the ocular apparatus as a whole from external injury and
- (2) To allow the ocular muscles a period of rest.
- (3) To shut out light stimuli.

(1) With the onset of sleep, visual stimuli no longer give rise to clear visual images, so that such protective reflex blinking as has the optic nerve for its centripetal path is no longer capable of affording complete protection. Directly this stage of semi-consciousness is reached, the eyelids droop and close, whether it is day or night, whether amidst quiet or noise. That this is inherited and not acquired is shown by its occurrence in the newborn infant and the congenitally blind.

(2) The second object, namely to allow the ocular muscles a period of rest, will form the subject of a succeeding section.

To sum up :—

That form of closure of the eyelids which accompanies the onset of sleep is an inherited, automatic act, which takes place when cortical inhibition reaches a certain degree, and serves the purpose of protecting the eyes from injury and allowing the ocular muscles to rest.

(ii). *Voluntary closure of the lids in preparation for sleep.* This is quite distinct from the preceding. Most people on lying down in bed close their eyes preparatory to sleep, although the room is dark and there are no moving objects to stimulate vision.

It is but one item in what Charters Symonds<sup>6</sup> has called "the ritual" of going to sleep. When sleep is desired under unusual circumstances, as in the daytime, shutting the eyes is one of the few available items of 'the ritual,' and has the added advantage of shutting out visual stimuli. Sleep may not follow the act for a considerable time, if at all. This form of closure of the eyes is thus not an actual part of sleep.

#### B. EYE CLOSURE OF REST NOT CONNECTED WITH SLEEP.

The eyes may be closed voluntarily at any time during waking hours, and for any length of time, without any intention or desire to go to sleep. It is not necessary to discuss this form of closure further.

There is, however, in some persons, an involuntary closure of the eyes of sufficient duration to interrupt vision, which occurs when in deep thought, or in trying to recall something from memory.

As in the case of reflex blinking—the voluntary closure of rest not connected with sleep may be forcible. The lids may, at will, be so tightly screwed up that it is impossible for an outsider to force them open.

#### III. UNILATERAL CLOSURE. (WINKING.)

In each of the above described varieties of closure the act is bilateral. Both lids act simultaneously and similarly. It is, however, possible to close only one eye at a time. This has no relation to sleep.

In this, the behaviour of the eyeballs is quite different from that which occurs when the two eyes are closed together. As this raises some particularly interesting points, it will be considered in detail later.

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## Section II—Sleep

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### The Position and Movements of the Eyes in Sleep

In considering the behaviour of the eyes when the eyelids are closed it is convenient in the first place to deal with that form of closure of rest which is part of normal sleep. (II A (i). in preceding section).

It has long been known that during sleep the position of the eyes under the closed lids, differs from that present when the lids are open.

More than a century ago Sir Charles Bell dealt with this and as the conclusions he then reached formed the basis of medical opinion during the next fifty years, and in certain particulars continue to do so to-day, it is desirable to consider them in some detail.

In a communication which he made to the Royal Society in 1823<sup>1</sup> there occur the following statements:—

(Page 177) *On the Two Conditions of the Eye, its State of Rest and of Activity.*

“ The eye is subject to two conditions, a state of rest with entire oblivion of sensation, and a state of watchfulness during which both the optic nerve and the nerve of voluntary motion are in activity. When the eye is at rest, as in sleep, or even when the eyelids are shut, the sensation on the retina being then neglected the voluntary muscles resign their office and the involuntary muscles *draw the pupil under the upper lid*. This is the condition of the organ during perfect repose.”

“ If it be further asked *why does the eye roll upwards and inwards*, we have to recollect that *this is the natural condition of the eye, its position when the eyelids are shut and the light excluded*, and the recti at rest and the obliqui balanced.”

Again, in his book “ On the Nervous System of the Human Body,” published in 1830, he writes (p. 166) “ During sleep . . . *the pupils of the eye are elevated*. If we open the eyelids of a person during sleep or insensibility, the pupils will be found elevated.”

It will be noticed that in one place this is said to be the “ natural condition of the eyes . . . when the eyelids are shut and the light excluded.”

During the next half century various views were expressed by different observers as to the exact position of the eyes in sleep. Whilst it was generally agreed that they are turned up, some found them “ up and divergent,” others “ up and convergent.”

In 1877 two physiologists, Raehlmann and Witkowski<sup>2</sup> published the results of a systematic examination of the position of the eyes in persons asleep and found that "When the lids are raised one can at once note the position of the eyeballs and convince oneself that they may occupy any possible position. They may be divergent, or convergent; there may be a difference in the horizontal level of the two eyes, and finally, the lines of vision are often directed parallel to each other."

Although their work was referred to in Schäfer's Text Book of Physiology in 1898<sup>3</sup> it does not seem to have received quite the attention which it deserves. A notable exception is to be found in Starling's Physiology<sup>4</sup> in which it is stated "There is irrefutable evidence that the eyes may occupy any position in sleep."

Professor Hartridge, who was responsible for the chapter on vision, in a personal communication, says that this statement was based partly on observations of his own which, however, he did not publish at the time because he found that his results had been so fully anticipated by Raehlmann and Witkowski's work twenty years earlier.

My interest in this question arose in connection with the so-called 'Oculo-gyric attacks' of chronic epidemic encephalitis, in which the eyes usually turn upwards. Being at the time unaware of Raehlmann and Witkowski's findings of half a century ago, I arranged for a series of observations on sleeping persons to be carried out in order to ascertain how far Bell's statements were correct as to the position of the eyes in sleep. For these observations, begun in 1929, I have to thank various resident medical officers and others. The method was as follows:—

On making night visits to the wards each eyelid of the sleeper was in turn gently raised and the position of the eyeball noted. All the visits were made between about 10 p.m. and 1 a.m. If there was any question of the person not being in deep sleep at the time, or of waking quickly, this was noted and the observation was not included in the series. The observers were asked to note whether the eyes were directed upwards, forwards, downwards or to the side. As the observations were made at different institutions by different persons the decisions as to whether a midway position between any of these should be put in one or other group, necessarily varied. The figures must therefore only be taken as giving a rough estimate. Even thus, however, they bring out some interesting points. In the first place they confirm the observations of Raehlmann and Witkowski that the eyes may be *in any position* during deep sleep. The following results were obtained.

TABLE I

*Position of eyes in deep sleep in persons of various ages, above one year old.*

Total cases examined	-	-	-	-	-	234
	(Males 145, Females 89)					
Eyes up	-	-	-	-	99 or 42	per cent.
Horizontal	-	-	-	-	104 or 44	per cent.
To one side	-	-	-	-	21 or 8'5	per cent.
Down	-	-	-	-	10 or 5'5	per cent.
					234	100

Most of these 234 persons were adults, only about 40 of them being below 20 years of age and only very few below ten years of age. None was below one year old.

In order to compare results in children only with these figures at all ages a series of observations was made by the then resident medical officer, (Dr. Colver) at the Sheffield Hospital for Sick Children. With the experience in the previous observations as to the difficulty of classifying lateral positions, it was arranged that in this series the three horizontal planes should alone be estimated, *i.e.*, up, horizontal and down, any lateral position being grouped in one of these according to its level.

TABLE II

*Position of eyes in deep sleep in children between the ages of six months and 13 years.*

Total cases examined	-	-	-	-	-	40
	(Boys 18, Girls 22)					
Eyes up	-	-	-	-	23 or 57'5	per cent.
Horizontal	-	-	-	-	17 or 42'5	per cent.
Down	-	-	-	-	0	0
					40	100

*N.B.*—In two of these cases the levels of the two eyes differed, one being above, the other on the horizontal level. It is interesting to note that in none of these cases were the eyes turned down when first examined. These observations will be dealt with again later.

In order to see how far loss of sight might affect the position of the eyes in sleep a series of observations was made on blind children at the Sheffield Royal Blind Institution. For this thanks are due to the kindness of the Superintendent who carried them out.

TABLE III

*Position of eyes in deep sleep in blind children from  
6 to 14 years of age.*

Number of cases observed	-	-	-	-	15
	(Males 9, Females 6)				
Eyes up	-	-	-	-	3 or 20 per cent.
Horizontal	-	-	-	-	7 or 46.5 per cent.
To one side	-	-	-	-	1 or 6.5 per cent.
Down	-	-	-	-	4 or 27 per cent.
					15    100

Six of these children are congenitally blind, in these they were up in one, forwards in four and down in one. Four are totally blind but were not so at birth, in none of these were the eyes up, but forwards in one, down in three. The remaining five children are not totally but almost blind. Though the numbers are too small to generalise upon still it is of interest to note the relative infrequency of the upward position, and the number of cases in which they were turned down.

It is, however, of particular interest that in only one of the four congenitally blind cases were the eyes turned upwards. As in these four children the opportunity of adjusting the eyes for binocular vision had never occurred, it seemed desirable to ascertain the position of the eyes during deep sleep at an age before binocular vision has been acquired. Thanks to the valuable assistance of the Maternity Sister at the Jessop Hospital for Women, this has been done. In six infants born in the department, daily records have been obtained of the position of the eyes when in deep sleep during the first ten days of life. These records differ somewhat from those of all the preceding series, which are single observations on each individual, whereas in the new-born they are successive daily observations for ten days. Another reason for presenting this record in the new-born somewhat differently from the rest is that in so many of the observations the two eyes during sleep were not symmetrically placed, as they usually are in adults. This "skew deviation" as it may be termed, was present in about one quarter of the observations. If one omits these as impossible to classify under any one of the four heads the results are as follows:—

TABLE IV

*Total observations in six newborn infants during first  
ten days of life.*

Eyes symmetrically placed	-	-	-	-	41
Skew	-	-	-	-	14
					55

TABLE V

*Of the 41 symmetrical—*

Eyes up	-	-	-	-	0	0
Horizontal	.	.	.	.	40 or 97.5	per cent.
Down	-	-	-	-	1 or 2.5	per cent.
					41	100

The complete absence of the upward symmetrical position of the eyes in sleep before the advent of binocular vision is noteworthy.

In order to bring in the considerable percentage of observations in which the eyes were not symmetrical, the observations may be expressed in terms of the two eyes. The results are shown in the following table. The position of each eye is recorded as Upwards (U), Forwards\* (F), Lateral (L), or Downwards (D). In the Table the letters in brackets are used—the first being the position of the Right eye, the second that of the Left.

TABLE VI

*Position of eyes in sleep.*

No.	Name	Sex	DAYS										
			Birth	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
1	Hum.	M	—	DF	FF	FD	FF	FD	FF	DD	FD	FF	DF
2	Hud.	M	—	FF	LU	DF	FF	FF	FF	FF	FF	DF	FF
3	Smi.	M	—	FF	FF	FF	FL	FF	FF	FF	FF	FF	FF
4	Gre.	F	—	FF	FL	FF	FF	FF	FF	FF	FF	FL	FF
5	Ash.	F	FF	LF	LF	FF	FF	FF	FF	FF	FF	FF	—
6	Ril.	F	FF	FL	FF	FF	FF	—	—	—	—	—	—

If the position of each eye is taken as a separate observation as regards its position in deep sleep, the following is found:—

TABLE VII

*110 observations on the position of one eye during the first ten days of life.*

Eye up	-	-	-	-	1	(0.9 per cent.)
Horizontal	.	.	.	.	93	(84.5 per cent.)
To one side	-	-	-	-	9	(8.0 per cent.)
Downwards	-	-	-	-	7	(6.6 per cent.)

110 100 per cent.

\* "Forwards" in the tables = horizontal elsewhere in the text.

### Variations in Position of Eyes during Sleep at Different Observations

The position of the eyes may vary in the same individual in different 'sleeps.' In a certain number of the adults examined the position of the eyes was observed on two or three separate occasions. In some there was no change. Thus in one of the women in whom the eyes were turned down—they were examined on three separate nights—they were down each time. In others the position differed on different nights. In two they were up twice and horizontal once. In one they were down the first night and up the next.

The following were the findings in some of the cases in which observations were made as to the position of the eyes in sleep, on more than one night:—

TABLE VIII

Name	Sex	Age	1st Time	2nd Time	3rd Time
			<i>S. Y. M. H.</i>		
H. I. - -	M	73	Up	Forwards	Up
E. L. - -	M	56	Up	Up	Forwards
S. J. - -	M	60	Forwards	Forwards	—
F. W. - -	M	9	Forwards	Forwards	—
J. H. A. -	M	43	Forwards	Up	—
C. S. L. -	M	27	Up	Forwards	—
J. A. - -	M	14	Forwards	Forwards	—
C. H. - -	M	44	Up	Forwards	—
E. S. - -	M	28	Down	Up	—
T. E. W. -	M	21	Forwards	Convergent	—
M. H. - -	M	41	Up	Forwards	—
F. S. - -	F	40	Down	Down	Down
			<i>S. R. B. C.</i>		
F. P. - -	M	13	Convergent	Forwards	—
J. W. - -	M	10	Down	Divergent	—
V. G. - -	F	6	Up	Down	—
			<i>C. G. H.</i>		
B. T. S. -	M	35	Forwards	Forwards	Forwards
B. S. - -	M	43	Forwards	Forwards	Forwards

### Children's Hospital

Fourteen children were examined more than once. Of these seven were in the same position each time (in two this was so on three occasions) whilst in seven the position varied.

#### Summary

(1) There is no one position which can be called the natural position of the eyes in sleep.

(2) Once binocular vision has been acquired the position of the eyes in sleep is usually either horizontal or upwards, in about equal proportions. They are usually symmetrical—in the sense that they may be convergent, divergent or both to one side. In a small percentage of persons the eyes may be down.

(3) Before binocular vision is established, the eyes are to a preponderant extent horizontal, and usually symmetrical, but a complete 'skew' deviation is not uncommon and may be in any direction.

(4) The position of the eyes may or may not differ in the same person in different sleeps.

#### Movements of Eyes during Sleep

Raehlmann and Witkowski<sup>5</sup> whose observations on the position of the eyes are thus fully confirmed by our cases, also found that when the eyelids of the sleeper were held open for some little time, movements of the eyeball would occasionally take place. In our earlier series of observations this particular point as to movement was not looked for, but in the series of observations on children under three years of age and in the new-born infants, the presence of movements was noted in every case.

#### Movements of Eyeballs in Sleep in Forty Normal Children, aged 6 months to 13 years

These were present in 13 cases (37.5 per cent.). Sometimes the movement was in one eye only, usually a slight horizontal excursion either remaining in the new or returning to the former position. More often the movements were conjugate. In eight of these thirteen children observations were made on more than one night, in two of them movements occurred both nights and in one, on two nights out of three. In one of these on both occasions the movements were particularly marked and continued so long as the lid was kept open. In two or three others they were considerable, whilst in the remainder they were only slight.

### Movements of Eyes during Sleep in Six New-born Infants (1st to 10th day of life)

In this group movement was present in 30 of the 55 observations (54.5 per cent.). On 15 occasions it was in one eye only and in 15 in both eyes. Here also as in the older children it was found more constant in some cases than in others.

	Both eyes	One eye	
Case 2—10 observations	- 7	2	9
Case 1—10	„ - 3	4	7
Case 4—10	„ - 2	2	4
Case 5—10	„ - 2	2	4
Case 6— 9	„ - 1	3	4
Case 3—10	„ - 0	2	2
	<hr/> 15	<hr/> 15	<hr/> 30

These findings are in full accord with those of Raelhmann and Witkowski, who call attention to the peculiar character of these movements, differing entirely both in rate and excursion from the ordinary eye movements when awake, and unlike the spasmodic movements sometimes seen in nervous disorders.

The movements during sleep are usually slow, smooth and uninterrupted, so as to appear purposeless, and though occasionally what appear to be co-ordinated movements occur, inco-ordinated are the more common. Also, as has been shown particularly in the new-born, the movement may be limited to one eye at a time.

Raelhmann and Witkowski<sup>6</sup> discuss whether these are of reflex or central origin. As against the former they refer to the fact that in certain persons with thin lids similar movements can be seen in sleep when the lids are closed, also in children with half-open lids.

In this connection it will be shown later that in a certain small number of normal persons when awake similar slow movements of the eyes occur when the eyes are shut. (Fig. 2.)

#### Summary

Movements of the eyes may occur during deep sleep. They are usually slow and inco-ordinate. They appear to be more common in some individuals than others. They may occur at all ages and are not uncommon during the first ten days of life.

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### Section III

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#### Behaviour of the Eyeballs during and after Closure of the Lids

The position taken up by the eyes when the lids are closed during deep sleep may be called for convenience "the position of rest" for that particular individual.

The question then arises; Is sleep necessary in order to bring about this "position of rest," or is it merely due to the act of closing the lids, whether awake or asleep?

To a certain extent the answer to this has been long known. Bell, a century ago, stated that the upward position is not only "natural" in sleep, but even when the "eyes are shut and the light excluded." Indeed, the movement of the eyeball on the affected side seen in a case of facial palsy when shutting the eyes, which he first described, is known particularly in foreign countries, as "Bell's phenomenon."

Except for the definitions of it found in text books and a few scattered records of cases presenting certain abnormalities, little has been added to Bell's observation, and the information on this point remains as scanty and incomplete as was that shown in the previous section as regards the position of the eyes in sleep.

The definition of Bell's phenomenon, given by Fuchs<sup>1</sup> is, "An outward and upward rolling of the eyeball on the attempt to close the eye; it occurs on the affected side in peripheral facial paralysis."

Oppenheim<sup>2</sup> describes it thus:—"On attempting to close the eyes, the upper eyelid sinks back through contraction of the levator palpebrae superioris, and the eyeball hastens upwards and usually outwards, until the cornea is covered."

Weiss<sup>3</sup> writes, "The orbicularis relaxes, the bulb is first turned upwards and inwards, then upwards and outwards, so that in this way the cornea lies under the upper lid. This, which takes place in any lengthy closure of the eyes, is known as Bell's phenomenon!"

These three definitions are probably based chiefly if not solely upon cases of facial palsy, and the fact that between them there are discrepancies indicates that even in the very small percentage of persons who suffer from this the differences in the "positions of rest" are considerable. Indeed, occasional cases of facial palsy with "an inverted Bell's phenomenon" have been recorded. These will be referred to in detail later.

In order to get a satisfactory answer to the question given above, it is necessary to know what happens to the normal eyes

when the lids are shut. When a person suffers from facial palsy, there is no reason to suppose that the eye on the uncovered side behaves in any way differently from what it is accustomed to do under normal conditions, so that "Bell's phenomenon" appears to be nothing more than the physiological "position of rest" of the eyes in the particular individual.

In this section an attempt is made to answer this question.

The material upon which the following conclusions have been based has been obtained from three sources:—

(1) Such cases of unilateral and bilateral facial palsy (Bell's type) as have from time to time presented themselves.

(2) A very few persons with unusually transparent eyelids.

(3) Systematic observation of normal persons, by holding up one eyelid during the act of closing and opening the eyes.

Each of these three sources of information has certain advantages and certain disadvantages. Qualitatively, the first two have the advantage, in that in neither of them is there any artificial interference with the physiological process.

Such cases are, however, too few to enable general conclusions to be drawn.

The third source, although involving interference with a normal process, is quantitatively unlimited. It is chiefly from this that the following results have been obtained. At the same time, the value of information from cases of Bell's palsy must not be underestimated.

The findings from all these three sources have been identical, and, providing due precautions are taken, the artificial interference necessary in the third method does not make any appreciable difference in the result.

This has been confirmed by cinematograph pictures from each source.

### **Changes in Position of Eyes in Voluntary Closure of Lids. Details of Method**

The method of preventing the closure of one eye which has been used in the following investigations of normal persons is carried out as follows:—

The observer, resting one hand on the forehead, presses the forefinger lightly but firmly on one upper lid so as to fix it and then asks the person under observation to "shut his eyes." The extent and direction of movement of the uncovered eyeball is noted, together with the position ultimately reached. The eyelid is held up for a shorter or longer time and any further movement of the eyeball noted. The person is then told to "open the eyes" again. The same process is repeated with the other eye.

If there is any doubt about the result, a useful means of confirming the observation is to ask the person to close his eyes as before, without touching him at all. When the eyes are thus lightly closed, one lid is quickly lifted up and it is easy to see whether the eyeball is in the same position as it was in the previous experiment. If so, it is probable that this is the normal physiological "position of rest." If the two positions are different, further examination is necessary to see which, if either of the two is "the natural" position.

Although this seems a simple and easy matter, yet some care and patience are often necessary if a satisfactory result is to be obtained. The chief difficulties are as follows:—

(1) *General nervousness.* Whilst in many persons the observations can be carried out with the greatest ease, at any time, and amidst any surroundings, in others the fact that the eyes are under observation interferes with the normal physiological act. In such nervous people, the absence of other onlookers and the carrying out of the test not as something special, but merely as part of a routine examination, preferably with the person laid down on a couch usually proves sufficient.

(2) *Local hypersensitiveness.* Some persons are exceptionally sensitive to being touched in the neighbourhood of the eyes. Their tactile (corneal) reflex is particularly sensitive. As a rule this also can be overcome with a little assurance and gentle handling.

(3) *Physical difficulties.* Real difficulty arises in some persons owing to the contour of the orbit in relation to the eyes. This may be such that it is difficult to prevent the descent of the upper eyelid by ordinary digital pressure.

Another source of difficulty, which is more common than one would expect, arises in persons who, when closing the eyes, habitually raise the lower eyelid more than usual. In a few cases the lower lid may come up half-way over the eye. This difficulty may be met by resisting the lower lid also.

In general however, each and all of these difficulties can be overcome, especially if it is made clear to the person that what is wanted is a quiet shutting of the eyes "as in trying to go to sleep."

One other point must be borne in mind. Some people, when one upper eyelid is resisted and they are asked to "shut the eyes" merely close the opposite (free) eye. In other words they "wink." This, as will be shown in a later section, is quite a different act, with different neuro-muscular associations, in which the ocular muscles take no part.

The following observations of the movements of the eyeballs during and after closure of the lids were begun in November, 1931.

Since then, altogether, 1250 normal persons have been examined

by the method described above, together with such few cases of facial palsy or persons with very transparent lids as have been available.

Most of the 1250 persons examined were adults, only a very few children, the youngest being 13 years old.

Many were in normal health, others had presented themselves for some illness, but in none was this due to organic nervous disease.

It soon became evident that as in sleep, the position which the eyes assume on closing the lids whilst awake, differs widely in different persons.

Whilst in most the eyes go upwards, either vertically or obliquely, yet the amount of upward movement varies in different persons, and in quite a considerable number there is no upward movement at all. It was at first suspected that these last named persons were not actually "shutting the eyes," but shutting the "free eye" only (winking) when, as will be shown later, the eyeball does not move. This, however, was disproved, not only by the confirmatory method described above of opening one lid after the eyes have been shut without any interference, but also by examinations at repeated intervals.

Still more rarely, the eyes actually turn down under the lower lids on closure.

In the examination of the first 400 cases so many different "positions of rest" were found, each varying slightly from the other that it became necessary to evolve some simple scheme for purposes of classification.

It was decided to make the degree of movement of the eyes upwards from the horizontal plane the basis of the scheme, and to leave out of consideration any associated lateral pull. The reasons for this will be given later.

The following scheme was therefore adopted for continuing the investigation.

All cases to be grouped solely according to the extent of upward movement of the eye on closure, under the following three headings.

Type 1. Upward movement maximal.

Type 2. Upward movement medium.

Type 3. Upward movement absent.

The amount of lateral pull being now left out of consideration, a merely horizontal movement is included in Type 3. Those few cases in which the eyes actually "go down" are also included in Type 3 and will be referred to in detail later.

This method of classification was not adopted until 400 cases had been observed.

The results of a further series of 800 consecutive observations grouped according to these three types are as follows:—

	No. of cases	Percentage
Type 1 - - - - -	477	59'6
Type 2 - - - - -	230	28'8
Type 3 - - - - -	93	11'6
Total - - - - -	800	100 per cent.

From these it is seen that in nearly 90 per cent. of normal persons Bell's statement that the eyes go upwards is correct, but in more than 10 per cent. it is untrue.

In these they do not rise at all above the horizontal and are apparently unable to do so, however powerfully the orbicularis contracts.

There is little or no difference in the two sexes. In women, the percentage of Type 1 is rather higher.

	Total cases	Type 1 Per cent.	Type 2 Per cent.	Type 3 Per cent.
Males.	537	58'7	28'9	12'4
Females.	263	61'6	28'5	9'9
Total	800			

It is also of interest to find how constant the proportion of each type has been in consecutive hundreds of persons examined from day to day as opportunities offered.

	Type 1 Per cent.	Type 2 Per cent.	Type 3 Per cent.
5th hundred - - -	52	30	18
6th hundred - - -	62	31	7
7th hundred - - -	60	25	15
8th hundred - - -	59	31	10
9th hundred - - -	66	24	10
10th hundred - - -	60	32	8
11th hundred - - -	61	29	10
12th hundred - - -	57	28	15
Total	800		

It is difficult at times to draw hard and fast lines between adjoining types and different observers may get slightly different figures, but as a rule the difference is sufficiently obvious. At any rate it is quite certain that in rather more than 10 per cent. of normal people the eyes either do not go up at all, or else to such a slight extent as to be almost inappreciable, and amongst these are a small number in which they normally go down.

The following is a more detailed description of the three types :

TYPE 1. "*Maximal upward movement.*"

In this type, the movement of the eyeball on eye closure takes place with the greatest ease and freedom on gentle eye closure; the cornea on the resisted side shoots up so that it gets behind the upper lid even when widely held open. It usually remains there, immobile, until the signal is given to open the eyes. It is always repeated in exactly the same way and there can be no doubt that it is a normal physiological process.

There are several variations. Whilst the movement is often sudden, immediate and directly upwards, it may be fairly slow, and preceded by a momentary hesitation, or even a slight downward movement.

In some persons both eyes go up straight; in others the upward movement is straight in one eye and oblique in the other. Both may diverge in conjugate fashion far to one side or the other, under the upper lids, or both may go right up into corresponding corners.

Sometimes the course is curiously circuitous. This may be so in each, or only in one eye.

Thus in one case the eyeball on each side at first moved inwards and upwards, then horizontally outwards over the top and became stationary outside the middle line, rather lower than the highest point of the earlier part of the movement, thus making an arc of a circle in the direction of clock hands from 9 to 2 in the left eye and anti-clockwise, from 3 to 10 in the right eye.

These variations do not affect the fact that in *Type 1 the eyes go so far upwards that even in the experimentally raised upper lid, the pupils are completely covered.*

TYPE 2. *Medium upward movement.*

In this group the eye also goes up on closure, but not so far as in the previous type. Under the ordinary conditions of the experiment, it does not go far enough for the pupil to be completely covered by the upper lid. If the resistance on the lid is slightly relaxed, so that the pupil is now completely covered by the lid, the eye usually remains at rest in the same position until the signal for opening is given. If however, the lid is kept open too widely, the eye, unable to go further up and so satisfy this primary need of the act of closure, *viz.*, to cover the pupil, may, after a few moment's hesitation, move quickly to one or other side, or even down.\*

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\* N.B.—It seems probable that this is what happened in Abraham's investigations referred to later (p. 284).

TYPE 3. *Minimal upward movement.*

In these there is no perceptible upward movement. When the lid is held open more than to the slightest extent, the pupil is not covered. When this happens, secondary downward or lateral movements readily occur.

The important fact about these cases of Type 3, is that however strongly the orbicularis contracts, the eyes never go up on closure. Obviously, the very condition necessary for the observation, namely, resisting descent of the upper lid, however slight it may be, prevents the pupil from being completely covered and therefore the act of closure is physiologically incomplete.\* In Type 3 it is not an uncommon thing for the eye which cannot move up under the upper lid, finding the lid resisted, to take cover *under the lower lid* by moving either straight down or to one side.

This does not happen always. In some the eye remains stationary.

Besides these two varieties of Type 3 there is a certain small number of persons in whom a downward, or lateral-and-downward movement appears to be normal for the individual. Such differ from those in which it seems to be a more or less artificial effect, secondary to the conditions of the experiment, in that in the former it occurs immediately, without any precedent immobility, or any hesitation, is repeated at each examination, and persists throughout the period of eye closure. In one of these cases in which the lids were exceptionally transparent, it was possible to see the eyeballs lying below the lower lid, when both eyes were fully closed without any artificial interference. They were in exactly the same position as they occupied during the experimental observations.

The existence of such cases has for long been known to ophthalmologists. Wilbrand and Sanger<sup>4</sup> quote v. Graefe as stating that "only a small number of people behave in the opposite way, that is, the eyeball turns down in shutting the eye." For the present these cases will be grouped as Type 3.

If this observation is correct, that in a certain percentage of normal persons, the eye does not move freely upwards on closure of the lids (Type 2), and in a still smaller percentage the eyeball *does not go up at all* or actually comes down (Type 3), it must happen that from time to time a Bell's palsy occurs in such individuals. I have met with at least three cases of this kind. Two of them probably belonged to Type 2.

One was a boy with a typical Bell's palsy on the right side. When I saw him the right upper lid had recovered to a certain

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\* NOTE—It is in this type of case that extra care must be taken to be sure that the person is actually "shutting the eyes" and not merely "closing the opposite eye" (winking). See later.

extent and came down about a third of its full distance. In spite of this, on shutting the eyes, the right eye did not go up sufficiently to ensure the whole of the pupil being covered and was not sustained at that level, but soon dropped so as to uncover the pupil, when it was again raised a very little. This constant restlessness of the eye is often seen in normal persons belonging to Type 2 when the upper lid is resisted too much.

In another case, the woman with Bell's palsy whose photographs are shown in the next section, the restless wandering of the eye on the paralysed side during closure suggests that she is, if not Type 2, at least one of the border-line cases between that and Type 1. (Fig. 2.)

As regards the still smaller group of Type 3, it is evident that for a Bell's palsy to occur in one of them must be comparatively rare. Indeed it is so rare that when such a case occurs it is often recorded, and since as a rule such cases easily acquire the habit of



FIG. 2.

*Movements of eyeballs during closure.*

Female. Left facial palsy.

Row A.—Closes the eyes (3, 4)—the left eyeball turns upwards and mesially (4 to 7).

Row B.—Right eye remains closed—the left eye still further in mesial upper corner (11). In 12 to 16 it moves from the mesial to the external upper corner.

Row C.—From 23 to 28 it moves back to the mesial upper corner.

Row D.—At 69 it is about centrally placed and the order is given to "open the eyes"—the left eye begins to descend at 72 and this is completed at 73.

(The pictures are numbered serially from one film. Ordinary rate.)



hiding the pupil under the lower lid, they have been spoken of as showing "an inverted Bell's phenomenon."

In December, 1931 I met with such a case. The patient was a middle-aged man who had been suffering from a left facial palsy for a week or two. When asked to close his eyes, the left, instead of going up, turned down into the extreme nasal corner, so that the pupil was completely hidden behind the lower lid. It remained there, immobile, until he was told to open the eyes again. At the same time, by holding the right lid open and asking him to close his eyes, the eye on the normal (right) side was seen to go down simultaneously, to the extreme right corner beneath the lower lid.

That this man belonged to Type 3 was proved later to be correct. When the facial palsy had practically recovered it was found that the eyes did not move upward at all when the lids were closed.

As was stated above, similar cases of Bell's palsy, or other defects of the lid, in which the eye turns down instead of up on closure have been previously recorded.

In 1905 Fleischer<sup>5</sup> reported such a case after injury to the eyelid.

The patient had lost the right eye from a powder explosion, while on the left side, although the eyeball was intact, the edge of the upper lid was defective. After a plastic operation the closing of the lid was successful though not completely so. The eyeball under these conditions moved up and out. Two months later the upper lid was thickened by scars. At this time the eye turned down when the eyelids were lightly closed, and up on strong closure. Two years later a slit remained open in the upper lid and every time the lid was closed the eye turned down and in, the cornea disappearing almost entirely under the drawn-up lower lid.

In 1925 Kestenbaum<sup>6</sup> reported two cases of what he called an inverted Bell's phenomenon. One of these was due to a cicatricial ectropion, the other was a case of Bell's palsy.

His observations are particularly relevant.

He stated that when the cause was removed the eyeballs moved in the normal direction on closing the eyes, but *if the upper lid was considerably lifted the eye rolled downwards* (italics are mine) not only when the lower lid was also raised but when a card was held up near the eye in place of the lower lid. Shading the upper part of the cornea with the card turned the phenomenon in its right direction once more. When one direction had been established it could only be changed after several experiments.

In the discussion which followed this communication, Bartels referred to a case of inverted Bell's phenomenon which he had shown a few weeks previously due to the loss of an eyelid three years before.

*In spite of a very successful operation which enabled the eye to*

*be completely closed, the turning down of the eye on closure had persisted* (italics mine).

Before trying to explain these recorded cases of inverted Bell's phenomenon, it may be of assistance to summarise the results of the observations on normal persons and to put together the views based upon them.

A.—The associated movement of the eye on closure of the lids differs widely in different normal persons.

This difference occurs both in the extent of upward movement and in the amount and direction of lateral movement.

For purposes of classification the upward movement has here alone been made use of. Three grades can be recognised.

Type 1. Upward movement very free.

Type 2. Upward movement moderate.

Type 3. Upward movement very slight or absent.

B.—Whilst closure of the eyes may serve various purposes, it is certain that one of these is to exclude light, and that until light is thus excluded the nervous mechanism which controls eye closure is not satisfied. In other words, until the pupils are completely behind the lids the act is physiologically incomplete.

But this exclusion of light may be brought about equally well whether the lid comes down over a stationary pupil or the pupil goes up under a stationary upper lid; or by a partial movement of each towards the other, provided these are together sufficient to ensure the pupils being covered.

In ordinary life when the eyelids close, the pupils are completely covered, whether the eyes move up or remain stationary. The act of closure therefore is equally efficient as regards the exclusion of light, whether the individual belongs to Type 1, 2 or 3.

C.—When, however, there is a defect in the downward movement of one or both upper lids, either from injury, disease or artificial interference, the physiological effects will differ in the different types of individual. In those in whom upward movement is extremely free (Type 1), there will be no inconvenience. However immobile the upper lid, the eye shoots up, the pupil gets under cover and the important function of excluding light is accomplished.

In those (Type 3) in whom there is practically no upward movement at all on closure of the lids, the pupil cannot find cover under the immobile upper lid and in many cases an alternative is found, either below the lower lid or at one side.

Between these two extremes—that is in persons of Type 2, what happens will vary with the extent to which the upper lid is able to descend.

Applying the above hypothesis to each of the various recorded cases mentioned above, the apparent anomalies in the cases referred to can be explained as follows :—

*Fleischer's Case.*<sup>7</sup>—In this man the right eye had been completely destroyed. The left upper lid was defective. At this time the left eye turned down on attempted closure because the upward movement was not sufficient to bring about covering of the pupil. Probably he belonged to Type 2.

Later a plastic operation enabled the lid to come down almost completely and this, with the normal slight upward movement of the eyeball (such as is seen in a Type 2 person) was enough to enable the pupil to be covered. Consequently, the eye now resumed its normal upward movement on closure.

Later, however, scarring of the upper lid prevented the lid coming down quite far enough, and again the physiological act of covering the pupil could not be completed by an ordinary effort at closure, and the pupil sought refuge under the lower lid.

If, however, a voluntary increase of contraction of the orbicularis was made, it came down just sufficiently to cover the pupil and the eye performed its normal slight upward movement.\*

Finally, two years later "a slit remained in the upper lid" and now, although apparently the lid could come down, it did not cover the pupil probably because of the slit. Consequently, the eyeball habitually went down under the lower lid.

Kestenbaum's<sup>8</sup> cases also probably belonged to Type 2. When the defective movement of the upper lid was at its worst, the eyeballs could not rise sufficiently to get the pupils covered so they turned down. When the cause was removed the lids came down far enough to meet the limited upward movement of the (Type 2) eyes. His experiments on these cases are extremely suggestive. If the lid was held up a little more than this the eye again went down. It could not reach cover upwards. Finally, if a shade was held over the upper part of the eye, it went up, even when the lid was resisted, whilst if the shade was put below, it went down.

He says, "the eye always fled from the light." Perhaps it might be put the other way round, "On closure the eye always seeks cover."

The case recorded by Bartels<sup>9</sup> seems to belong to that form of Type 3 previously referred to, in which, not only is there no upward movement at all but actual downward movement as the normal synergic action.

In his case the man had lost an eyelid, and the eye, on attempted

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\* When a person of Type 3 screws up the eyes tightly, it does not, in my experience, actually increase the upward roll of the eyeball, but it raises the whole eyeball a little by the lower lid contracting strongly, and so pushing it up from below. Possibly in Fleischer's case this was just sufficient to bring about covering of the pupil.

closure turned down. A very successful operation was performed which enabled the eye to be completely closed, and yet, three years after, the eye still turned down on closure.

As there is no information as to how this man's eyes moved before the lid was injured, it is impossible to be dogmatic, but it seems quite likely that they had always turned down.

In connection with this an interesting paper was published recently by Abraham,<sup>10</sup> which, although dealing with other points, includes some observations on the movements of the eyeball in normal persons when the lid is resisted, in much the same way as described in this section.

The number of persons he examined was only small (32), and the grouping that he adopts does not appear to lead to important distinctions. The point, however, which he brings out, is that in these 32 normal persons, examined in the way described earlier in this section, namely, by resisting closure on one lid, he was able to obtain an inverted Bell's phenomenon in quite a large percentage. Actually it was obtained by him in no less than 62.5 per cent.!

According to the hypothesis given above it seems probable that most of these cases were persons who belonged to Types 2 and 3 in a certain number of whom no such movement would have occurred had the resistance been a little reduced.

It is also suggestive that this observer got very different results in the first 16, from those in the second 16 examined.

Whilst the numbers examined are too small to base data upon, yet it is interesting to find that in his 32 cases about 40 per cent. moved the eyes upwards under the resisted lids however much these were resisted. These must have certainly belonged to Type 1 and the percentage is not very different from that in my cases.

Possibly the explanation of this turning down of the eyes by persons of Types 2 and 3 when the eyelid is resisted, or otherwise prevented from closing, so that the pupil is not covered in the act of closing the eyes, is that it is merely an indirect attempt to lower the upper lid. In the ordinary act of "looking down" the upper lid follows the eyeball in its descent, so that in the extreme downward gaze the upper lid is almost in apposition with the lower. When the act of shutting the eyes has been completed, and has not proved physiologically successful, the indirect means of getting the lid to close, namely by lowering the eyes, may be called into play as an alternative.

It is also noteworthy, that in the conditions of "closed eyes" one of the restrictions referred to in Section 1, namely that the pupil must not go under the lids, is now no longer in force, so that the pupil can cover itself completely behind the lower lid, a thing quite impossible to do with the "open eyes."

Although in these observations on normal persons and in cases of Bell's palsy, the movements of one eye at a time are alone visible, yet there are good reasons for believing that similar movements are occurring simultaneously under the other closed lid.

This can be shown in cases of Bell's palsy by resisting closure on the sound side, or in normal persons by resisting the descent of both eyelids at the same time or quickly pulling up both

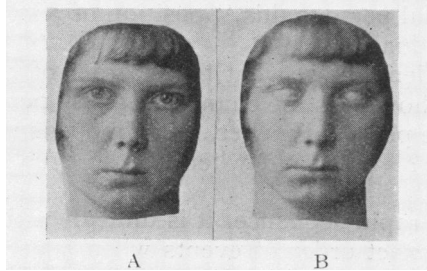


FIG. 3.

*Closure of the eyes in a case of facial diplegia.*  
(Epidemic encephalitis.)

A.—Eyes open.

B.—Attempted closure of eyes.

closed lids together. It is also seen in persons with transparent eyelids, and in rare cases of facial diplegia of peripheral type. (Fig. 3.)

Indeed, in the course of these investigations, the corresponding amount of elevation of the two eyes has been so constant that as a rule there was no difficulty in placing both in the same type.

In only a very small number of cases has this been otherwise. In 800 cases, such difficulty was noted in 21 persons, and then it was usually a question of adjoining types. No case was met with in which one eye belonged to Type 1 and the other to Type 3.

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### Section IV

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#### The Sequence of Events in Closing and Opening the Eyes

It has been shown in the two previous sections that when the lids are closed so as to interrupt vision, the eyes take up their "position of rest" whether the individual is awake or asleep; also, that in normal persons this "position of rest" differs widely in different individuals.

The question then arises, what is the order of events when the eyelids close and how does the change from the position of fixation to that of rest take place? Further, what happens when the eyelids are opened again? How and when do the eyes get back to the primary position?

Owing to their rapid sequence, it is difficult with the naked eye to make out the exact order of events when a person with Bell's palsy (or a normal person with one eyelid resisted) closes or opens the eyes.

Cinematograph pictures, taken either at ordinary rates, or better "slow motion" show that the various parts of the act always take place in a definite order.

As they are the same in normal persons as in those suffering from Bell's palsy, the one description applies to both.

#### SEQUENCE OF EVENTS IN THE ACT OF CLOSING THE EYES. (Fig. 4.)

When told to close the eyes, there is necessarily a brief interval occupied by the reception and transmission of the nervous impulse, before any result is seen on the film. The eyelid then begins to close. This continues until the upper lid reaches the level of the pupil and covers it partially or completely. Until that point is reached, the eyes usually remain in the primary position, without any visible movement.

This constitutes the first part of the act of closure and will be referred to as the "palpebral phase." With the covering of the pupils the movement of the eyeballs begin. The primary position is now abandoned and the eyes begin to move towards their position of rest. Even after the downward movement of the upper lid has been completed, the eyes still continue moving to their "position of rest" if they have not already reached it. This continued action of movement after the lids are completely shut is best seen in those persons belonging to Type 1, in whom the approach to the position of rest is rather slow. In cases belonging to Type 3 it is so slight as to be difficult to see.

This period, during which the eyeballs are moving to their position of rest is the second or "global phase" of the act of closure.

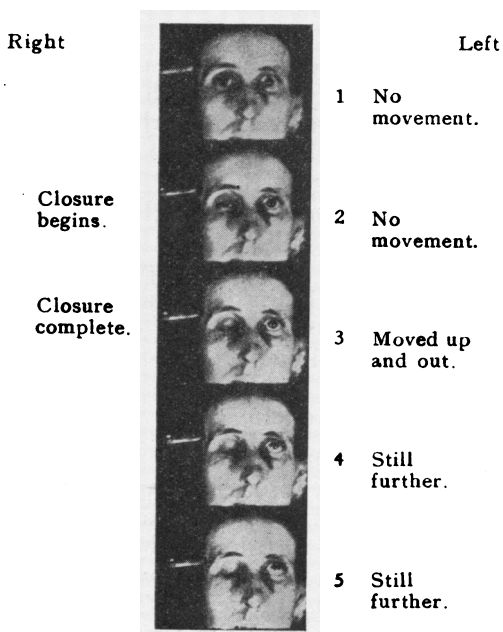


FIG. 4.

*Shutting the eyes.*

Female. Left facial palsy.

At 2 the right eye begins to close. This is completed at 3. (Palpebral phase.)

At 3 the right eye begins to move up. This continues until 5. (Global phase.)

(Ordinary rate. 16 pictures per second.)

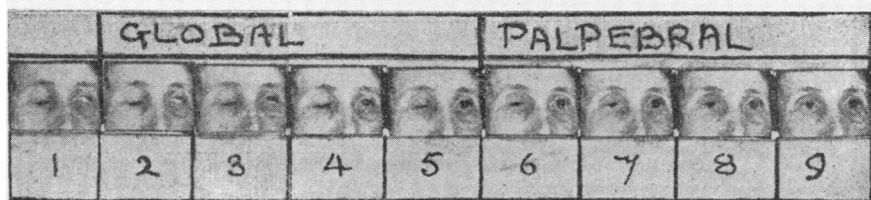


FIG. 5.

*Opening the eyes.*

Female. Left facial palsy.

At 2 the left eyeball begins to descend. This continues until 5. (Global phase.)

The right eye does not begin to open until 6 and continues until 9. (Palpebral phase.)

(Slow motion pictures.)

SEQUENCE OF EVENTS DURING THE ACT OF OPENING THE EYES.  
(Fig. 5.)

On opening the closed eyes the biphasic character of the act is seen even more strikingly than on closure. The two phases now take place in reverse order. In looking through a cinematograph film it is always possible to foretell the opening of the eyes a few pictures before it begins, because the eyeball has already begun to leave its "position of rest" (global phase) and indeed, reaches the primary position before, or coincidentally with the beginning of the second or "palpebral phase."

Once the existence of this biphasic sequence of events is realised it is easy to recognise it by the naked eye, especially in well-marked cases belonging to Type 1.

### Conclusions

The act of closing the eyes, voluntarily when awake, is biphasic in character. The movement begins in the eyelid "palpebral phase." When this is completed or nearly completed, the eyes begin to change their position (global phase) and continue to do so until the position of rest has been reached. The act is then complete. The order of the phases is (1) palpebral (2) global.

In the act of opening the eyes the two phases are reversed in order of time. The global phase occurs first, and not until it is completed do the lids begin to open (palpebral phase). The opening continues until complete. Here the order of events is (1) global (2) palpebral.

The act of closing the eyes may be divided into two phases:—

(1) A phase in which the lids come into apposition, whilst the eyeballs remain in the primary position. As during this period movement is practically limited to the lids it may be called the "palpebral phase."

(2) A phase in which the eyeballs move from the primary position to their "position of rest," whilst the position of the eyelids remain unchanged. As the movement during this period is limited to the eyeballs it may be called the "global phase."

### Sequence of Events in the Act of Blinking, Reflex or Spontaneous

Seeing that under normal conditions, the eyes abandon the "primary position" and move into the "position of rest" whether the eyes are closed voluntarily when awake, or involuntarily as part of sleep, the question arises:—

Does the same happen in the various acts of involuntary rapid closure which occur either reflexly or otherwise during waking hours—and known as "blinking"?



It is a question of some interest because it has been suggested that the object of spontaneous blinking, which in many people is so frequent, especially if nervous or excited, is to give rest to the eye muscles.

If one watches a person with unilateral facial palsy, it is seen that there is a momentary change in the position of the exposed eye when an ordinary blink occurs. Such movement however, appears to be only very slight and it is evident from a consideration of time alone that in persons belonging to Type 1 and probably in those of Type 2, in whom the position of rest is at some distance from the primary position, the whole act of blinking which only occupies 0.13 to 0.2 seconds, is insufficient for the eyes to move from the primary position to their position of rest and back again in the brief fraction of a second during which the lids are closed.

Whilst the palpebral phase undoubtedly occurs in "blinking" as in "closure of rest" it would appear that the global phase cannot be carried out completely except perhaps in persons belonging to Type 3.

If this is so the amount of rest given to the eye muscles or to the retina by the act of "blinking" is almost negligible.

### **Voluntary Closure of Rest with Continuation of Eye Movements**

Whilst probably in all cases the eyes assume their position of rest at the time of closure, and if undisturbed will remain in this position until the eyes are opened again, yet it is possible to move the eyes at will under the closed lids so as to look in various directions.

These movements of the eyeballs can readily be seen in persons with thin eyelids and rather prominent eyeballs.

Lateral movements are particularly well seen, and suggest that the eyes move further to the sides than when they are open. Probably this is due to the absence of the controlling brake associated with the open lid.

## **Section V**

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### **Closure of One Eye—Winking**

Whilst the muscles acting upon the globe itself can only act bilaterally, those which move the eyelids can also act unilaterally.

One eye can be closed whilst the other is allowed to remain open. At the present day this is known as "winking."

Originally however, "to wink" had no such unilateral significance; it meant to "shut the two eyes." It is thus used by Chaucer in the *Nonne Preestes Tale*;

"This Chaunticleer stood hie up-on his toos,  
Streechyng his nekke and heeld his eyen cloos,  
And gan to crowe loude . . . . ."

later having successfully escaped from the mouth of the fox, he moralises from his safe perch in the tree,

"Thou shalt namore thurgh thy flatereye,  
Do me to singe and winke with myn yè "

Had Chaunticleer "winked" in the modern sense, he would not have been caught by the fox and the world of letters would have been the poorer.

Even in Johnson's time, although the word had acquired secondary meanings, there is no suggestion of unilateral action. His dictionary gives four alternative definitions:—

1. To shut the eyes.
2. To hint or divert by motion of the eyelids.
3. To close and exclude the light.
4. To connive, to seem not to see, to tolerate.

Definition 2, which almost alone of them corresponds with "winking" to-day, says eyelids, not "one eyelid."

Although we still use the word in its original sense and speak of "winking" at, *i.e.*, being blind to some fault, or when the eyes are suddenly exposed to a very bright light (dazzle reflex).

Yet when both eyes are closed the usual term to-day is "blinking."

The extent to which individuals can close one eye only (wink) varies widely:—

(1) Some persons can do so with either eye without difficulty and without visible movement of the opposite lid.

(2) Others can wink with one of their eyes but not with the other. Any attempt to do so on the other side is accompanied by more or less movement of the opposite lid.

(3) Still others cannot wink on either side; every attempt is accompanied by a complete or partial closure of the opposite eye.

*N.B.*—Exactly what a person does when asked to "wink" differs widely in different individuals. Very often there is no closure of the eye, merely a twitch of some part of the orbicularis oculi, and possibly of some of the adjacent facial muscles.

The act of unilateral closure (winking), when normally carried out, differs from that of bilateral closure in that there is no associated change of position of the eyes, *i.e.*, there is no global

phase. The eyes remain in the primary position whilst the one eye is being closed and during the whole time that it remains closed. When it is opened again they are already in the primary position for fixation.

This is easily seen in cases of Bell's palsy, provided that the person belongs to the group capable of winking with the eye which remains sound. It can be seen equally well by resisting one eyelid in normal persons who can wink.

That these two acts, bilateral closure (blinking) and unilateral closure (winking) have two distinct neuro-muscular paths, can be demonstrated by the following simple experiment. (Fig. 6.)

The person with facial palsy (or the normal person with resisted lid) is asked to close the eye on the sound side (as in the act of winking) but, having done so, to keep it closed. If he has really done this, *i.e.*, closed one eye only, the eye on the paralysed side will have remained absolutely unmoved. He is then asked, whilst the normal eye still remains closed, to "shut his eyes." Except for a possible slight increase of contraction of the eyelid, there is no evidence of the palpebral phase. The eyelid on the sound side is already shut, and on the other side the paralysed (or resisted) lid, cannot move. The fact that the order to "shut the eyes"

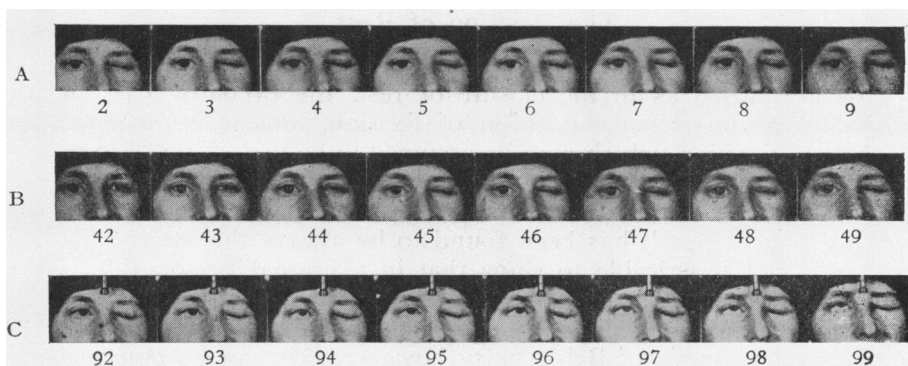


FIG. 6.

*Experiment to show different effect on eyeball of unilateral (winking) and bilateral (closure of rest) closure.*

Female. Right facial palsy.

In the upper row (A) the left eye is closed as in winking. Closure begins at 3 and is complete at 6. There is no accompanying movement of the right eyeball.

In the middle row (B) the condition remains unchanged, the left eye is still closed and the right eye in the primary position.

In the bottom row (C) a pencil touching the forehead has given the signal to "shut the eyes" (bilateral closure). As the left eyelids are already closed, and the right are paralysed the performance of the act is only shown by the global phase. The right eyeball begins to move up at 94 and continues until 99.

(Slow motion pictures from continuous film.)

has been received and acted upon is however, at once shown by the visible eye beginning to move from the primary position to its position of rest. In other words, the global phase of blinking comes into action and is alone seen.

Whilst the above description refers to the movement or absence of movement of the eye on the side of the paralysed or resisted eyelid, the same thing is happening under the lid on the normal side.

As has been mentioned in a previous section, this absence of movement of the eyeball on unilateral closure has to be distinguished from the absence of movement on bilateral closure in persons of Type 3 (Section 3). It is therefore important before placing a person in that category to be quite sure that he is really performing the act of "bilateral" and not of "unilateral" closure. Confirmation or otherwise may in such a case be obtained by the method described in Section 3 of quickly lifting the closed lids and seeing where the eyes are.

## Section VI

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### The Position of Rest

It has been shown in the foregoing sections that when the two eyes are closed as in the closure of rest, the eyeballs cease to remain in the primary position of fixation, and take up some different position, which may be assumed to be their "position of rest."

By repeated examination of the same individual at intervals this "position of rest" has been found to be always the same.

It is not practicable to show that in a normal person this is exactly the same as the position assumed in the act of going to sleep because of the difficulty of resisting one eyelid during that process. In cases of Bell's palsy however, this can be observed with a little care, and in such few cases as it has been possible to observe, the position of rest on going to sleep is the same as when shutting the eyes when awake.

In trying to explain why the eyeballs should find their "position of rest" above the horizontal level in nearly 90 per cent. of normal persons, one may consider how other muscular groups in the body take their rest. This varies in different groups according to the character of their activities during waking hours.

Certain groups, such as the muscles which maintain the upright posture of the head and body must be in more or less continuous action throughout waking hours in order to maintain the body posture when up and about.

For this group it is necessary to support the trunk or lie down for a long spell of rest.

So also with the ocular muscles. During waking hours they are always in a state of tonic fixation.

As regards the body musculature, full sleep is incompatible with the upright position and although where sleep is urgent and overdue, a man may take up almost any position of safety that offers, yet under normal circumstances most of us have some particular position which we constantly assume when going to sleep, provided it is possible to do so.

Some lie on the back, others on one side or semi-prone, some with limbs outstretched, others with them drawn up.

It would be difficult to say that any one of these positions is more suitable than another as a rest for the postural muscles, or that one could tell from the position of rest the particular nature of the day's work.

Amongst the many contributory factors, habit acquired in early life probably plays an important part.

The position of rest which is assumed at the time of going to sleep is however, not necessarily maintained throughout the whole sleep. Johnson, Swan and Weigand<sup>1</sup> carried out a series of observations on the changes of position during sleep in a large number of normal students. By means of a fixed camera taking pictures at regular intervals they showed that during an ordinary sleep the position of the body was changed from 20 to 45 times. Such changes of position are no doubt made in order to relieve discomfort due to local pressure upon or continued strain of some part or parts.

As regards the body musculature therefore, two facts stand out, firstly that on going to sleep some more or less constant position is assumed, and secondly that during sleep this position may be frequently changed. It is however, noteworthy that in normal sleep, whatever such change may be, it does not involve full use of the postural muscles.\*

All the facts so far observed during closure of the eyes whilst awake or asleep point to a similar order of events in the ocular muscles.

They take up a constant position of rest when the eyelids close, and during sleep they may change that position. How often the latter may occur it is impossible to say, but that it does is known from seeing the movement under the closed lids, or if the lids be raised. Also, it has been found that when the eyes of a sleeping person are examined on successive nights the position of the eyes may vary on each occasion.

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\* This does not apply to such abnormal conditions as somnambulism.

Why then is it that in more than 50 per cent. of persons "the position of rest" should be one in which the eyes are turned upwards to an extent to which they are never turned when the eyes are open, whilst in some 10 per cent. they do not rise at all, and in the remainder the upward movement is somewhere between the two?

Assuming, as we may, that whatever position is taken up on closure of the lids is the position of rest for that person, it is natural to suppose that during waking hours this particular combination of muscular tone has been less used than any other, so that when the general postural stimulation to all the eye muscles is reduced to the resting standard, this group predominates in action.

Now, the comparatively slight use of upward eye movement in ordinary everyday life is well recognised.

A few years ago, Edwin Bramwell<sup>2</sup> emphasised this in a presidential address to the Neurological Section of the Royal Society of Medicine. Discussing the upward movement of the eyes he said, "The objects which engage our attention are almost always situated at or below the level of the eyes . . . we rarely look up, we are indeed not in the habit of doing so, for we do not anticipate the unexpected."

As illustrations of this he recalled the children's game of "hunt the thimble" in which, if the object is put above the level of the children's eyes, even in a conspicuous position, it will probably not be noticed.

It is quite certain that in most occupations vision is at or below the level of the eyes, and that there are but a few in which looking up at near objects is at all common.

Indeed it may be said that in ordinary every-day life any elevation of the eyeballs themselves must be quite rare. The act of looking up is performed by throwing back the head and until that is unsuccessful the actual elevation of the eyeballs does not come into action.

It would seem therefore that in ordinary life, during the greater part of our waking hours the eyes are directed either at or below the horizontal plane, and to a much less extent upwards.

On these grounds it is not unreasonable to explain the presence of an upward trend when the lids are closed and the eye muscles are at rest.

As supporting this view, the facts recorded in Section 2 on the position of the eyes in sleep may be referred to. It was there shown that whilst in persons of all ages above one year the eyes were up in 42 per cent., in blind children the percentage was only 20 and in six new-born infants examined daily during the first 10

days of life it was only 0.9 per cent. (This was one eye only out of 55 observations.)

It would seem therefore that there is some direct connection between the acquirement and use of binocular vision, and the elevation of the eyes as their position of rest.

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PIGMENTED DEPOSITS IN THE LENS AND  
CORNEA OF DOUBTFUL NATURE

BY

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THE case concerning which this note is a brief record seems sufficiently interesting for publication if only because we have not seen such a condition before and do not know whether it may be regarded as similar in type to the changes met with in chalcosis or pseudo-sclerosis described in the literature. The notes of the case are long and tedious and it is not proposed to deal with them in detail, but rather to start with the description of the condition as it appears now, and then consider points which may be pertinent.

R. T., Hindu, male, aged 17 years, was first seen in 1924 for what seemed to be a mixed condition of trachoma and conjunctivitis eczematosa, and has been under almost continuous observation ever since, with one long interval of over two years—1926 to 1928. At the present time the boy is apparently in the best of health, his eyes are quiet, the conjunctivae smooth, scarring is present but not marked, and the remnants of generalised pannus are easily observed on focal illumination even with the naked eye, but the vessels are pale and bloodless. There is no lacrymation or discharge, but a slight intolerance of glare. The picture, from a water colour painting, gives some idea of the naked eye appearance of the eyes. The corneae present a fairly uniform olivaceous tint, translucent when looked at direct and taking on a more cloudy opalescence as one changes the direction of gaze and views the eye from the side. Looking through the corneae yellowish-brown opacities appear to occupy the pupils.